

IEA Heat Pump Centre

NEWSLETTER



CFC and HCFC Replacement



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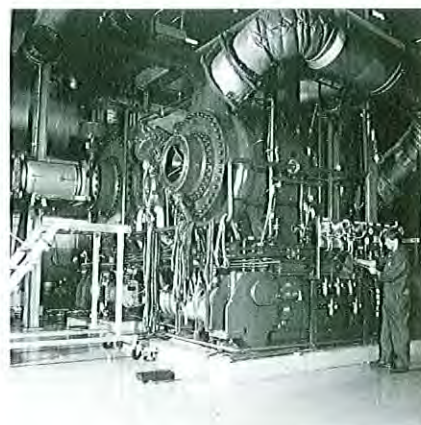
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CFC and HCFC Replacement

The need to use alternative refrigerants continues to be a dominant concern in the evolution of heat pump technology. Following on from March 1994, this issue of the *IEA Heat Pump Centre Newsletter* looks at recent progress in the application of new working fluids, including the development of new equipment and the retrofit of existing systems.



Front Cover: (H)CFC replacement poses many questions for the heat pumping industry, but for the world's largest heat pump, HFC-134a has been found to be a successful solution. The article on page 32 explains this further.

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International Overview 13

Bert Stuij, IEA Heat Pump Centre
The (H)CFC replacement market is potentially enormous. Those who want to succeed must come to terms with a bewildering mix of environmental, safety, technical and regulatory factors, that often change with time and from place to place.

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Performance with HFC Refrigerants
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R-407C and R-410A are emerging as the primary options for replacing HCFC-22. Tests made on a water-source heat pump indicate the likely consequences of using these HFC blends in tomorrow's equipment.

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North America
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Status and Policy Review
Bert Stuij, IEA Heat Pump Centre
The HPC's worldwide study is now complete. The most recent volume adds many more countries, including China, Mexico and Poland, to this global view of the heat pump situation.

New Refrigerants 22

for Japan's Heat Pump and Refrigeration Markets
Moriyoshi Sakamoto, Japan
Most manufacturers now market equipment with CFC alternatives. Market reaction has been mixed so far. Now they must respond to the even bigger challenge of HCFC replacement.

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A Natural Choice



The heat pumping and refrigeration industry is experiencing unprecedented change because of the search for environmentally-friendly and energy-efficient refrigerants. The search has focused on new families of synthetic fluorocarbons as well as existing "natural" chemicals such as ammonia, propane, carbon dioxide, water, air, etc.

Anhydrous ammonia, one of the most widely used of the "natural" chemicals, is an excellent refrigerant with more than a century of successful application in large industrial refrigeration systems for food processing, food preservation and cold storage. Besides these and other uses, ammonia is

well-suited as a refrigerant for large heat pump systems. The critical temperature of ammonia (133°C) is higher than that of many other refrigerants making it capable of effective heat rejection in a heat pump. Office buildings, industrial processes and central heating and cooling (district energy) complexes are practical applications for ammonia-based heat pumps. The inherent ability of ammonia to provide maximum capacity at high efficiency, with the least amount of refrigerant, makes it particularly well-suited in a world where environmental compatibility and a need for minimizing the amount of refrigerant used (reduced charge) are important factors.

Ammonia is a critical part of the natural nitrogen cycle. Billions of tonnes of ammonia are produced naturally every year as part of this cycle. Ammonia is therefore abundant and inexpensive. Because it has zero ozone depletion potential and virtually no global warming impact, ammonia is as environmentally benign as water and air.

Ammonia has well-known toxicity and flammability characteristics which must be addressed whenever it is used in refrigeration or heat pumping applications. However, years of experience in thousands of industrial refrigeration installations have demonstrated that we know how to safely apply ammonia. As those with ammonia experience understand, the keys to the safe use of ammonia are compliance with existing safety codes and design standards, making safety a high priority, and thorough education and training of those who work with ammonia.

While ammonia will never be a universal answer in the elusive search for a "perfect refrigerant", it does have great potential to be used more widely in large heat pumps, central cooling, thermal storage, combustion air pre-cooling of gas turbine cogeneration plants, commercial refrigeration, etc. In these applications, ammonia is "a natural choice".

Kent Anderson

Executive Director, International Institute of Ammonia Refrigeration

News & Views

Dutch government formulates heat pump policy plan

The Netherlands – In the year 2000, energy conservation through the use of heat pumps will reach an annual rate of 5 PJ. This is the initial target figure set by the broad outline for a "Policy Plan for the Implementation of Heat Pumps", which has been drawn up for the Ministry of Economic Affairs. The target figure of 5 PJ, which accounts for just under 0.2% of the nation's current energy consumption, will be met through heat pump implementation in the domestic buildings, commercial buildings and industrial sectors.

Certainly the biggest challenge is to bring about significant heat pump use in domestic buildings, where almost no heat pumps are installed today. Basic structures for a programme of large-scale heat pump installation in new homes have already been set up by the Netherlands Agency for Energy and the Environment (Novem) in cooperation with the energy sector (Novem is the Operating Agent for the IEA Heat Pump Centre). The initial task will be to prove

the viability of advanced heating concepts with heat pumps in new housing projects. At the same time, the programme will work on the essential task of mobilizing the equipment supply side through international cooperation and with the support of national institutes. Large-scale market introduction of heat pumps is envisaged in three years, leading to the realization of at least 35,000 new houses heated by heat pumps by the year 2000.

Somewhat less work is needed to stimulate the commercial buildings sector where heat pumps are already beginning to penetrate the market on a small scale. But while the technology is proven, many institutional challenges must be met in order to achieve wider penetration. The new programme will seek to collaborate with equipment suppliers with the relevant expertise. A major contribution to market growth is expected from retrofit projects on government buildings and from local energy distribution companies.

In industry, a market introduction programme, conducted by Novem, is already in place to encourage the use of energy-saving technologies such as heat pumps. The approach for heat pumps is based on process integration, with much attention given to the additional (as well as energy saving) advantages of using heat pumps, such as the reduction of waste emissions and the lowering of ground-water consumption. An important step towards increasing the use of heat pumps in industry has been the work of Annex 21 of the IEA Heat Pump Programme, described further on page 12.

The broad outline for the heat pump policy plan is the result of a market consultation conducted in 1994. Further development of the programme is now being carried out for the Ministry by Novem in cooperation with the main market groups.

(Source: Dutch National Team)

Refrigerant concerns aired at European forum

France – "Reduce working fluid charges in systems", "hermetize systems", and "demonstrate the reliability of equipment" – these were typical of the statements made at the *2nd European Refrigeration Forum* held on 21 to 22 November 1994 in Lyon, and reflect the current concerns of the European heat pumping equipment manufacturing industry.

The meeting began with statements made on behalf of the European Union (EU), France and the US, and a speech by a representative of the European compressor manufacturers. Dr Ray Cohen of the US, reminded the audience of the 20th anniversary of the publication of the ozone depletion theory by Dr Molina and Dr Rowland. The two chemists were honoured shortly before this forum for "sounding the alarm".

The EU presentation triggered intense debate on working fluid regulations. While the stated EU policy is to avoid regulatory shocks for industry, many concerns need to be addressed. A plea was made for a constructive dialogue with industry.

It was reported that targeted regulations had not been achieved, and that efforts to phase out CFCs in eastern Europe were encountering great difficulties. Alarming developments are the stockpiling of refrigerants and the illegal import of CFCs. More regulations are needed in these areas. Other presentations considered the replacement of (H)CFCs, refrigerant leakage, and advanced CFC recovery procedures.

Away from refrigerants, the forum also explored new markets and opportunities

for heat pumping technologies. One speaker presented the results of a qualitative market study on heat pumps in ten European countries. This study was conducted under the EU Joule 2 programme. In the report, the role of market players is discussed and marketing suggestions are given.

In a separate session, national overviews were presented on education and training. The forum was held in conjunction with the international exhibition of energy technologies "ExpoTherm". This offered the chance to see many examples of refrigeration and air-conditioning products currently on the market.

(Source: Jos Bouma, IEA Heat Pump Centre)

Systems receive "Superior Status" award

Japan – The 1994 "Superior Status" award has been granted to the nine heat pump systems shown in Table 1. This award is made every year by the Heat Pump Technology Center of Japan (HPTCJ) after a rigorous examination procedure. The aim is to promote heat pump systems which offer major energy saving and environmental benefits, plus high economic efficiency and quality engineering.

(Source: Japanese National Team)

In-depth study on GSHPs

N. America - A research study for ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) is documenting case studies of the design and performance of a wide variety of commercial ground-source heat pump (GSHP) systems. ASHRAE Research Study 863-RP will identify existing installations, and prepare a detailed report on 20 to 25 systems, giving information on their energy and demand performance, plus their design characteristics and operating systems.

(Source: Doug Cane of the Canadian National Team, and Principal Investigator for this project)

Table 1: 1994 winners of Japan's superior heat pump status award.

Company	Heat pump system
Hokuriku Electric Power Company	Control system for heat pumps with water thermal storage
Kajima Corporation	Individual air-conditioning system using air-source heat pumps
Kyushu Electric Power Co., Inc.	STL (storage of latent heat) thermal storage system
Mitsui Fudosan Co., Ltd.	Individual air-conditioning system using air-source heat pumps
The Chugoku Electric Power Co., Inc.	Crystal liquid ice thermal storage system
Taisei Corporation	Air-conditioning system with water thermal storage for computer room
Mayekawa Mfg. Co., Ltd.	Heat recovery multi-function heat pumps with water heat source and water thermal storage
The Kansai Electric Power Co., Inc.	Individual air-conditioning system with ice thermal storage for a factory
Takenaka Corporation	District heating and cooling system using heat recovery heat pumps with ice/water thermal storage

Technology and Applications

Monovalent unit for low-energy homes

Germany - A recently introduced government decree on thermal insulation will result in the construction of low-energy houses in future. The lower heating needs of these homes means that a water-to-water or brine-to-water heat pump can cover the heating demand with monovalent operation. Responding to this, Stiebel Eltron have launched a new heating-only heat pump in 1995. The WPWE 8 K model uses water or soil as the heat source. It is designed for

use with very low-temperature hydronic heat distribution systems.

For example, if the water in the heating system has a flow temperature of 35°C, and brine is supplied at 0°C, the heat pump reaches a COP of four. When using water, such as well-water, at 10°C as the heat source, it achieves a COP of almost five. For these examples, the heat supplied by the heat pump is 7.8 kW for brine operation and 10.1 kW for well-

water operation. The WPWE 8 K uses propane as refrigerant. Since last year, all Stiebel Eltron's heat pump water heaters have been filled with propane. This year, the company will changeover to propane for all its space heating heat pumps as well.

(Source: Ms Sylvia Spanjol, Stiebel Eltron GmbH & Co.KG, Holzminden, Germany. Fax: +49-05531-702480)

New equations to aid plate heat exchanger design

Switzerland - Thanks to high heat transfer coefficients and virtually pure countercurrent flow, plate heat exchangers make it possible to achieve very small temperature differences between two liquid streams with a very compact design. Unfortunately, very few generally accessible documents are available that calculate the behaviour of liquids as a flow medium in this type of equipment.

Prof. A. Bölcs and Mr R. Bogaert are helping to rectify this situation through their work at the laboratories of applied thermodynamics and turbo machines (LTT) in EPFL, Lausanne. They have performed pressure loss and heat transfer measurements on three types of plate heat exchanger, all with soldered plates, to provide new correlation equations for use by heat exchanger design engineers. The equations are listed in a report where they are compared with the measurements. They can be used directly for design purposes

by the engineer responsible for planning. A dimensioning example facilitates the use of the relationships found.

The measurements were made on the carefully expanded test apparatus shown in the photograph. The full range of flow types were measured (from laminar-flow, through the transition region, to turbulent flow) under a range of flow conditions, as represented by Reynolds numbers of 10 to 2000. The new correlation equations provide the drag coefficient and the Nusselt number as a function of the Reynolds number and the Prandtl number. Further investigations using the same test equipment are envisaged.

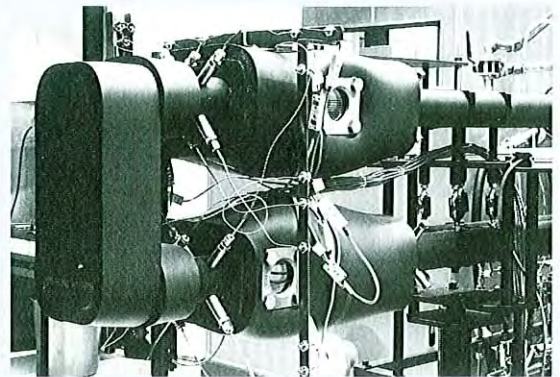


Plate heat exchanger measurement equipment.

The 37 page report (No. 9201071), is published in French by ENET, P.O. Box 142, CH-3000, Bern 6, Switzerland, price CHF 20 (US\$ 13). The authors can be contacted at: Fax: +41-21-693-3502.

(Source: Prof. Martin Zogg, Swiss National Team)

Introducing the oil-free compressor

Switzerland - A new four-stage piston electric compressor, developed by Sulzer Burckhardt, requires no lubricating oil. Originally developed for natural gas filling stations, this oil-free compressor, also has an interesting potential for heat

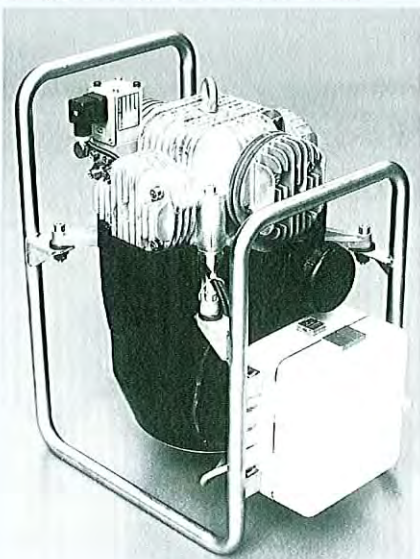
pump applications with supercritical vapour cycles. For the moment, its main application will be the compression of gases such as air, N_2 , CO_2 , H_2 , and He, from atmospheric pressure up to 20 MPa (200 bar).

The photograph shows the modular design of the compressor-motor unit, which is supported on a tube frame. The compact compressor has a weight of 32 kg, a flow-rate of 2.4 Nm^3/h and an electric power consumption of approximately 1.1 kW.

The compressor and motor form a hermetically sealed unit without a shaft seal, and ceramic materials are used for the piston-cylinder arrangement of the fourth stage. Vibration and noise have been minimized through the use of a Scotch yoke drive, multiple plastic plate valves and a cross cylinder arrangement. The motor and the compressor are cooled by a separate fan. The power supply and all necessary controls are housed in a small module attached to the frame.

(Source: Mr Heinz Baumann, Sulzer Burckhardt, Fax +41-52-262 0019)

Oil-free compressor-motor unit.



Expansion turbine on show

USA - One of the most interesting exhibits at the recent ASHRAE/ARI Show (Chicago, January 30 to February 1) was a demonstration by Carrier of an air-conditioning system featuring an expansion turbine. A long-time dream of design engineers, the expansion turbine reduces power consumption by recovering energy from the pressure drop during expansion, and using it to help drive the compressor motor. Carrier claim to have reduced energy consumption by about 5% in this way.

One of the main difficulties with expansion turbines is that liquid refrigerant must be prevented from entering the turbine. This problem is easier to resolve with HFC-134a and energy recovered by the expansion turbine more than compensates for the drop in performance associated with HFC-134a. This has enabled Carrier to offer a range of chillers with a non-ozone depleting refrigerant and a competitive performance.

(Source: IEA Heat Pump Centre and Energie en Milieu Spectrum, 1/2 1995, The Netherlands)

Two-step system heats university campus

Norway - Making use of its coastal location, the University of Bergen is installing a unique heating system for its campus, whereby heat from the sea is upgraded in two steps.

In 1991, various heat pump systems were considered as options for upgrading and replacing old heating systems, and for providing space conditioning and water heating in new buildings. The need to minimize future energy consumption was a prime concern.

In the chosen system, a central sea-water heat pump supplies water at intermediate temperature for distribution around the campus. This is used as a heat source for several decentralized heat pumps which serve separate buildings or groups of buildings.

The system, shown in Figure 1, offers simultaneous heating and cooling operation. The total heating load at design conditions is estimated at 3.4 MW, with an annual heating demand of 5.3 GWh. The maximum cooling load and the annual cooling demand are approximately 1.5 MW and 0.6 GWh, respectively. Due to the mixture of old

and new buildings, the required supply temperatures in the buildings range from 55 to 80°C at design conditions. The central heat pump has a heating capacity of 1.15 MW at design conditions, whereas the heating capacity of the decentralized heat pumps range from 150 to approximately 600 kW. In the first phase of construction, two decentralized heat pumps will provide space and water heating, while three units are designed to provide both heating and cooling.

The central heat pump can operate in either "heating mode" or "cooling mode". In "heating mode", the unit will supply water of 15 to 25°C via uninsulated pipelines to the decentralized heat pumps. In "cooling mode", the central heat pump is switched off, and a sea-water heat exchanger is activated.

Depending on the sea-water temperature and on whether there is a deficit or surplus of heat in the system, heat will either be extracted from or given off to the sea-water. If future cooling demand becomes substantially higher than today, the central heat pump can easily be adapted to supply both heating and cooling.

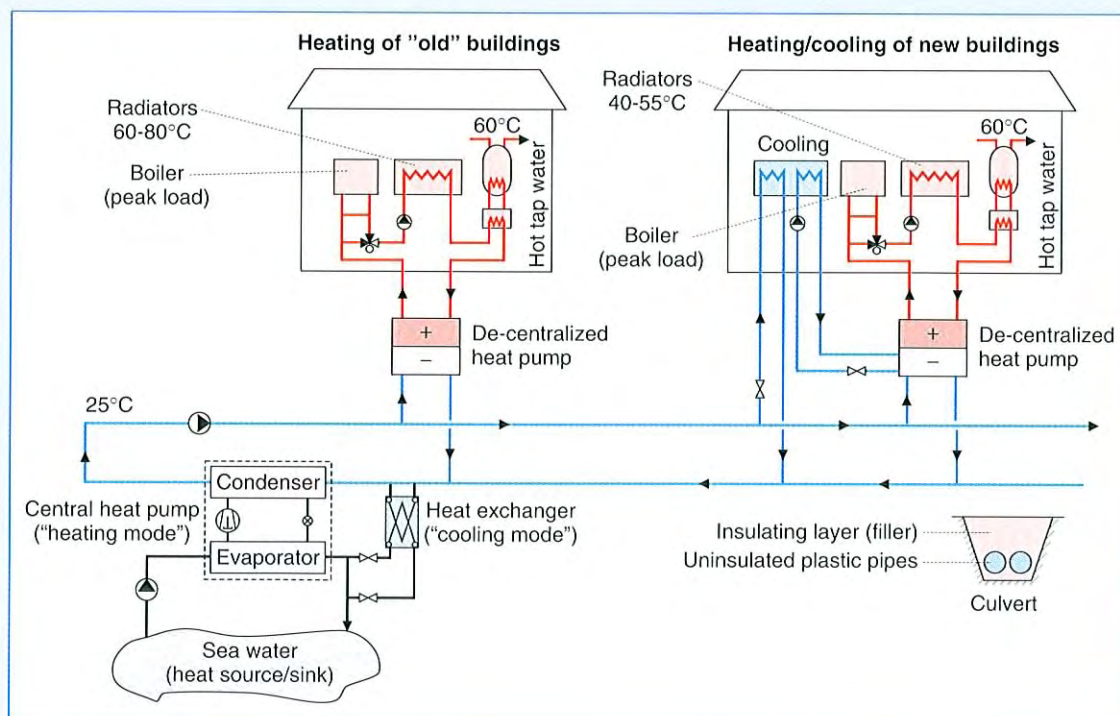
Ammonia

Both the central heat pump and the decentralized units use ammonia as working fluid. Adequate safety precautions have been taken to ensure safe operation and maintenance. The main safety measures include fail-safe ventilation, water-spray systems and gas detectors activating alarm systems. The central heat pump and one of the decentralized units will be in operation from early 1995. The remaining four decentralized heat pumps will be installed during the period 1995 to 1996.

Due to the unique system design and the use of ammonia as working fluid, the heat pump system has become a prototype and demonstration plant, and receives grants from the Norwegian Authorities. NTH-SINTEF Refrigeration Engineering is responsible for the overall system design and control strategies, as well as instrumentation and monitoring of the heat pump system.

(Source: Mr Jørn Stene, Norwegian National Team and NTH SINTEF Refrigeration and Air Conditioning, Trondheim, Norway, Tel: +47-7359-1642; Fax: +47-7359-3926)

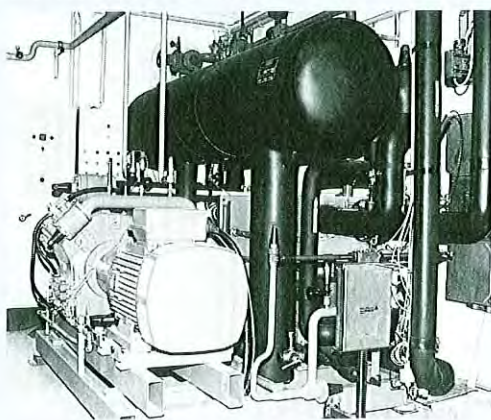
Figure 1: Two steps to heating: the central heat pump provides a heat source for the decentralized units.



Working Fluids

Ammonia used in ground-water heat pump

Germany - The Institut für Luft- und Kältetechnik (ILK) in Dresden has demonstrated the feasibility of using ammonia working fluid in combination with ground-water by



using a prototype ground-water heat pump to heat its offices and laboratories. The 220 kW (heating capacity) electric heat pump (see photograph) has demonstrated COPs in excess of four at source temperatures of 5 to 9°C and sink temperatures of 38 to 48°C. This is about 10% better than the similarly-sized HCFC-22 heat pump used previously. The ammonia heat pump employs a reciprocating compressor and serves a bivalent heating system. Although the evaporator (a plate heat-exchanger) is flooded, the

specific refrigerant charge is minimized to 0.15 kg/kW.

The system has shown that measures, such as the use of pH monitors, allow the safe use of ammonia in combination with ground water. However, the cost of such safety measures adds 6% to the first cost of the system, which was about US\$ 300/kW (DM 500/kW) in this case. It is expected that these additional costs would limit the application of this type of heat pump to systems with a heating capacity above 100 kW.

(Source: Mr Wolfgang Eichler and Mr Eberhard Wobst, ILK, Germany. Fax: +49-201-183-2584)

Direct-expansion probe gives leak warning

Switzerland - In ground-source heat pumps, geothermal probes usually use a water-glycol mixture to transport heat from the probe to the evaporator. While this system is often convenient, both for the installer and the heat pump manufacturer, direct evaporation (direct expansion) of the refrigerant in the geothermal probes would be preferred since it leads to higher efficiency by eliminating one level of heat exchange.

However, in Switzerland, the placing of conventional direct-expansion geothermal probes containing the widely-used refrigerants is forbidden, as the leakage of refrigerant into the soil cannot be positively excluded. For this reason, a safety probe has been developed which will warn of leakage. In the safety probe, the copper pipes containing refrigerant are separated from the soil by a surrounding polyethylene protection tube filled with water-polyethylene-glycol. Any leakage, in either the probe or the protection tube, is detected and an alarm is triggered.

Two leak detection systems have been developed. Tests on HCFC-22 have shown that a leakage of between 15 and 80 g of refrigerant into the protection tube can be detected, depending on the type of detection system used. The photograph shows the test equipment in action.

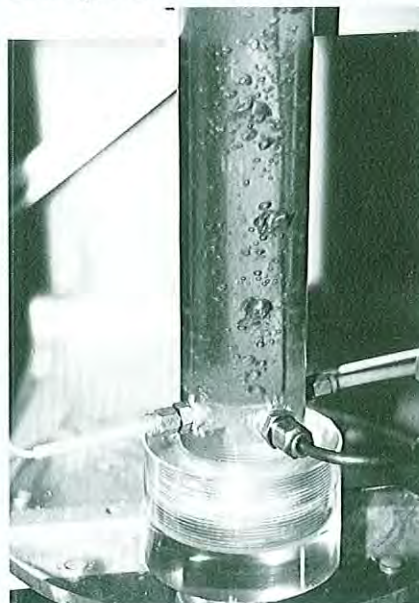
Laboratory and field tests have been carried out to compare the heat transfer properties of the safety probe with a conventional direct-expansion probe. The results show that the water-polyethylene-glycol safety tube raises the total heat transfer resistance by approximately 10% (3 to 13% according to soil composition).

An estimation of the influence of this deterioration on the performance of a heat pump showed that a safety-type direct-expansion system would exhibit a 1 to 7% better performance than a conventional geothermal probe with a water-glycol heat transfer media.

Further information is available from Prof. Peter Suter, Laboratory for Energy Systems, ETHZ. Fax +41-1-632 1176.

(Source: Prof. Martin Zogg, Swiss National Team)

Putting leak detection to the test.



Markets

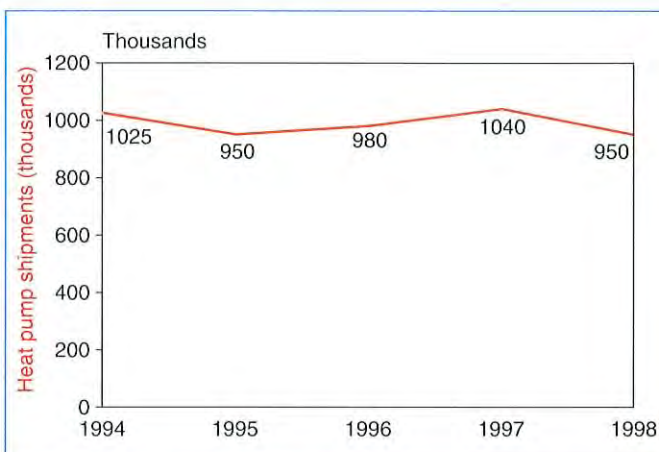
Factory shipments reach 1 million

USA - While absolute figures were not available at the time of writing, it is expected that annual shipments from factories of air-source unitary heat pumps will have reached one million in 1994 – an all-time record. The previous record shipment figure of 882,000, set in 1993, was almost exceeded in the first ten months of 1994 when 871,000 heat pumps were shipped to distributors.

This impressive performance comes on the back of an even bigger rise in shipments of cooling-only unitary air-conditioners. 1994 11-month shipments of these units were 4,599,640, already exceeding the previous annual record of 4,324,000 units, set in 1989.

However, 1995 is not predicted to be such a good year for manufacturers. According to a forecast by Honeywell, a build up of distributor inventories will reduce factory shipments of heat pumps to below the million mark for 1995. As

Figure 2: Predicted shipments of air-source unitary heat pumps (Source: Honeywell).



shown in Figure 2, annual heat pump shipments will fluctuate around 1 million units for the coming four years.

(Sources: Air Conditioning, Heating & Refrigeration News, January 2 and 9, 1995, and Koldfax from ARI, January 1995.)

Room unit shipments up 34%

Japan - Annual factory shipments of room heat pumps rose a massive 34% in the year ending October 1994, to register a new record for this category. Table 2 presents shipment figures for the past five years. According to an industry source, actual sales of room air

conditioners (both heat pump and cooling-only) reached 7,086,000 units in the same period, up 39% on the previous year. The hot summer of 1994 helped boost the demand for this equipment and led to a sharp reduction in distributor inventories. This in turn encouraged

manufacturers to introduce new models boasting higher energy efficiency and other features such as easier handling and improved foot-level temperature (using flaps to avoid chilled air-flows near the floor). The demand for more efficient equipment is said to be driven by an increased use of heat pumps during the winter.

(Source: JARN, November, December 1994 and January 1995)

Year Ending	Room heat pumps		Packaged heat pumps	
	Shipments	Share	Shipments	Share
Oct '90	4,242,929	72%	725,129	78%
Oct '91	5,342,855	75%	859,176	80%
Oct '92	4,911,610	79%	747,239	81%
Oct '93	4,180,101	83%	645,260	82%
Oct '94	5,604,216	83%	613,603	82%

Table 2: Japanese domestic heat pump shipments. Share indicates the proportion of heat pumps to total air-conditioning equipment.

IEA Heat Pump Programme

Annex 22 sets out on the natural way

Norway - Annex 22, "Compression Systems with Natural Working Fluids" was set underway on January 1 this year, with the participation of eight countries (see Table 4). The Annex aims to further develop the technology and expand the knowledge on natural working fluids in compression heat pump, air-conditioning and refrigeration systems. The fluids that will be covered are: ammonia, hydrocarbons (pure fluids and blends), carbon dioxide, water and air.

Annex 22 will be in operation from January 1, 1995 to December 31, 1997. The Research Council of Norway is designated the Operating Agent of the Annex, acting through NTH SINTEF Refrigeration and Air Conditioning. The main objectives of the Annex are to present state-of-the-art information, carry out research, development and demonstration activities, and to establish acknowledged guidelines for component and system design. The following publications will be issued:

- Guidelines for Design and Operation of Compression Heat Pump, Air-Conditioning and Refrigeration Systems with Natural Working Fluids;
- Final report;
- Workshop proceedings.

Readers of the *Newsletter* will be informed of the availability of these publications.

Activities

The Annex will consist of both task-sharing and cost-sharing activities. The participants will contribute to the Annex by gathering relevant national information (Country Reports), by establishing and monitoring prototype and demonstration plants, by undertaking R&D projects and by participating in workshops. The Operating Agent will compile and analyze the information from the participants, together with data on state-of-the-art technology and working fluid properties from an extensive literature survey.

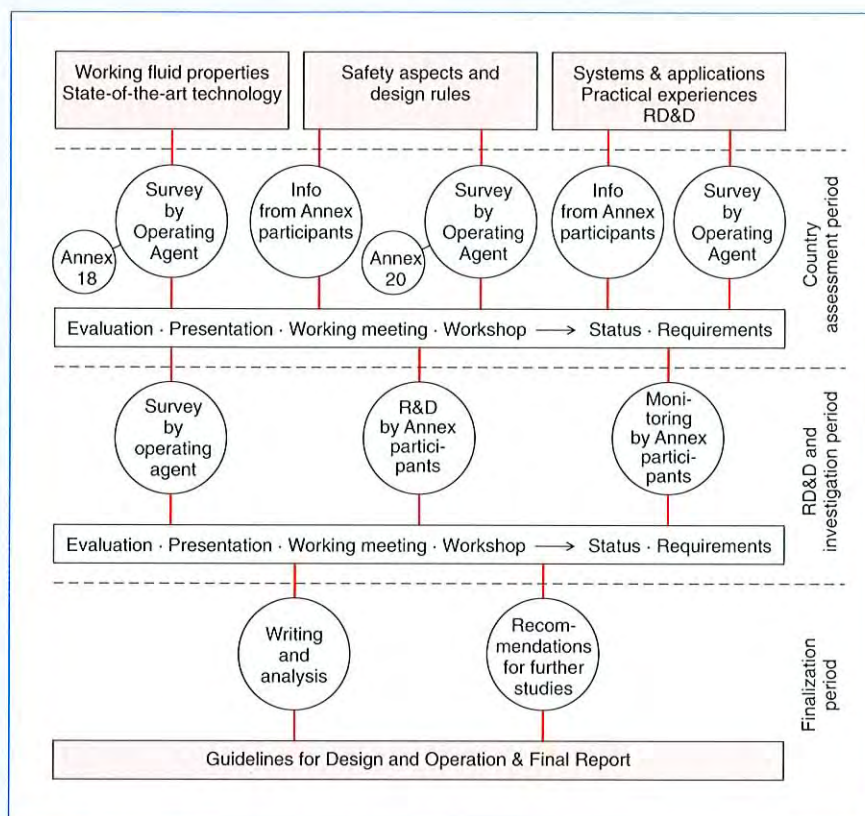


Figure 3: Annex 22 operation schedule.

As shown in Figure 3, the activities are divided into three working periods:

- Country assessment period (1995);
- RD&D and investigation period (1995/1996);
- Finalization period (1997).

Workshop

A workshop to present and discuss current knowledge on this topic will be held in Trondheim, Norway on 16-18 October 1995. Participation is welcomed from all countries.

(Source: Mr Jørn Stene, Norwegian National Team and NTH SINTEF Refrigeration and Air Conditioning,

Trondheim, Norway, Tel: +47-7359-1642; Fax: +47-7359-3926)

Erratum

In *IEA Heat Pump Centre Newsletter* Vol.12, No.3 page 9, the annual energy savings from the 6.2 MW MVR heat pump now being installed in an oil refinery in the Netherlands should have been given as 1.2 PJ and not 1.2 TJ.

Executive Committee discuss new Annexes and 5th Conference

The most recent Executive Committee Meeting of the IEA Heat Pump Programme, held in London, UK on November 15-16, 1994 discussed the status of ongoing Annexes and the introduction of new Annexes. As shown in Table 3, Annex 22 has been launched and the operation of Annex 21 has been extended to June 1995. Italy has withdrawn its membership of Annex 16 (IEA Heat Pump Centre).

Two new Annex proposals were presented at the meeting: Mr Hans Schärer of Switzerland proposed a project to look at "Heating Systems with Heat Distribution at a Temperature Level < 30°C"; Mr Björn Sellberg of Sweden introduced a proposal on absorption heat pumps.

Also at the meeting, it was confirmed that the 5th IEA Conference on Heat Pumping Technologies will take place in Toronto, Canada on September 22-26, 1996. The designated theme for the conference is "Heat Pumping

Participants of the London Executive Committee Meeting.



Technologies Towards the Next Century: Applications and Markets". While oral papers are by invitation only, those interested in submitting a poster paper are invited to submit an abstract (200-300 words) by 1 May 1995.

Contact: Dr Vincenza Galatone of EDRL, Canada;
Fax: +1-514-652-5177
E-mail: vgalaton@cc2smtp.emr.ca

(Source: IEA Heat Pump Centre/TSSU)

No.	Annex	Operating Agent	Participants	Start Date	Completion Date
16	Heat Pump Centre	NL	AT, CA, JP, NL, NO, CH, US	Jan 1990	
18	Thermophysical Properties of Environmentally Acceptable Refrigerants	US	AT ¹⁾ , CA, DE, JP ²⁾ , NO, SE, UK, US	Dec 1989 Jan 1993	Dec 1992 Dec 1996
21	Global Environmental Benefits of Industrial HPs	US	CA, FR, JP, NL, NO, SE, UK, US	Jan 1992	June 1995
22	Compression Systems with Natural Working Fluids	NO	CA, DE, JP, NL, NO, CH, UK, US	Jan 1995	Dec 1997
Participating countries: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), Spain (SP), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US). ¹ Phase one only. ² Japan is the Cooperating Agent of phase two.					

Table 3: Summary of on-going IEA Heat Pump Programme activities.

Annex 21: Dutch plot IHP potential

The Netherlands - A study for Annex 21, "Global Environmental Benefits of Industrial Heat Pumps" has examined the potential for industrial heat pumps (IHPs) in nine industrial sectors, representing about 85% of industrial energy consumption in the Netherlands. The results are shown in Table 4.

While an accurate assessment was difficult to make for many sectors, particularly for the chemical industry, the study estimates that IHPs could reduce CO₂ emissions by 2.4 Mtonnes per annum. According to IEA data, this is about 1.5% of energy related CO₂ emissions in 1992.

Data of a selected number of processes were gathered and pinch analyses were carried out. Computer programs developed under Annex 21 were used to select heat pump systems and to examine their technical and economic feasibility in these processes. The final selection of these processes took place in cooperation with other National Teams from Annex 21. Processes from the following industries were selected: dairy (cheese, milk, whey), textiles, paper, building ceramics (bricks, tiles), methanol, ethylene (naptha feed), ureum and starch. In all these processes, except the methanol process, heat pumps were found to be feasible.

The study was carried out by TNO (Netherlands Organisation for Applied Scientific Research) who were commissioned for Annex 21 by Novem (Netherlands Agency for Energy and the Environment) and the Dutch Heat Pump Implementation Programme. The results are published in the report "The Application of Industrial Heat Pumps in The Netherlands" – TNO-report 94-376, January 1995 and will be presented at a national workshop in 1995.

(Source: Mr Jan B. de Wit, TNO-ME Department of Heat and Refrigeration Technology, The Netherlands, Tel:+31-55-493179; Fax:+31-55-493740)

Table 4: Potential for Heat Pumps in the Food and Drink Industry.

Sector	Heat pump type	Capacity (MW)	Power (MW)	No. of instalations	Energy- savings TJ	CO ₂ emission reduction (ktonne/year)
Dairy	MVR	450	30	60	10,686	545
	closed cycle	60	20	40	212	11
Sugar	MVR	500	40	8	3,069	157
	closed cycle	neg	neg	neg	neg	neg
Starch	MVR	200	8	4	2,899	148
	closed cycle	neg	neg	neg	neg	neg
Beers & Malt	MVR	6	0.3	6	150	7.6
	closed cycle	4	1	6	39	1.9
Oils & Fats	MVR	≈200	10	n.a.	4,752	242
	closed cycle	n.a.	n.a.	n.a.	n.a.	neg
Paper	closed cycle	80	15	20	1,167	59.5
Textile Finishing	MVR	neg	neg	neg	neg	neg
	closed cycle	4	0.8-1	10-15	30	1.5
Ceramics and glass	MVR	neg	neg	neg	neg	neg
	closed cycle	12 ¹⁾	0.5 ²⁾	3	308	15.7
Chemicals	MVR	≈1,000	80	n.a.	22,000	1,000
	closed cycle ³⁾	36.8	1	6	94.4	48.1
Base materials	MVR	neg	neg	neg	neg	neg
	closed cycle	n.a.	n.a.	n.a.	n.a.	pm
Total		2552.8	204.8	n.a.	46,993	2396.3
neg = negligible; n.a. = not available						
¹⁾ Some of these are heat transformers in the ceramics industry.						
²⁾ Drive power of heat transformers not taken into account.						
³⁾ Ethylene and ureum production.						

CFC and HCFC Replacement

An International Overview

Bert Stuij, IEA Heat Pump Centre

The CFC and HCFC replacement market that is now emerging is driven by a complex and volatile mix of environmental pressures, safety concerns, technical limitations, regulations, and economics. This article provides an overview of these issues, based on topic appraisals in a number of countries, the results of which are summarized in the blue boxes. Use was also made of the findings of the HPC workshop on "Consequences of (H)CFC replacement in HVAC applications", held at Gothenburg, Sweden, September 1994. For more details on the proceedings of this workshop, see page 41 of this Newsletter.

* * *

The (H)CFC debate is rapidly moving to the market place. The academic question of what options are possible has been replaced by the questions: "What options are offered by the manufacturers?", and "Which solutions are demanded by the users?". Workers in the field have to deal with practicalities and may wonder what refrigerant changeover procedure they should follow. Refrigerant safety has become a matter of public perception, rather than for academic risk assessments. Manufacturers, installers and users have to try to understand and comply with the latest regulations.

An Environmental Issue

Concerns about ozone depletion have been translated politically into phase-out dates for CFCs and HCFCs. These dates do act as solid market boundaries. However, in particular for export-oriented companies, it is trying that the HCFC phase-out requirements vary from country-to-country, and are subject to frequent and sometimes unpredictable updates. Concerns about global warming have not yet led to regulations restricting the use of certain refrigerants. Indeed, such regulations are difficult to make since the global warming impact of a refrigerant is not only determined by its own direct impact upon release, but also by its affect on equipment efficiency.

It is now widely argued that, from an environmental viewpoint, it is preferable to use substances which are naturally present in the biosphere, and have demonstrated their harmlessness, provided that they

are otherwise suitable as refrigerants. Candidates include ammonia, hydrocarbons, CO₂, water, air and the noble gases. However, the use of ammonia and hydrocarbons has safety implications, and further technical development is required to make efficient equipment using CO₂, noble gases or air.

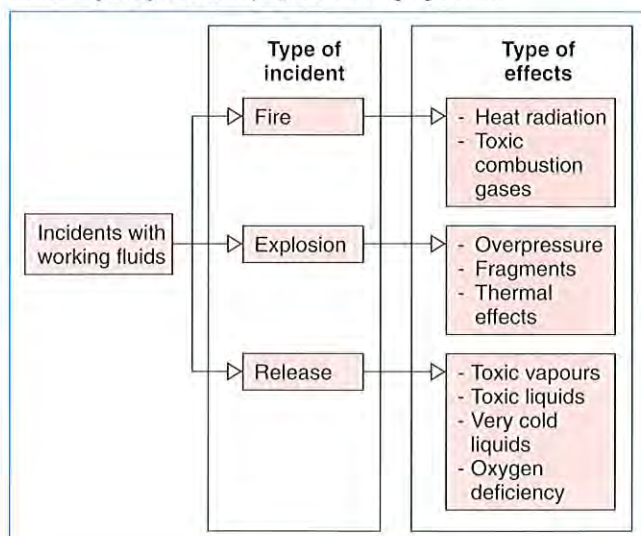
Apart from a policy driven phase out of certain refrigerants, manufacturers may also experience a market pull in an environmental direction. A number of Swedish and German heat pump manufacturers, for instance, are now converting their heat pump production lines to propane, in response to actual or expected environmentally driven market forces in Europe.

A Safety Issue

The changeover of refrigerants must not affect the safety of heat pump users. This makes the conversion of existing equipment to flammable or toxic refrigerants difficult at best, whereas their use in new equipment may require engineering upgrades. The use and location of the equipment can also be affected.

Figure 1 shows an overview of the potential implications of the use of hazardous refrigerants. This is taken from the report "Working Fluid Safety", a result of Annex 20 of the IEA Heat Pump Programme

Figure 1: Incidents and effects involving working fluids in heat pumps and refrigeration equipment.



Austria

CFCs have been forbidden in new equipment since 1994. HCFC-22 is the dominant alternative in all new applications with condensing temperatures up to 55°C. HCFC-22 was already the main refrigerant for heating-only heat pumps, it is now also the preferred choice for heat pump water heaters, which formerly used CFC-12. HFC-134a is thus far only used in applications with temperatures above 55°C. No retrofits from CFC-12 to HFC-134a were reported. Ammonia has always been used in large refrigerating systems and is increasing its market share for such systems. Interestingly, ammonia is now also used increasingly in heat recovery systems. Legal problems remain for its use in small to medium applications. Propane is used in heat pumps with outdoor installations, in particular outdoor air-to-air units and direct-evaporation ground-coupled systems. Further market penetration of propane systems is hampered by regulations, which forbid its use below ground level in residential and commercial buildings, and mandate a separated engine room. The truly challenging phase-out will be the one for the now widely applied HCFC-22. Austria is discussing a phase-out schedule tighter than the European Union.

(Source: Mr Hermann Halozan, Austrian National Team)

Canada

CFC consumption in Canada has dropped by 62% from 21 kilotonnes in 1987 down to 8 kilotonnes in 1993. This can be viewed as an indication of the effectiveness of Canada's Ozone Layer Protection Program, which runs under the direction of Environment Canada. The programme has enabled the federal government to go beyond the role of regulation, and work closely with industry, environmental groups, the public, and other levels of government to create an awareness of the measures necessary to reduce the consumption of ozone depleting substances.

One of the key mechanisms available in this strategy is the replacement of CFCs by HCFCs and HFCs in refrigeration systems and air-conditioning applications. Although actual performance statistics are unavailable, without system modifications the consequences of such conversions can be 10 to 15% less capacity, and a 2 to 5% lower cycle efficiency. The impact of replacements on factors such as energy consumption is expected to be addressed in a current study partially sponsored by the Canadian Electrical Association and entitled "Capitalizing on the Energy Saving Opportunities Presented by CFC and HCFC Phaseout in Non-Domestic Refrigeration". For existing commercial and industrial refrigeration applications, some conversions have commenced from HCFC-22 and R-502 to various HFC and HCFC blends. At the same time, CFC systems are still frequently retrofitted to, or replaced by, HCFC-22 equipment. For new equipment, domestic appliance manufacturers have begun producing refrigerators using HFC-134a in place of CFC-12. For automotive air-conditioning, manufacturers have agreed to switch from CFC-12 to HFC-134a for all new vehicles starting in model year 1995.

In general the present trend amongst refrigerant users is to opt for containment if possible. This is the cheapest and simplest choice, and may only require improvements to plant leak detection and monitoring practices. To some extent this also reflects uncertainties in some areas about the viability of HFCs as long-term alternatives, given the concerns about global warming and unknown future regulatory decisions in that area. Doubts about the effects of further regulation are also evident in that so far, there is no large shift away from HCFCs – example are the tendency to replace some CFC-12 and R-502 systems with HCFC-22 as indicated above, and the continued use of HCFC-22 in unitary air-conditioners and heat pumps. Some interest is beginning to emerge in the application of natural refrigerants. One manufacturer of industrial refrigeration systems has seen an increase recently in the use of ammonia in place of CFC-12 for ice rink installations. Also, Canada will participate in the new Annex 22 dealing with natural working fluids, with representation from the National Research Council and support from Environment Canada.

(Source: Mr Keith Snelson, National Research Council Canada and Canadian National Team)

Italy

In Italy HFCs are viewed as the most promising alternatives for CFCs. HFC-134a and the blend R-407C are gradually penetrating the market. Practical consequences of the changeover from CFC-12 to HFC-134a, which include a larger compressor to maintain capacity and a dryer to minimize the amount of water in the circuit, are expected to raise the price of air conditioning to a degree. A loss of market is anticipated. For small air-conditioning systems HFC-134a may not be the preferred choice, but it is not yet clear which other alternatives will emerge.

(Sources: Ms Laura Manduzio, ENEA)

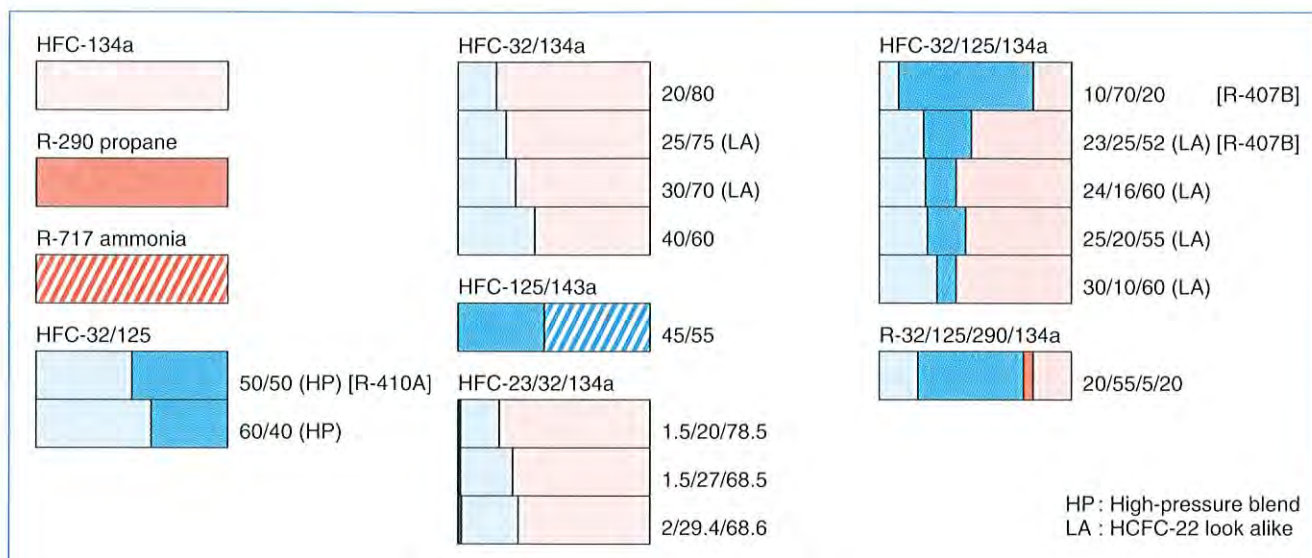


Figure 2: Composition of refrigerants tested under the Alternative Refrigerants Evaluation Program (AREP).

published by the IEA Heat Pump Centre in 1994 (ordering details on page 43 of this Newsletter). This report also provides guidelines for a quantitative risk assessment. Such an assessment should form the basis for working fluid safety regulations.

At the HPC workshop on (H)CFC replacement in Gothenburg, it was highlighted that halocarbons also have safety implications, although there are limited data on actual incidents. Prof. Lorentzen contended that the "sneaking risk" of suffocation in heavy gases with no smell has taken many lives.

A Technical Issue

Refrigerant changeover is a technical challenge in many respects. New equipment will, in general, need to be redesigned to perform optimally with a new working fluid. For equipment currently using HCFC-22, a replacement is needed that minimizes the extent of redesign. Figure 2 shows the options under consideration by the Alternative Refrigerants Evaluation Program (AREP).

The zeotropic HFC mixture, R-407C, commands considerable attention as an HCFC-22 "look-alike". Zeotropic blends tend to be less efficient in heat transfer than single-component refrigerants. On the other hand, their temperature glide at condensation and evaporation can improve cycle efficiency, if counter-flow heat exchangers are used. But this requires equipment modification, of which the advantages have to outweigh the costs. Another issue is the potential refrigerant fractionation if a leak occurs, which complicates refilling and maintenance.

Other HFC blends to replace HCFC-22 in new equipment are high-pressure, azeotropic mixtures of HFC-32 and HFC-125 (R-410 series). Concerns about fractionation and the effect of a temperature glide are

eliminated. However, the higher pressures will require a complete equipment redesign with stronger containment vessels, heavier refrigerant tubing, and smaller compressors.

If flammables are used, refrigerant charges must be minimized, complete leak tightness is a necessity, and extensive modifications to the heat pump manufacturing plants may be required. Because of the excellent thermodynamic properties of ammonia and hydrocarbons, the most probable flammable alternatives, higher cycle efficiencies are likely to be achieved.

For existing equipment, in particular larger CFC plants, refrigerant retrofits are now common. Well over 10,000 retrofits over the last three years were reported from Sweden. Retrofit procedures are maturing everywhere. Table 1 shows a Swedish example. Most retrofits are to HFCs, although Norway,

Table 1: A ten step retrofit procedure from Sweden.

Step	Action
1	Identify system to retrofit, make a list of components
2	Verify function and performance of the system
3	Correct problems and leaks, if any
4	Verify components compatibility with HFC / Esteroil
5	Remove mineral oil with oil changes or flushing
6	Change drier and other components
7	Evacuate carefully
8	Start up, adjust expansion valve, verify function
9	Mark installation clearly with oil and refrigerant
10	Take oil sample after approximately 100 hours

(Source: AKA Kyla AB presentation at the HPC workshop "Consequences of (H)CFC Replacement in HVAC applications", Gothenburg, Sweden, September 1994)

Germany

The shift away from HCFC-22 is urgent in Germany as this refrigerant will be banned on 1 January 2000. After the success of the domestic refrigerator with propane/iso-butane as working fluid, all leading manufacturers have now begun the large-scale production of small to medium sized residential heat pumps with propane as working fluid. The long-term environmental compatibility of hydrocarbons, the near certainty that they will not be restricted by future environmental regulations, and the excellent efficiency they allow, has made them the preferred choice. German manufacturers are convinced that for small to medium sized units the safety implications can easily be covered by relatively simple technical means. Current safety regulations allow the use of 1 kg of propane below floor level, and up to 2.5 kg above ground level without imposing any particular safety requirements. This is sufficient for all residential and many commercial applications. A new standard which is now out in draft form, DIN 7003, specifically deals with flammable refrigerants, and again does not restrict their use in these sectors. In Germany, HFCs are viewed as a transitional solution for the working fluid issue. Yet HFC mixtures and HFC-134a will play a significant role for the foreseeable future, notably in medium sized applications.

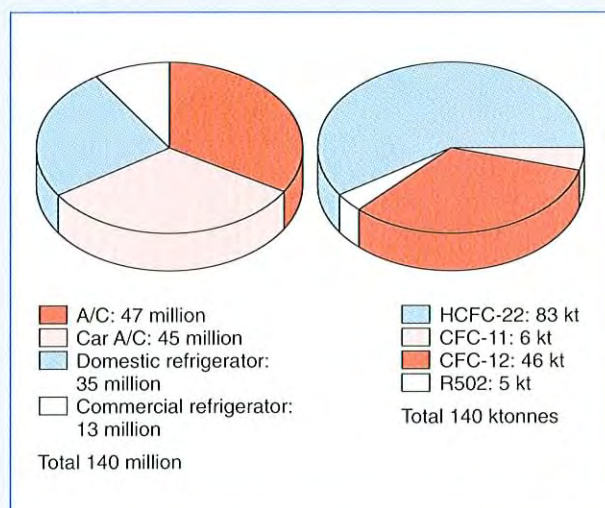
(Sources: Informationszentrum Wärmepumpen und Kältetechnik and IEA Heat Pump Centre)

Japan

Japan regards an internationally coordinated approach to the phase-out challenge as indispensable. It has therefore joined a number of international initiatives such as the Alternative Refrigerants Evaluation Program (AREP), Alternative Fluorocarbon Environmental Acceptability Study (AFEAS) and relevant IEA Heat Pump Programme Annexes. In Japan itself, 13 equipment manufacturers are collaborating in JAREP (Japanese Alternative Refrigerants Evaluation Programme). As in AREP, alternatives for HCFC-22 and R-502 are being reviewed. Efforts are currently focusing on HFCs and HFC blends. At the same time natural refrigerants such as ammonia, hydrocarbons, CO₂, air and water are receiving more and more attention in Japan, because of their complete environmental compatibility. Japan is participating in Annex 22 ("Natural Working Fluids") of the IEA Heat Pump Programme, with heavy industrial and academic involvement.

Products with HFC-134a are coming on the market, and some CFC-11 chillers have been converted to HCFC-123. The figure shows the current stock of refrigeration and space-conditioning systems (including heat pumps), and indicates the type and amount of working fluids used in them.

(Japanese National Team)



Number of installed air-conditioning (A/C) (including heat pump) and refrigeration systems and the amount of working fluid they contain.

Netherlands

The Netherlands has no systematic retrofit programme. Occasional retrofits have taken place, mainly from CFC-12 to HFC-134a. Some R-502 was replaced by R-404A, and some HCFC-22 by R-407C. For new systems, CFCs have been forbidden since 1993. Existing systems may be operated with CFCs, as long as they are leak tight. The current emphasis is therefore on emission reduction, rather than retrofits. It is expected that the need to retrofit will rise in the near future, driven by a CFC shortage. From January 1995 it is no longer allowed to import, sell or stock CFCs, apart from recycled CFCs. In general, however, the focus on emission reduction is expected to persist, including technical requirements for equipment, and competence requirements for installers and manufacturers.

(Mr René van Gerwen, Netherlands Organisation for Applied Scientific Research TNO)

Norway

About 17,000 heat pumps are currently installed here, with a total working fluid charge of about 280 tonnes. About 45 tonnes (16%) are CFCs, mainly CFC-12. A limited number of heat pumps use R-500 or R-502, and some industrial heat pumps use CFC-114. Less than 300 refrigeration and heat pump plants have as yet been retrofitted, and only very few of these are heat pumps. HFC-134a is the long-term candidate, but simpler and cheaper retrofit procedures have led to HCFC-22 or HCFC mixtures being used to retrofit most heat pumps with a limited remaining lifetime (< 5 years). Conversions to propane or HFC-152a have not yet happened, because of the flammability question. From January 1995, only reclaimed CFCs will be available for recharging, and it is expected that the ensuing CFC shortage, together with the growing experience of contractors, will lead to a rapid rise in the number of conversions.

Retrofitting has not caused major operational problems. To ensure optimum practice, NTH-SINTEF Refrigeration and Air Conditioning, in cooperation with contractors and consultants, has issued a step-by-step guide for CFC-12 to HFC-134a conversion. A guide for R-502 conversions is in preparation. Practical retrofit examples from Norway include the conversion of R-500 to HFC-134a in a district heating and cooling plant in Sandvika, changeovers from CFC-12 to HFC-134a in district heating plants, and an actual replacement of a CFC-12 heat pump in a dairy by an ammonia plant. In the coming years, HFCs and HFC blends will remain the common replacements for CFCs. It is expected that while HCFC-22 will be restricted for new equipment, its use in existing applications will continue to be allowed.

(Source: Mr Jørn Stene, NTH SINTEF Refrigeration and Air Conditioning, and Norwegian National Team)

Sweden

In total, about 100 large heat pumps (> 2MW) are in operation. Most of them originally used CFC-12, but there are a few with R-500 and some very large ones with HCFC-22. Ten of them have now been converted to HFC-134a, five are being worked on, and several more are planned to be converted in the near future. Results have in general been positive. The cycle efficiency improved in most cases but the capacity dropped somewhat. For smaller systems, over ten thousand conversions have been reported by AKA Kyla, distributor and wholesaler of components for the refrigeration industry in Sweden. Most conversions were from CFC-12 to HFC-134a, with a few from R-502 to R-404A, and more recently some HCFC-22 to R-407C changeovers.

On a more fundamental level, some parties in the commercial sector are rebuilding their installations to an indirect system, which gives them the possibility to use, for instance, ammonia or propane. For the residential sector the interest in using natural refrigerants is growing, and at least one major Swedish heat pump manufacturer (Electrolux) has abandoned HFC-134a for the residential heat pump market, in favour of iso-butane.

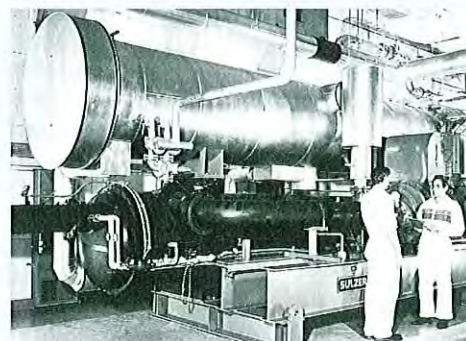
(Source: HPC Workshop Proceedings HPC-WR-13: "Consequences of (H)CFC Replacement in HVAC Applications", Papers by Eric Granryd of the Royal Institute of Technology, and Klas Berglöf of AKA Kyla AB).

Switzerland

Most heat pumps and refrigeration installations here use HCFC-22 as an interim solution to replace CFCs. However, there is a trend towards natural working fluids and HFC mixtures. While ammonia is mainly used for refrigeration, two-stage heat pumps with sink temperatures up to 70°C have also become popular. Hydrocarbons do receive attention, but contrary to their German counterparts, Swiss manufacturers have not yet decided to mass-produce hydrocarbon-filled heat pumps. The liability remains poorly defined, and there is still a lack of some components (e.g. compressors) for hydrocarbons.

A number of manufacturers are now using HFC mixtures, and others consider their use for the future. The use of HFC-134a as a replacement for CFC-12 is now increasing rapidly, notably also in high-capacity turbo-compressor heat pumps. The photograph shows a turbo cooler in the Swiss bank in Zurich, which was converted as early as 1991.

(Source: Mr Thomas Afjei, Swiss National Team)



United States

Attention in the US is focusing on finding a good alternative for the massively applied HCFC-22. Propane is recognized as an alternative with excellent thermodynamic properties, but it is still widely felt that the safety demands would either be impossible or extremely costly to comply with. There are also liability concerns about the market introduction of a potentially "explosive" appliance. A large number of refrigerants have been evaluated under the international Alternative Refrigerants Evaluation Program (AREP), but it now appears that manufacturers are homing in on two alternatives: the zeotropic blend, R-407C and the azeotropic high-pressure R-410 series.

R407-C causes concerns about fractionation and the effect of temperature glide, although the latter can lead to a higher efficiency. The high pressure R-410 blends allow compact, high efficient equipment, but require a complete redesign with stronger containment vessels, heavier refrigerant tubing and a smaller compressor.

(Sources: Mr Mark Menzer and Mr David Godwin, ARI and US National Team. See also the article on page 29 of this Newsletter).

for instance, reports that older equipment is commonly retrofitted from CFCs to HCFC-22 or HCFC blends, because it is simpler and less expensive. Furthermore, a number of retrofits of CFC-11 chillers to HCFC-123 are reported, e.g., in Canada and Japan. There are cases of changeovers from CFC-12 to ammonia. The high pressure requires extensive plant modifications, whereby the existing CFC-12 compressors can be used as the first stage, with a second stage added.

In general, refrigerant replacement has not resulted in appreciable performance losses. Limited tuning of the equipment is in general sufficient to maintain or slightly improve efficiencies. Some interesting examples of significant performance improvements have been reported; notably in the changeover from CFC-12 to HFC-134a, and HCFC-22 to propane.

It should also be noted that while halocarbons have many virtues, they do set fundamental performance limitations. Halocarbon systems, in particular if filled with mixtures, suffer from heavy flow-resistance losses and poor heat transfer. The more radical shift away from halocarbons, to fluids like ammonia, hydrocarbons or CO₂, could lead to appreciable system efficiency improvements.

A Regulatory Issue

The refrigerant changeover market is driven and constrained by regulations which vary enormously from country-to-country, and are subject to frequent updates. Developed countries are bound by the Montreal Protocol and its amendments. Developing countries, which include large emerging markets like China, India and South America, have a much more relaxed phase-out schedule for CFCs, with no dates as yet agreed for HCFCs. In Europe, the HCFC phase-out regulations are significantly tighter than those imposed by the Montreal Protocol. Alternative refrigerants are also affected by regulations. The use of hazardous substances such as hydrocarbons and ammonia has to comply with safety regulations. These

again vary strongly from country-to-country, and were in general not designed for the use of these substances as refrigerants in hermetic applications. In the US it has been estimated that compliance with current safety regulations would increase heat pump system costs by 50% if flammables were used. In the US there are also very serious liability concerns. HFCs are nowhere covered by regulations, although most of them are fairly potent greenhouse gases. Some European countries may consider curtailments on the basis of their direct global warming potential.

Manufacturers have to anticipate the regulatory environment of the future, which may include strict limitations on the use of flammable refrigerants, but may alternatively set constraints on the use HFCs. With this uncertainty many manufacturers are waiting for more clarity, before shifting away from HCFC-22.

An Economic Issue

Ben Lieberman at CEI in Washington estimated recently that over the next ten years, consumers will pay a total of up to US\$ 5 billion for the CFC phase out, and up to US\$ 7 billion for HCFC phase out. This may seem a phenomenal amount, but it is perhaps a price worth paying for the continued and environmentally sustainable availability of commodities so essential to life as heating and cooling.

At the same time it is clear that errors are extremely costly for society. One such error would be that the industry converts to alternatives that, in turn, become replacement candidates within the next ten to twenty years. For it is equally true for the installer who changes the refrigerant in the plant in front of him, as it is for the international community which steers this changeover with regulations: it has to be a worthwhile conversion, at the right time, with the correct procedure, to a sound alternative.

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Safety Aspects of Natural Working Fluids

René van Gerwen, The Netherlands

Natural working fluids, such as ammonia, butane and propane, are among the most important long-term (H)CFC alternatives. While the technical aspects of their application are relatively well known, the dominant concern related to their application is safety, due to their flammable and toxic nature.

This article addresses the safety aspects of the current and future application of ammonia and hydrocarbons. Using evidence from accident records, the risks and causes of accidents are discussed, and progress in the development of safety regulation and standards is considered.

* * *

The treatment of safety aspects differs largely from country-to-country. Each country has different legislation, rules and standards that determine the application possibilities for ammonia and hydrocarbons.

Application of Ammonia

As part of IEA Heat Pump Programme Annex 20 "Working Fluid Safety" (the report has been recently published by the IEA Heat Pump Centre) an inquiry into the current application of ammonia in the Netherlands has been carried out [1]. One finding of this inquiry is that approximately 50% of the food industry uses ammonia as a refrigerant. Based on the refrigerant content, ammonia accounts for approximately 65% of the refrigerant used. The mean ammonia content per system is 5770 kg (see Table 1). A rough estimate of the mean ammonia content

related to the refrigerating capacity is 7.5 kg ammonia per kW. A trend in the food sector is observed towards smaller systems and lower ammonia content per kW. Heat pumps are rarely used in the food sector in the Netherlands. A few ammonia-water absorption systems for cooling or combined heating and cooling are reported.

An important ammonia application is skating rinks. For every 20 skating rinks, approximately 15 use ammonia as refrigerant. The total amount of ammonia in this sector is estimated as 150,000 to 200,000 kg. Relatively new applications can be found in the commercial refrigeration sector (supermarkets), and in building climatization where chillers and heat pumps are used in combination with secondary refrigerant systems using water, brine, or ice slurry. In both these sectors, ammonia has been used only rarely in the last 40 years. From an environmental point of view, these applications are very attractive. Nevertheless, current safety regulations still cause practical hindrance in many countries. In general, there is a need for internationally harmonized safety regulations and standards for ammonia applications, specifically for use in the urban environment, based on generally accepted quantitative risk assessment studies.

Application of Hydrocarbons

The last 40 years have seen very little use of pure hydrocarbons as a refrigerant. Two years ago, a breakthrough was triggered by Greenpeace. The use of a propane/butane mixture in home refrigerators was strongly supported by this organization, while manufacturers and chemical industries tried to obstruct this new development. At the moment, the use of propane/butane as the refrigerant for home refrigerators is generally accepted in Western Europe. Almost all new appliances will be equipped with this natural refrigerant from the beginning of 1995.

In the US, this application of propane and butane is still not accepted for safety reasons. In this context, it is interesting to observe that one of the few well-based risk assessment studies for domestic refrigerators was made in 1991 by an American company by order of the US Environmental Protection Agency. This study generally resulted in acceptance of the safety risks related to such applications [2].

The safety aspects of using hydrocarbons in domestic refrigerators in developing countries still have to be

Table 1: Refrigerant content in the Dutch food industry.

Refrigerant	Total content		Mean system content kg
	kg	%	
CFC-12	23,000	3	450
HCFC-22	242,000	31	2100
R-502	11,000	1	370
Ammonia	502,000	65	5770

considered carefully, due to the specific logistic and servicing situation in these countries.

Recently, a quantitative risk assessment study was carried out on the application of propane as a refrigerant in transport refrigeration equipment [3]. As a preliminary result, the safety risks related to this type of application can be considered to be acceptable. The results of this study are now being discussed with manufacturers to identify the practical possibilities of applying hydrocarbon refrigerants in transport refrigeration equipment in future. This discussion seems to be hindered by the economic interests of the equipment manufacturers.

Based on the results of the safety studies cited in this article, the application of hydrocarbons in other small equipment, combined with measures to reduce the refrigerant content, may be realistic for the near future. For the application in equipment such as small residential heat pumps, small room air conditioners and automotive air conditioning, proper internationally harmonized safety regulations have to be developed, based on quantitative risk assessment studies.

Accidents with Ammonia

Another part of IEA Heat Pump Programme Annex 20 related to accidents, causes and related risks. Data were provided by FACTS, a database for industrial safety made by the Netherlands Organisation for Applied Scientific Research – TNO, in which worldwide information has been collected on accidents with ammonia as a refrigerant over the last 20 years. This database survey noted only 37 accidents with 152 injuries (including 135 injuries from one accident in Indonesia) and 2 fatalities. One fatality was related to a domestic ammonia refrigerator.

Other sources give some additional information about accidents. In the Netherlands, five accidents causing injuries and one fatality took place in the last 14 years. In Norway, over a period of 20 years, 18 accidents took place, causing six injuries and two fatalities. In Japan, over a period of 40 years, there were 178 accidents, 179 injuries and 15 fatalities.

The FACTS database gives additional information about the causes of accidents. This information, extended with other sources, shows that more than 50% of the causes are related to human failure or unconscious operation. Frequently mentioned causes are wrong use of valves during operation and maintenance, leakage through valves or valve glands, wrong installation of valves, and damage of plant parts by fork-lift trucks. Based on this limited and inconsistent information, it is not possible to calculate the general ammonia refrigeration risks in a sufficiently accurate way. It is recommended that risk figures are investigated further, using more accurate and consistent accident data. Based on risk



In the services: This ammonia heat pump serves a military base in Norway (source: SINTEF).

calculations, the risk related to ammonia applications in industrial refrigeration plants is considered to be acceptable in The Netherlands, as long as the proper national safety regulations are applied.

Accidents with Hydrocarbons

Practical experience with the use of hydrocarbons as a refrigerant is too limited to investigate risks based on accidents. Calculated risk figures for the application in home refrigerators given in the US study [2], show an almost negligible risk during operation. Additional measures are recommended in relation to disposal to reduce risks to an acceptable level. The quantitative risk assessment of propane as a refrigerant in transport refrigeration equipment, described in [3], shows a general risk during operation far below the international accepted limits. Some additional measures related to servicing, maintenance and logistics are recommended to keep risks acceptable.

Quantitative Risk Assessment

Quantitative Risk Analysis (QRA) is the best way of measuring and comparing the risks of activities. Risk is determined by two factors: the *adverse effect* or *consequences* of an exposure to hazard, and the *frequency* that these consequences occur. In making a QRA, two criteria for risk are used:

- **Individual risk:** the frequency of fatal injury on a certain distance from the activity as a result of accidents with the activity concerned;

- **Societal risk:** the frequency of a minimum number of fatalities due to an accident with the activity concerned.

In the latter case, the actual presence of people in the surroundings is taken into account. For the determination of risks, several aspects have to be quantified. Standard methods have been developed, which are applied nowadays by many industrial companies, authorities and consultants over the whole world [3]. These techniques have been used in studies [2] and [3]. They are based on standard methods for the calculation of *physical effects* (release rates, dispersion rates etc.), *consequences* (fire, explosion, vulnerability models etc.) and *probability* (accident frequency, failure probability etc.). The proper use of these methods requires professional expertise in the field of industrial safety.

Standards and Directives

At the moment, national safety standards and directives concerning refrigerating systems are extremely diverse. Within the European Union, there is a process going on towards international harmonization. Several directives and standards exist. Some of them are:

- Draft European Standard prEN-378: "Safety and Environmental Requirements for Refrigerating Systems and Heat Pumps. This draft standard covers all kinds of refrigerants, including ammonia and hydrocarbons (in progress by CEN Technical Commission TC-182);
- European Standards concerning valves, flexible pipe elements, liquid level indicating devices, safety switching devices, flow diagrams, pressure vessels (in progress by CEN Technical Commissions TC-182 and TC-54);
- Pressure Equipment Directive;
- Construction Product Directive;
- Machinery Directive;
- Low-Voltage Directive.

This harmonization process takes a long time. For example, the final version of EN-378, the development of which started in 1989, is expected in 1996 at the earliest. One of the main problems is the conflicting interests of national parties (industrial, governmental and political) involved in this standardization process. Another problem is the limited interest of industries in being involved in such standardization processes. In fact, standards are developed by a very limited number of parties, despite their future impact.

Essential to Consider

Ammonia and hydrocarbons are very important alternative refrigerants for CFCs, HCFCs and HFCs. When applying these refrigerants, it is essential to consider the safety aspects, due to their toxic and flammable nature.



*On the market: Propane heat pump manufactured in Germany
(Source: KVS Klimatechnik)*

More work is needed to quantify the accident risk. Quantitative Risk Assessment studies (QRA) form the best technique for the determination of risks and provide an essential basis for evaluating the necessary measures to keep risks acceptable. Such measures include safety directives and standards. Within the European Union, progress is being made towards greater harmonization in this area. But the process takes a long time and only a limited number of parties is involved at present. Because of the future impact of such measures, more consideration for this standardization work is recommended.

References:

- [1] Vermeulen P.E.J. "The Use of Ammonia as Refrigerant in the Dutch Food Industry" TNO, the Netherlands, Report 92-180, May 1992, Dutch.
- [2] "Risk Assessment of Flammable Refrigerants for use in Home Appliances" Arthur D. Little Inc., USA, Ref. 64123, September 1991.
- [3] van Gerwen R.J.M.; Jansen C.M.A. "Risk Assessment of the use of Flammable Refrigerants" TNO, the Netherlands, Draft file nr. 8327-24191, June 1994.

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New Refrigerants for Japan's Heat Pump and Refrigeration Markets

Moriyoshi Sakamoto, Japan

Although the phase out of CFCs in new equipment does not come into force until the end of 1995, most manufacturers have already finished their CFC replacement programmes, and are now marketing equipment using either HFC-134a or HCFC-22. However, market acceptance of such equipment has generally been low.

Manufacturers are also working towards the longer-term aims of replacing HCFCs in space-conditioning equipment. This article gives an update on refrigerant replacement in Japan, considering first the market situation for CFC replacements, and then the development programmes for replacing HCFCs.

* * *

As shown in Figure 1, CFCs are scheduled to be phased out in new equipment in Japan by the end of 1995. To meet this goal, products using either HFC-134a or HCFC-22 have been marketed since 1993. These include automobile air conditioners using HFC-134a, and household refrigerators using HFC-134a or HCFC-22. The performance of these products is competitive with traditional equipment. The use of heat exchangers, compressors and refrigerant controls that are properly designed for the alternative refrigerants, has led to this success.

A major difficulty for designers using HFC-134a is compressor lubrication. A mixture of HFC-134a and a

lubricant is more reactive and less lubricating than a CFC-12 and mineral oil mixture. For this reason, much work, including time-consuming endurance tests of compressors, has been carried out to determine the materials which are compatible with the HFC-134a/lubricant pair. The choice of new materials has also led to other changes such as in thermal insulation foam, in the inside liner of refrigerators and in compressor manufacturing facilities. Such modifications have caused an increase in equipment price.

Automobiles

An automobile air conditioner employing HFC-134a was first put on the market in 1993 and now dominates the market – nearly all air conditioners in cars made in 1994 use HFC-134a. Such air-conditioning systems have the following features:

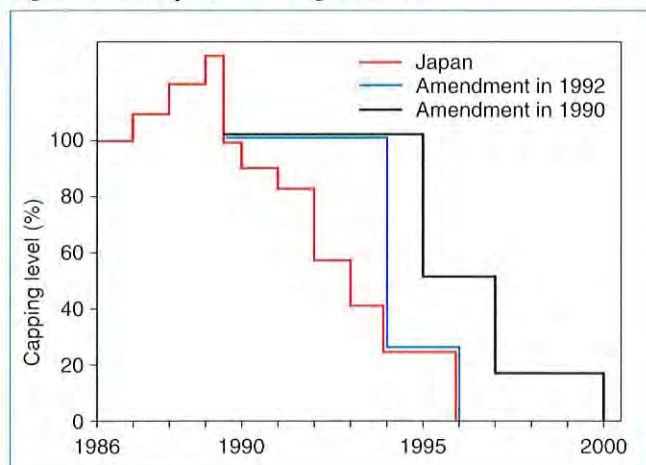
- a compressor lubricated by a new synthetic oil known as PAG, polyalkylene glycol;
- a condenser with a 20% larger capacity than the conventional one;
- a shaft seal to minimize leakage of HFC-134a;
- a refrigerant circuit attached with zeolite dryers to avoid water entering the circuit.

Household Refrigerators

CFC-12 has been replaced by HFC-134a in small capacity refrigerators, and R-502 by HCFC-22 in large refrigerators. Refrigerators employing these alternatives have been manufactured and marketed since the autumn of 1993. The household refrigerator industry is now ready to entirely eliminate CFCs from its products, before the end of 1995.

To minimize the charge of HFC-134a, which is 1.5 times more expensive as CFC-12, improvements in the performance of heat exchangers and compressors were completed at an early stage in the course of the technology development. One difficulty with the compressor for the household refrigerator was that PAG, the best lubricant for automobile applications, turned out to be of insufficient quality for refrigerators. Eventually, polyolester was chosen as the lubricant, after much effort had been made to test the durability of materials so as to minimize the wear occurring at the bearings and sliding parts of the compressor.

Figure 1: CFC phase-out regulations.



All refrigerators using alternative refrigerants are marked with the label shown in Figure 2, indicating that the product is free from CFC and therefore environmentally benign. It is a pity that the prices of refrigerators carrying the CFC-free mark are more expensive than those using CFC-12. However the freon-free products are gaining an increasing share of the market. Production of refrigerators with CFC alternatives is estimated to be over 60% of total annual production, which was about four million units in 1994.

Turbo Refrigerators

Refrigeration equipment driven by turbo-compressors employing HFC-134a was first marketed in April 1994. The performance of the turbo refrigerator is nearly the same as that of the traditional machines using CFC-12. This has been achieved by developments to increase the efficiency of the turbocompressor and by using high-performance heat transfer tubes in the evaporator. The refrigeration capacity of the latest equipment ranges from 390 kW to 4400 kW (110 to 1250 RT).

Only a modest number have been installed so far. It is, however, reported that manufacturers are receiving increasing numbers of enquiries about these products from potential installers. Many of these request information on field experiences with CFC-free products, highlighting the need for information exchange in this area.

Ammonia Refrigeration

The installation of large ammonia refrigeration facilities has tended to increase in the past few years. One example is an 80 MW (22,645 RT) system built in March 1994 for a food storage depot. The system is driven by 13 screw compressors, each with a capacity of 870 kW (246.6 RT). To reduce the ammonia charge, a lightweight and dry-type evaporator has been designed and manufactured. Electronic controlled expansion valves, which adjust in accordance with an optimum control scheme, and a computer control system, ensure optimized operation of the refrigeration system to minimize its energy



Figure 2: Label for CFC-free refrigerators.

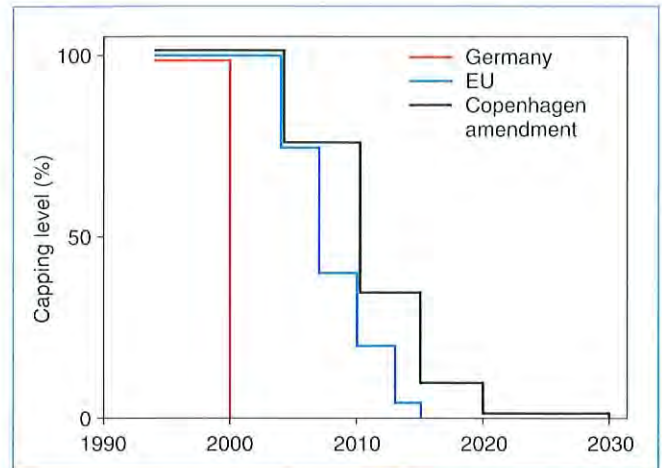


Figure 3: HCFC phase-out regulations.

consumption. A safety operation system detects the slightest leakage of ammonia gas and can control the system operation to prevent toxic hazards.

The system was carefully designed within the framework of the current regulations and with the support and guidance of the agencies involved with the regulation of high pressure gases. In fact, it is strongly felt in Japan that the refrigerant safety issue must receive prominent attention. It is expected that regulations on ammonia equipment will be reviewed to allow ammonia to be used more widely in future.

HCFC Replacement

The majority of space-conditioning heat pumps in Japan use HCFC-22, and will continue to do so for some time. In accordance with the 1992 Copenhagen Amendment to the Montreal Protocol (see Figure 3), Japan has been developing HCFC phase-out programmes so that a successful first step in reduction can be taken in 2004. One of the programmes is the Japan Alternative Refrigerants Evaluation Program (JAREP), under which heat pump equipment manufacturers and refrigerant manufacturers have been collaborating on testing the performance of current equipment using promising alternative refrigerants. An introduction to JAREP was given in *IEA Heat Pump Centre Newsletter* Vol. 12, No. 1, March 1994.

Recent progress in JAREP was presented at the "International Symposium on HCFCs Replacement", held on December 8 and 9, 1994, in Kobe, Japan. There it was reported that significant advances have been made in the development of components and equipment for alternative refrigerants. However, small-capacity space-conditioning heat pumps have not yet been introduced onto the market.

Under JAREP, six types of heat pump equipment, including split-system heat pumps, chillers and screw chillers, have been tested using six alternative refrigerants. Test results obtained so far strongly

indicate that the following blends would be preferable for split-system heat pumps with small capacity: HFC-32/125 and HFC-32/125/134a. Manufacturers have been testing compressors and systems appropriately designed for these blends with different compositions of the mixture components. Some of the data measured on these systems have proved that with some blend compositions, COPs are equal to or better than the COPs of HCFC-22 machines.

HFC-32/125

The near azeotropic blend, HFC-32/125 (60:40 wt.%), has a vapour pressure of about 1.5 times as much as that of HCFC-22. This, coupled with the high vapour density, requires an appropriate reduction in the discharge compression volume of the compressor. The size of the heat exchangers, in particular the condenser, must also be increased so that the refrigerant can be cooled down to the required degree of subcooling. Heat pumps equipped with optimized components have demonstrated a better performance, both in COP and energy consumption, than heat pumps for the baseline refrigerant, HCFC-22. The better performance was exhibited in both heating and cooling modes and over a wide range of compressor speeds.

The high concentration of HFC-32 may affect the reliability of heat pumps modified for this azeotrope, because of its flammability and its high vapour pressure. For this reason, further developments, including durability tests of component materials, need to be conducted prior to designing fully optimized equipment. Field tests must then be carried out to ensure their reliability.

HFC-32/125/134a

The zeotropic blend, HFC-32/125/134a (23:25:52 wt.%), has a temperature glide of up to 7°C. Since such temperature variation can worsen the performance of a heat pump, modifications must be made to obtain a uniform temperature distribution. For this purpose, changes in the arrangement of the refrigerant circuit and in the location of inlets and outlets to heat exchangers have been made. These modifications, along with the provision of an additional flow control valve, have significantly improved the performance in both heating and cooling. The COPs of modified systems for this ternary blend range between 92 and 98% of that exhibited by a system for the baseline refrigerant, HCFC-22.

Costs and Performance

Manufacturers now have the know-how to design heat pumps with new refrigerants with a performance competitive with current heat pumps. However, the modifications to compressors, heat exchangers and controls, as outlined above, suggest that considerable extra costs are involved in using alternative refrigerants. If the market is to accept products using

environmentally-friendly substances, then performance improvements must be made at lower cost. Furthermore, techniques and skills must be established to ensure reliability and safety of the products.

Heat Pump Chillers

Air-source heat pumps driven by a screw compressor, known as screw heat pump chillers, are used for space heating, hot water supply and snow melting in cold climate regions. The traditional chillers use HCFC-22. A range of screw chillers using HFC-134a with 0.32 to 2.4 MW (90 to 670 RT) cooling capacity is now marketed with an annual energy efficiency equal to that of the traditional products, but at a higher price. Another type of air-source heat pump chiller using HFC-134a, driven by reciprocating compressors, has been put on the market more recently. This system produces water at a maximum temperature of 60°C and its heating capacity ranges from 137 to 247 kW (118,000 to 212,000 kcal/h).

Despite the non-ozone depletion advantage, these products are enjoying only a small share of the market because they are less competitive in terms of price. Further development of the market can be expected by finding opportunities in niche markets such as government facilities and public buildings.

Responding to the Challenge

The experience of recent years shows that manufacturers are able to respond to the challenge of phase-out dates by introducing new products well before the deadline. However, in general, such environmentally-friendly equipment has not been widely accepted by the market. The three year recession in Japan, coupled with the higher price of the new equipment, have both contributed to the low sales. On the other hand, large-size refrigeration equipment and heat pumps with HFC-134a are gaining a growing share of the market.

In response to the phase-out regulations for HCFCs, manufacturers are developing equipment using HFCs. The work conducted under JAREP has shown how optimization of compressors, heat exchangers and refrigerant controls can result in performances with HFC blends that are competitive with those of existing heat pumps. Now, the challenge is to bring down costs and to address the crucial issues of reliability and safety.

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Water-Source Heat Pumps with HFC Refrigerants

Paul Glamm, USA

In the search to find an alternative to HCFC-22 for water-source heat pumps (WSHPs), a 10.6 kW (3 ton) system has been tested with two HFC blends, R-407C and R-410A. The performance with R-410A was slightly better than that for HCFC-22, while R-407C suffered a performance loss relative to HCFC-22. In addition, R-407C can suffer from freeze-up problems during low ambient heating, due to the very low refrigerant temperatures entering the water heat exchanger. However, the current compressor product lines are sized appropriately for application with R-407C, not for R-410A. In the short-term, the industry can substitute R-407C for HCFC-22, although with some loss in performance, a narrower operating range and uncertain reliability. Both compressors and heat exchangers must be redesigned to fully optimize WSHPs for use with either R-407C or R-410A, just as the industry is doing with HFC-134a applications today.

* * *

Water-source heat pumps (WSHPs) are applied in commercial buildings in the United States where low first cost is important and simultaneous heating and cooling modes may exist. The water source is usually a sealed loop which exchanges heat with the heat pumps, central boiler and cooling tower. The boiler and cooling tower are operated to keep the water loop temperature between 15.6°C (60°F) and 32.2°C (90°F). The heat pumps may be either ducted or unducted systems, and are controlled from thermostats in the conditioned spaces. Virtually all the commercial WSHPs in the United States use HCFC-22 as the refrigerant, so an intense search is underway for alternatives which are more environmentally acceptable.

Two alternate refrigerants, R-407C and R-410A, were tested against an HCFC-22 baseline. R-407C is composed of R-32/125/134a with a mass composition of 23/25/52%. R-410A is composed of R-32/125 with a mass composition of 50/50%. R-407C was chosen because of its close match in capacity to HCFC-22, while R-410A was chosen because of its very low refrigerant glide during boiling and condensing. Ester oil was used with both refrigerants. Both R-407C and

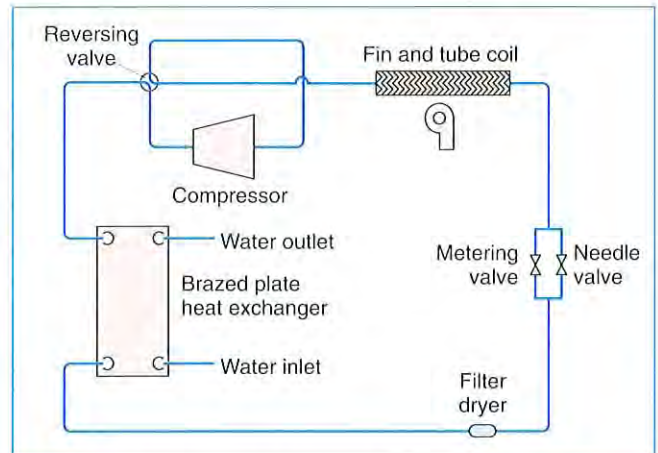


Figure 1: Schematic of the tested water-source heat pump.

R-410A are provisional designations assigned by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

Test Description

All tests were conducted with a breadboard WSHP, shown schematically in Figure 1. Primary components include compressor, refrigerant-to-air heat exchanger, refrigerant-to-water heat exchanger, expansion valve and air blower. The refrigerant-to-air heat exchanger is used to supply conditioned air to the occupied space. The heat pump was tested in both heating and cooling modes of operation. A hand valve was used to control refrigerant flow and evaporator exit superheat.

Heat Exchangers

The refrigerant-to-air heat exchanger is a classical fin-and-tube coil design with copper tubes expanded into aluminium fins. The coil was circuited to provide thermal cross-counter flow for HCFC-22 in the cooling mode (physical parallel flow in the two phase tubes, counter flow in the superheat tubes) as shown schematically in Figure 2. This circuiting arrangement also provides thermal cross-counter flow in the condenser and subcooler. For a zeotropic refrigerant like R-407C, this circuiting pattern is cross-parallel flow in evaporation except for the superheat section which is counter flow. It is cross-counter flow for condensing and subcooling.

ARI 320 Rating Point

Air dry bulb temperature
Air wet bulb temperature
Entering water temperature
Leaving water temperature
Air flow rate
Water flow rate

Cooling mode

26.7°C
19.4°C
29.4°C
35.0°C
0.472 m³/s
0.000505 m³/s

Heating mode

21.1°C
21.1°C
0.472 m³/s
0.000505 m³/s

Table 1: Rating point test conditions.

The refrigerant-to-water heat exchanger is a brazed plate design which acts as both condenser and subcooler in the cooling mode, and as both evaporator and superheater in the heating mode. Heat transfer is counter flow during the cooling mode and parallel flow in the heating mode.

Compressors & Refrigerants

Three different compressors were used to conduct these tests. A single hermetic reciprocating compressor was used with both HCFC-22 and R-407C. Two scroll compressors were built to provide the same capacity as the HCFC-22 reciprocating compressor, one using HCFC-22 and the other using R-410A. The R-410A compressor displacement is about $\frac{2}{3}$ of the HCFC-22 compressor displacement. Ester oil was used with all three refrigerants.

Test Conditions

Performance data were collected in both heating and cooling modes at the ARI-320 rating points as described in Table 1. The heat pump was charged in the cooling mode to provide 32.2°C liquid temperature leaving the condenser and 4.4°C superheat leaving the evaporator. The superheat setting applies to the R-407C zeotrope as well, and is actual superheat above the dew point, not above the average evaporator temperature. The heating mode charge was not the same as the cooling mode charge. Furthermore, rather than following a charge

optimization procedure, the heat pump was charged to provide a minimum subcooling at 4.4°C superheat and modelling tools were used to compare performance. Table 2 gives the test conditions for examining the low ambient heating performance.

Test Results

Although a wide range of experimental parameters were measured and analyzed, this article describes only the product level results.

Cooling Performance

The cooling rating point capacities of the HCFC-22 scroll and HCFC-22 reciprocating compressors were within 5% of each other, as shown in Table 3. More important is the experimental comparison of refrigerant behaviour in the heat pump: the R-407C reciprocating capacity was within 2% of the HCFC-22 reciprocating compressor capacity; and the R-410A scroll capacity was within 1% of the HCFC-22 scroll capacity. The coefficient of performance (COP) with R-410A was higher than with HCFC-22 in spite of the weaker theoretical thermodynamic performance of R-410A. The good performance of R-410A resulted from a slight reduction in compressor lift and a significant improvement in compressor adiabatic efficiency. The compressor lift was reduced due to better heat transfer performance in the heat exchangers, while the R-410A scroll compressor exhibited about 6% better adiabatic efficiency than the HCFC-22 scroll compressor.

On the other hand, the COP with R-407C is not as good as that for HCFC-22. Although the compressor adiabatic efficiency with R-407C is nearly the same as that for HCFC-22, the heat exchanger effectiveness is reduced due to glide mismatch and lower heat transfer coefficients.

Heating Performance

As in the cooling mode, the heating capacities were closely matched as shown in Table 4. However, the liquid temperatures with each refrigerant were not

Table 2: Low ambient test conditions.

Entering air temperature	15.6°C
Entering water temperature	7.2°C
Air flow rate	0.472 m ³ /s
Water flow rate	0.000505 m ³ /s

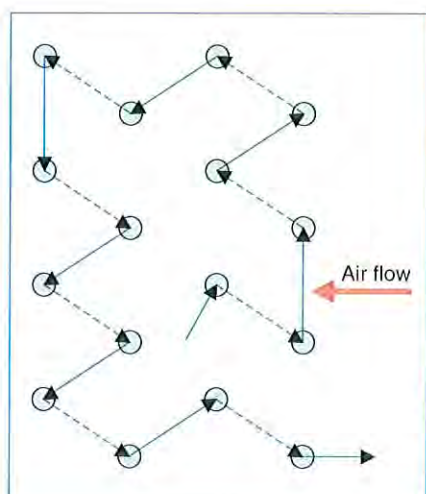


Figure 2:
Circuiting
arrangement for
the fin-and-tube
coil in the cooling
mode.

Refrigerant	Compressor type	Capacity (kW)	Compressor power (kW)	COP
HCFC-22	Recip.	10.311	1.860	5.54
R-407C	Recip.	10.260	2.030	5.05
HCFC-22	Scroll	9.828	1.870	5.26
R-410A	Scroll	9.806	1.820	5.39

Table 3: Performance at cooling rating point.

held close to each other and analytical techniques must be used to compare performance fairly.

At low ambient heating conditions and the same charge levels as in the rating point tests, an operational problem was observed with R-407C. The water heat exchanger showed external frost build-up on the lower third of the heat exchanger. No frost formed with the other refrigerants. Although the heat exchanger did not plug due to ice formation inside, the danger is readily apparent. Table 5 provides detailed results.

The frost formed with R-407C for two reasons:

- R-407C exhibits about 5.6°C glide during the evaporation process (near zero pressure drop in the brazed plate evaporator);
- the water heat exchanger is piped in parallel flow during the heating mode. As can be seen in Table 5, parallel flow with HCFC-22 and R-410A did not cause a frost problem because of the constant temperature behaviour of these refrigerants.

Modelling

A modelling approach was used to conduct a fair comparison of R-407C and HCFC-22 in the heating mode. The software package REFPROP 4.0 was used to model the thermodynamic cycle characteristics of HCFC-22 and R-407C, each under the following boundary conditions:

- 70% compressor adiabatic efficiency;
- zero pressure drop in connecting lines;
- zero pressure drop in the evaporator;
- zero superheat leaving the evaporator to avoid pinch-point anomalies;
- 35°C average saturated condensing temperature;
- 27.2°C liquid temperature leaving the condenser.

The COP was calculated over a range of evaporating temperatures and the results are shown in Table 6. Although the COP values for the two refrigerants are within 2% of each other, the dew point and inlet temperature data are particularly interesting and have been plotted in Figure 3. The graph shows a typical exit water temperature of 5°C and a typical design saturated refrigerant temperature freeze limit of -2°C. A range of heat exchanger sizes can be implemented which result in HCFC-22 saturated refrigerant temperatures between the freeze limit and water exit temperature. On the other hand, the range of heat exchanger sizes is much more limited for R-407C due to its glide mismatch with the water in parallel flow. The average refrigerant temperature for R-407C is limited to between 1 and 2°C as bounded by the freeze limit and water exit pinch point. Thus the R-407C COP is limited to a value of 6.12 while the HCFC-22 COP can be as high as 6.65 – about 9% higher.

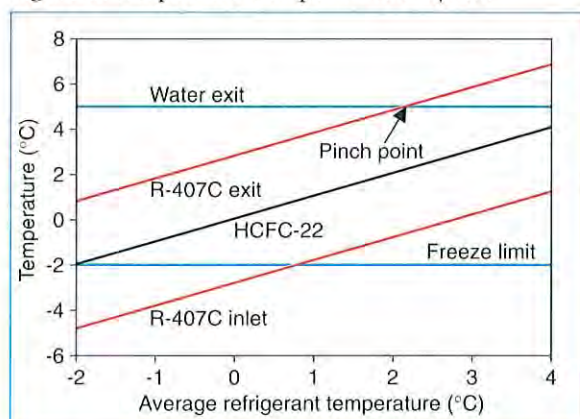
The easiest way to solve the frost problem with R-407C is by selecting a heat exchanger with enough refrigerant side pressure drop to keep the refrigerant inlet temperature at least as high as the saturated refrigerant exit temperature. This is typical with HCFC-22 or R-410A, although it results in much lower log-mean temperature differences, more heat transfer surface and limits the performance due to pinch-point problems at the water exit. Other solutions may involve piping the water heat exchanger in counter flow during the heating mode and sacrificing some cooling mode performance. Alternatively, waterside reversing valves may be added to provide counter flow in both heating and cooling modes.

Impact on Design

So, what do these results mean to the product development engineer?

Based on this experience, the manufacturing cost of a WSHP optimized for the chosen refrigerant is expected

Figure 3: Evaporator Temperature Profiles.



Refrigerant	Compressor type	Capacity (kW)	Compressor power (kW)	COP	Liquid temp (°C)
HCFC-22	Recip.	12.358	2.140	5.77	42.1
R-407C	Recip.	12.537	2.500	5.01	38.2
HCFC-22	Scroll	13.164	2.300	5.72	33.4
R-410A	Scroll	12.953	2.220	5.83	34.7

Table 4: Performance at heating rating point.

Refrigerant	Compressor type	Capacity (kW)	Compressor power (kW)	COP	Refrigerant temp entering water heat exchanger (°C)
HCFC-22	Recip.	9.311	1.680	5.54	-0.8
R-407C	Recip.	9.150	1.920	4.77	-4.5
HCFC-22	Scroll	9.607	1.740	5.52	-1.1
R-410A	Scroll	9.675	1.760	5.50	-0.3

Table 5: Performance at low ambient heating.

to be lower with R-410A than with R-407C, primarily because of the difficulty of dealing with refrigerant glide in a reversible system. To meet or exceed the HCFC-22 performance in both heating and cooling modes, the R-407C WSHP must contain heat exchangers which perform well in both heating and cooling modes of operation. This requirement may force the designer to use more components and larger heat exchangers. This conclusion must be tempered somewhat by the additional material needed to contain the higher operating pressures of R-410A. The cost of this additional material is still under evaluation.

Other Applications

Reversible chillers face the same problems as WSHPs when using R-407C. The conflicting needs of providing high efficiency in one or both modes of operation, while protecting the chiller from operational problems at extreme conditions, presents a difficult technical challenge for the system design engineer. In addition, reversible chillers are exposed to higher condensing temperatures than are commercial WSHPs, which leads to very high condensing pressures with R-410A. In this case, HFC-134a may be the best solution in spite of its higher pumping capacity requirements.

Work for the Future

A lot of work remains before HFCs can be implemented in WSHPs over a broad market application. For both R-407C and R-410A, compressor lubrication systems need to be developed in appropriate capacity ranges. For R-410A, compressors and heat exchangers must be developed for the higher operating pressures. For R-407C, cost-effective designs are needed to enable its use in reversible systems. Eventually, the choice of refrigerant will depend largely on economic criteria. Consequently a key area of work will be to make economic comparisons of products optimized for R-410A, R-407C and HFC-134a.

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	Average Evaporator Temperature (°C)	HCFC-22 COP	R-407C COP	R-407C dew point temperature (°C)	R-407 evaporator inlet temperature (°C)
Table 6:	-2	5.53	5.43	0.8	-4.8
Modelled per-	-1	5.69	5.59	1.8	-3.8
formance at	0	5.86	5.75	2.8	-2.8
typical low	+1	6.04	5.93	3.8	-1.8
ambient	+2	6.23	6.12	4.8	-0.8
heating con-	+3	6.43	6.32	5.8	0.2
ditions.	+4	6.65	6.54	6.8	1.2

HCFC-22 Phase Out in North America

Impact on Future Equipment Production

David Godwin and
Mark Menzer, USA

The scheduled phase out of HCFCs in 2020-2030 has required that manufacturers in the air conditioning and refrigeration industry begin to identify alternative fluids. In North America, where HCFC-22 is the most widely used refrigerant, future unitary air conditioners and heat pumps will have to be designed to accept the alternatives that replace HCFC-22. During the same time frame (post-2000), new US regulations are expected to increase the minimum efficiency that these unitary systems must achieve. The combination of new refrigerants and higher efficiencies will require system engineers to rethink unitary equipment designs.

This article reviews the options for new refrigerants and discusses the impact of some of these options on future equipment design. The blue box gives further insight into the choice of new refrigerants by providing an update on the international programme AREP (the Alternative Refrigerants Evaluation Program).

* * *

Today, there are several refrigerants that have thermodynamic properties that are similar to, or, from a performance standpoint, better than HCFC-22. One of these is R-290 (propane). However, strict building and mechanical room codes in North America generally precludes the use of R-290 as a refrigerant. Additionally, one manufacturer has estimated that the cost to comply with these codes would result in a 50% increase in equipment costs. Hence, there is a race to identify and quantify alternative fluids that provide the benefits of HCFC-22 while ensuring environmental and human safety.

For the past two years, equipment manufacturers from North American, Japan, and Europe have been engaged in jointly testing HCFC-22 substitutes through AREP (see blue box). The purpose, organisation and test plan established under AREP have been explained in more detail in *IEA Heat Pump Centre Newsletter* Vol. 10, No. 3. Results from compressor calorimeter and system drop-in tests were summarized in *IEA Heat Pump Centre Newsletter* Vol. 12, No. 1. A summary of results from soft-optimized system tests is also available from ARI (Air-Conditioning and Refrigeration Institute). Table 1 shows the alternatives that have been evaluated under this programme.

Table1: Alternative refrigerants tested as part of AREP. Percentage composition by weight is shown in [] for blends.

Possible HCFC-22 replacements

HFC-134a	R-125/143a [45/55]
propane (R-290)	R-23/32/134a [1.5/20/78.5]
ammonia (R-717)	R-23/32/134a [1.5/27/71.5]
R-32/125 [50/50]*	R-23/32/134a [2/29.4/68.6]
R-32/125 [60/40]*	R-32/125/134a [10/70/20]
R-32/134a [20/80]	R-32/125/134a [23/25/52]†
R-32/134a [25/75]†	R-32/125/134a [24/16/60]†
R-32/134a [30/70]†	R-32/125/134a [25/20/55]†
R-32/134a [40/60]	R-32/125/134a [30/10/60]†

Possible R-502 replacements

R-32/125/290/134a [20/55/5/20]
R-125/143a [45/55]
R-125/143a [50/50]
R-23/32/125 [5/25/70]
R-32/125/134a [10/70/20]
R-32/125/134a [20/40/40]
R-32/125/143a [10/45/45]
R-125/143a/134a [44/52/4]

Notes:

- Refrigerants are not listed in any particular ranking order.
- Compositions are nominal, and do not include deviations of charged or circulating compositions from nominal.
- All refrigerant components are HFCs apart from R-290 and R-717.

* high-pressure
† HCFC-22 'look-alike'

The Alternative Refrigerants Evaluation Program (AREP)

For the past few years, heat pump manufacturers have been cooperating internationally in identifying and testing possible substitutes for HCFC-22 and R-502, a mixture of HCFC-22 and CFC-115. The performance of a multitude of non-ozone-depleting refrigerants have been tested in a variety of systems under the Alternative Refrigerants Evaluation Program (AREP).

Original Goals Met

The initial goals of the AREP programme were:

- To identify promising alternatives to R-22 and R-502 for major ARI product categories;
- To establish testing protocols for evaluating the candidate replacements;
- To conduct tests using the candidate refrigerants;
- To review and release the results of these tests.

Through the cooperative efforts of over 30 companies internationally, these goals have been successfully realized. Tests have been conducted with 19 refrigerants identified as potential replacements for HCFC-22 and with seven refrigerants identified as potential R-502 alternatives (see Table1). Nearly 200 compressor calorimeter, system drop-in and soft-optimized system test reports have been provided by the participating companies. All of these reports are available to the public from ARI.

Despite the large number of fluids tested, manufacturers now appear to be narrowing their choice of refrigerant(s) to pursue for use in their equipment, as described further in this article.

Honoured With Awards

AREP has been such a success that it has recently been recognized with some prestigious environmental awards. In October 1994, the United States Environmental Protection Agency presented a 1994 Stratospheric Ozone Protection Award to AREP "in recognition of exceptional contributions to global environmental protection." In November 1994, the US National Awards Council for Environmental Sustainability awarded AREP with a certificate of environmental achievement. Also,

the AREP programme will be listed in Renew America's 1995 *Environmental Success Index*.

To Be Continued

The programme participants, and the industry in general, realize that there are still many issues that must be addressed before CFCs and HCFCs, especially HCFC-22, can be completely phased out. Issues such as fractionation, flammability, long-term reliability of equipment using new refrigerants and lubricants, and others still remain unanswered.

Therefore, the AREP programme will be continued in order to provide a mechanism for the industry to continue to work cooperatively in addressing the challenges it faces in phasing out CFCs and HCFCs. With the continuation of the programme, the focus now shifts from identification and exploration of new refrigerants to addressing practical issues with implementing chlorine-free choices.

Testing protocols for this next phase will have to be established by the Technical Committee. It is expected that some tests to be conducted under the continuation of the programme could include:

- **Heat transfer tests.** Manufacturers would build heat exchangers using tubes designed for chlorine-free refrigerants. New heat exchangers would be incorporated in equipment and system performance would be tested.
- **Lubrication Investigations.** Various refrigerants with various lubricants (polyolesters, mineral oils, etc.) and various additives would be tested. Oil return, compressor wear, and other data would be reported;
- **System Modelling.** Results of proprietary equipment modelling programs would be compared to laboratory tests;

Equipment manufacturers interested in participating in the continuation of AREP should contact ARI for more information.

As a result of tests carried out under AREP, many equipment manufacturers seem to be focusing on two families of refrigerants; HCFC-22 "Look-Alikes" (specifically R-407C) and blends with higher pressure than HCFC-22 (specifically the R-410 series of refrigerants). Small quantities of these refrigerants were provided by chemical suppliers for testing and it is expected that in the future they will be available in commercial quantities from multiple sources.

Look-Alikes

It is no coincidence that R-407C has a performance similar to HCFC-22. Its three components, HFC-32, HFC-125, and HFC-134a have been combined in a ratio such that the temperature-pressure relationship is similar to HCFC-22. In addition, R-407C's heat of vaporization is similar to HCFC-22. These facts suggest that R-407C should perform in a manner similar to HCFC-22 and that *unitary, direct expansion equipment* utilizing R-407C can be quite similar to HCFC-22

equipment. It is anticipated that compressor size, refrigerant tube diameter, and wall thickness should all be similar to today's HCFC-22 equipment.

Yet, there are numerous questions regarding the design of heat exchangers to efficiently utilize R-407C. For one thing, zeotropic blends (such as R-407C) tend to be less efficient in transferring heat than do single component refrigerants. If this holds true, then heat exchangers using R-407C may have to be bigger (and more costly) than those in today's equipment. Also, since the refrigerant-side surface treatment of heat exchanger tubes has been optimized for HCFC-22, it is likely that costly re-optimization will have to be conducted for new blends. Finally, unlike HCFC-22, which evaporates or condenses at a constant temperature, R-407C experiences temperature glide (7°C): the evaporator and condenser work over a range of temperatures. However, it should be noted that temperature glide can actually be used to increase cycle efficiency.

In order to achieve this, the refrigerant and the medium to be heated or cooled must travel counter to each other. This can be relatively straightforward by using a tube-within-a-tube water/refrigerant heat exchanger. It is more difficult when refrigerant/air heat exchange is needed. When air is the medium, "quasi-counterflow" heat exchangers have been proposed. System designers will have to determine if the advantages of such configurations outweigh their costs.

The same physical properties that lead to temperature glide also lead to fractionation – the tendency of the refrigerant components to boil off separately when not contained in the system. The result of fractionation is that, if a leak occurs, the composition of the refrigerant left in the equipment will change, lowering efficiency. System technicians may not be able to simply "top-off" a refrigerant charge as is often the current practice. The system may need to be fully evacuated of its refrigerant and then recharged with refrigerant of a known composition. Fractionation is also a disadvantage in HCFC-22 *bundled tube water chillers*. Here, single component refrigerants, azeotropes or very low glide zeotropes will have to be employed.

High Pressure Blends

As of this writing, the only blend in the R-410 series to receive an ASHRAE designation is R-410A – a 50/50% (mass composition) blend of R-32/125. However, other, similar R-32/125 formulations have been proposed. These blends result in approximately 50% higher pressures, at a given temperature, than those of HCFC-22. As a result, stronger containment vessels and thicker refrigerant tubing walls will be required. On the other hand, the higher energy density of these blends (cooling effect per unit volume of refrigerant circulated) can result in smaller compressor volume and smaller diameter tubing. These high pressure

"Look
alikes"

"high
pressure"

capacities	√	√
efficiencies	√	+
temperature glide	–	√
toxicity/flammability	√	√
materials/lubricity	√	√
fluid cost	√	√
equipment cost	?	?

Where:

√ = Attribute is expected to be about the same as that of HCFC-22
– = Attribute is expected to be slightly worse than that of HCFC-22
+ = Attribute is expected to be slightly better than that of HCFC-22
? = Costs of these future systems compared to HCFC-22 are currently unknown.

Table 2: Comparison of the two classes of alternatives to HCFC-22.

alternatives are either azeotropic in nature or have very low temperature glides. Hence, the trade-off for the higher pressure is that heat exchanger designs are more straight forward while temperature-glide and fractionation concerns are eliminated.

Pluses and Minuses

As a result of the on-going effort to identify and quantify alternatives, it is safe to say that acceptable alternatives will be in place by the mandated HCFC-22 phase-out dates. The alternatives will offer varying advantages and it will be up to the equipment engineers to make the best selection based on the features that each manufacturer will seek to offer. As can be seen in Table 2, the "look-alikes" and the "high pressure blends" offer a number of pluses and minuses. Hence, it is very well likely that two distinct classes of equipment will be produced in the future utilizing these two types of refrigerants. To satisfy market replacements needs, and existing applications that require operating pressures similar to HCFC-22, the "look-alike" refrigerants will be used. Systems engineered to operate at high operating pressures will be offered for new equipment applications.

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Replacing CFC-12 in the World's Largest Heat Pumps

Klas Berglöf and Anita Bertelsen, Sweden

The largest heat pumps in the world are located in Sweden. The Rya Heat Pump Plant in Gothenburg has four heat pumps which supply a maximum of 160 MW heat to the city's district heating system. Two of these are in a class of their own, being the largest in the world with a heating capacity of around 50 MW each.

Installed between 1982 and 1986, all these heat pumps were designed for use with CFC-12 refrigerant. Since 1993, work has been going on to replace this refrigerant with HFC-134a. In this article, those involved in the replacement process, report on the progress so far.

* * *

Sweden has many large and well-developed district heating systems, for which some 100 sizable heat pumps were constructed between 1982 and 1986 (ED: heat pumps account for just over 15% of the

Tackling the big one: The world's largest heat pump undergoes retrofit work to replace CFC-12 with HFC-134a.



heat supplied by district heating in Sweden). The Gothenburg district heating plant is one of the largest in Europe, with 165,000 households linked to its 480 km network.

Interesting Mix

At Gothenburg, an interesting mix of energy sources is used. Waste heat, the least harmful option, supplies about 65% of the heat. This waste heat is recovered from refineries, from a refuse incineration plant, from Volvo factories and from the sewage plant at Rya. Most of the additional heat production is from natural gas, with 10% from heating oil. Biomass fuels may also be used in future – environmental effects and financial aspects are being evaluated.

Since the beginning of the eighties, there has been a great reduction in environmentally harmful emissions associated with energy production in Gothenburg, and the air quality in Gothenburg has improved (see Figure 1). The project has attracted considerable attention abroad. So much so that the district heating company, Gothenburg Energy AB, has formed a daughter company, Gothenburg Energy International Corp., to share its experience with the international market.

Heat pumps play a significant role in the recovery of waste heat. At the Rya sewage plant, all waste water from Gothenburg and its suburbs is cleaned – amounting to around 12,000 m³ water, every hour, all year around. The heat from this waste water is utilized by four heat pumps in the Rya Heat Pump Plant to supply up to 160 MW heat to the district heating system. The energy from the Rya Heat Pump Plant covers about 20% of the district heating system's total annual energy need of 3250 GWh.

Concern

While the heat pump plant offers many environmental benefits, the use of CFC-12 refrigerant has been a cause for concern. "We now know that CFC-12 is one of the most harmful refrigerants, with a high ozone depleting effect," explains Christer Wikström, Project & Maintenance Manager of Gothenburg Energy. "Therefore we decided at an early stage to replace the refrigerant by the best available alternative, i.e. HFC-134a."

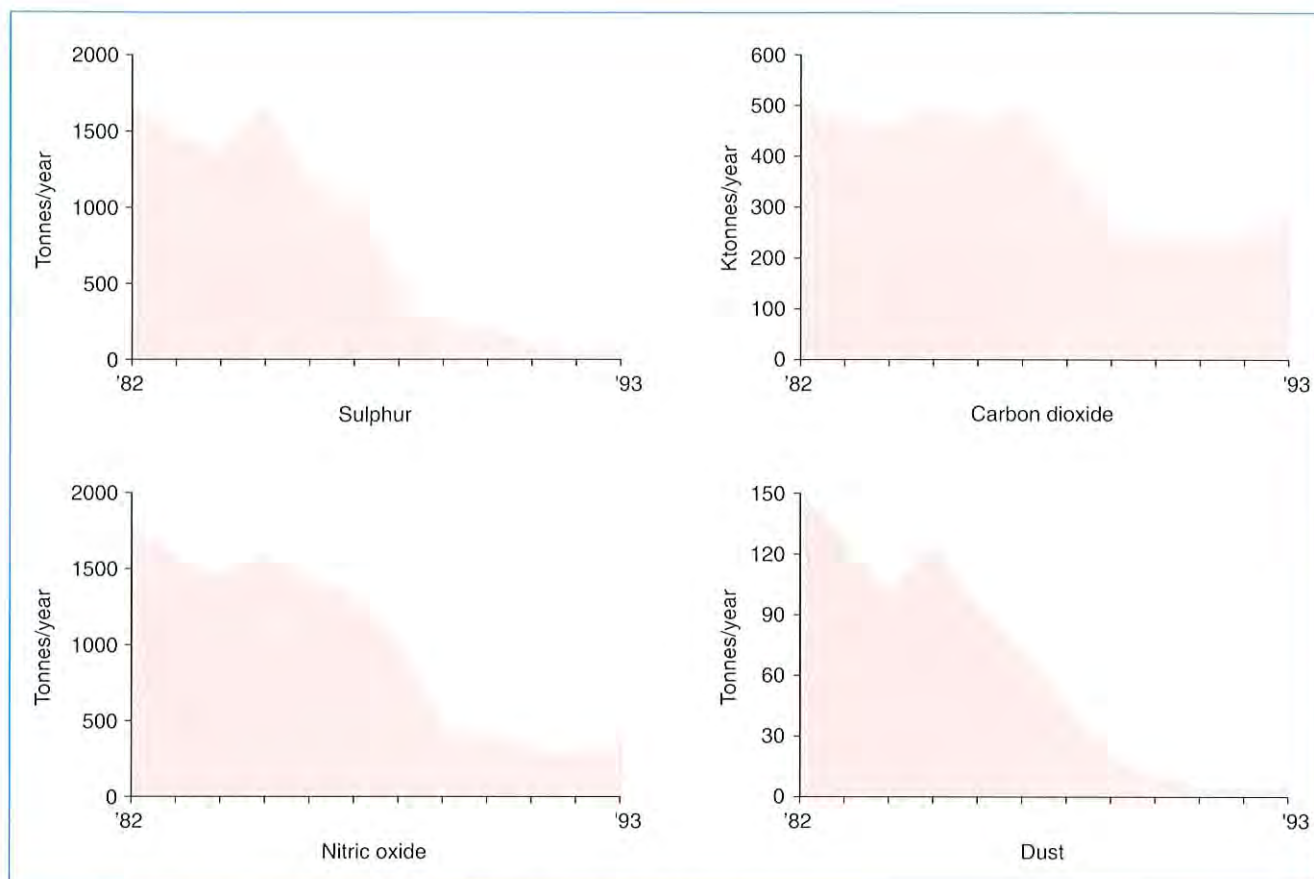


Figure 1: Diminishing emissions from Gothenburg's district heating system.

The Swedish government has banned the recharging of CFC from 1 January 1998, and on using CFC from the year 2000. "The refrigerant retrofit shall be finished well before the date when CFC-12 is not allowed to be used any more," says Wikström. "The environmental objective of Gothenburg Energy goes beyond the legislation of the authorities and international agreements."

In 1993, Gothenburg Energy awarded the retrofit contract to Götaverken Miljö, the original suppliers of the heat pumps. A total of 110 tonnes of CFC-12 was to be replaced.

The retrofit programme was initiated in spite of the fact that leakage of CFC-12 at the plant had been reduced to below 2%. "We started to retrofit one large heat pump in 1993 and have continued to retrofit one every year," says Wikström. "Today, two thirds of the CFC-12 has been replaced with HFC-134a. The remaining third will be replaced when the two smaller heat pumps are retrofitted in 1995 and 1996."

Consequences

Replacing CFC-12 with HFC-134a is costly and often means a reduction in capacity. "It is especially difficult to produce water that is warm enough," explains

Håkan Landberg, Project Manager for Gothenburg Energy. "With CFC-12 we could produce up to 95°C. Now we only manage to get 85°C!"

By adapting the working conditions of the retrofitted heat pumps, the capacity loss has been reduced to around 10% compared to the capacity for which the heat pumps were originally built. "The two remaining smaller heat pumps can be more difficult to retrofit," adds Landberg. "We expect a reduction in annual heat production of about 25% when they are retrofitted."

Optimizing

Gothenburg Energy is now investigating the possibilities for optimizing the heat pumps after retrofit. "We might find very rewarding solutions, with repayment times of only a couple of years," says Landberg. "For instance, a lot of money has been invested in the distribution of district heating to reduce the temperature levels. This has benefits for both heat pumps and electricity plants. Up till now we have managed to keep the heat production capacity, and in some cases even increased it. We hope to be able to continue this trend during the whole retrofit period."

Last summer, the compressor of the first retrofitted heat pump was modified to compensate for the

capacity loss. This summer, considerable rebuilding of the compressor will take place for the second retrofitted heat pump, which will increase its heat capacity by 20%. "Then it will be the largest in the world with a heat capacity of more than 60 MW on peak conditions," says Landberg. "The increased heat production from this heat pump will then compensate for the drop in capacity when the other two heat pumps are retrofitted."

Studies show that with the new working conditions and HFC-134a, the heat capacity of all four heat pumps should increase by as much as a fifth heat pump would give. "During the CFC-12 period we planned a fifth heat pump but now we don't need that any more," says Landberg. "While 'heat pump fans' like ourselves would welcome such a development, we understand the need to compete for investment budget with other profitable energy projects."

Positive

"The refrigerant replacement with HFC-134a has been positive," says Gunnar Åsblom of Götaverken Miljö, the company assigned to carry out the retrofit. "The first replacement was completely free of problems and we got experience that we could use in the second retrofit which took place in August 1994."

"Each machine is different," explains Åsblom. "The small heat pumps with piston or screw compressors are not affected so much by the refrigerant retrofit. The turbo compressor used in the big heat pumps is, however, much more sensitive. The big heat pumps have to be rebuilt. The compressors have to be sized correctly to work well. If these adjustments are made you can increase the energy production."

Åsblom continues: "We have a 50% better heat transfer coefficient in the evaporator, as the HFC-134a does not seem to boil as vigorously as CFC-12. Therefore, we can fill the evaporator better." But Åsblom is of the opinion that there is no real incentive to retrofit as long as there are no economic benefits: "Now we only have the threat of the ban on recharging and the ban on using systems with CFC."

Information Shortage

Håkan Landberg is searching for more accurate and detailed information about previous retrofit pilot projects: "It has been difficult to get information about retrofitted pilot projects. The reports have been glossy like advertising. It's no use to just give positive reports. What we need is detailed information."

"For instance, few people realize the consequences of using the oils correctly," continues Landberg. "The retrofit has to be watched and completed so that the oil works. We have learnt that the polyolester oil used for HFC-134a is not easy to handle. It has many excellent properties but it quickly deteriorates if not

*Replacement in progress:
Thorbjörn
Andersson, of
AKA Kyla,
controls the
transfer of HFC-
134a.*



treated correctly in atmospheric oil systems. It is important to keep it free from moisture. That is, however, not easy in the big open systems that we are working with in our large heat pumps. Then you have to attack the problem from two sides: first to prevent the oil from getting in contact with moisture, and second, to dry it if it does so."

"It is important to be specific when planning such an assignment with the contractor. That's what we did when we specified the function after the retrofit. To achieve such functions has required a great effort, both from Götaverken Miljö and ourselves. We have learnt a lot and now believe that we have got an oil system in which the oil will get a long lifetime and still keep its quality!" says Landberg.

Halfway to the Optimum

Gothenburg Energy is nearly halfway to completing its retrofit work. The replacement of refrigerants and oil, and the careful cleaning and control which is done in connection with a retrofit means that the heat pumps really are optimized. Reflecting on the benefits of retrofitting, Landberg states: "Now we can meet our objectives of reaching high availability and keeping leakage to a minimum. The first retrofitted heat pump had 99.9% availability and a very small leakage during the first operation season. Good figures for both Gothenburg Energy and the environment."

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International Heat Pump Status and Policy Review

HPC completes comprehensive study

Bert Stuij, IEA Heat Pump Centre

The recent publication of Part 2B of the International Heat Pump Status and Policy Review completes the most comprehensive assessment of the global heat pump situation to date. The complete report, made in close collaboration with the International Institute of Refrigeration, now covers 25 countries¹⁾.

Part 1 of the report is an analysis with international comparisons and overviews. This analysis is based on the first 16 countries examined, detailed reviews of which ('National Position Papers') are contained in Part 2A. Part 2B, just published, covers 11 more countries. This article discusses a few findings of the analysis work. The blue boxes contain some highlights from the countries covered in Part 2B.

* * *

Current strategies to cope with the economic, security and environmental challenges associated with the worldwide growth in energy demand include the utilization of renewable energy sources, and improving the efficiency of energy consuming technologies. Heat pumps have a role in both. They effectively utilize renewable thermal energy resources, such as natural or waste heat, and significantly reduce the primary energy demand in the provision of a number of key energy consuming services, including space heating and cooling, water heating, and industrial process heating.

For a proper appreciation of heat pumps it has to be realized that heat pump technology has many variations, can be applied in many ways, and that experiences with heat pumps have consequently been wide ranging. By analyzing the situation in a cross-section of countries, the 'International Heat Pump Status and Policy Review' provides an insight into these experiences, and assesses the current significance and potential of the heat pump option.

¹⁾ Countries covered in Part 1 and 2A: Austria, Belgium, Canada, Denmark, France, Germany, Greece, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the USA. Countries covered in Part 2B: Bulgaria, China, Czech Republic, Israel, Republic of Korea, Mexico, New Zealand, Poland, Portugal, Slovakia, Turkey.

Basic Factors

The potential of heat pumps to achieve energy savings, environmental benefits and a significant market penetration, depends on a number of basic factors. These factors include the national energy resource situation, energy prices, climate, building standards, and the type of industrial activity in a country. The report discusses how each factor impacts on the heat pump market. An impression of the potential size of the heat pump market is provided by comparing the heat demand in various market sectors with the total final energy consumption in a number of countries (see Table 1). Some recent developments

Table 1: Total final energy consumption (TFC) excluding feed stocks and consumption in sectors relevant for heat pumps in % of TFC.

Country	TFC (TWh/year)	Space heating [%]	Hot water heating [%]	Process heat, total [%]	Process heat, <200°C [%]
Austria	263	30	2	23	n.a
Belgium	422	26	4	25	4
Canada	1,836	24	4	37	n.a
Denmark	175	26 ²⁾	–	21	n.a
France	1,777	21	3	n.a	n.a
Germany	2,890	26	5	20	6
Greece	178	13	7	17	7
Italy	1,419	20	n.a	29	n.a
Japan	3,547	7	6	32	5 ¹⁾
Netherlands	645	31	3	25	7
Norway	207	18	5	15	5
Spain	740	11	–	n.a	34 ²⁾
Sweden	379	25	5	37	n.a
Switzerland	240	32	7	9	n.a
UK	1,773	32	7	26	20
USA	15,895	17	6	24	n.a

n.a. – not available

1) Process heat <300°C

2) Includes hot water heating

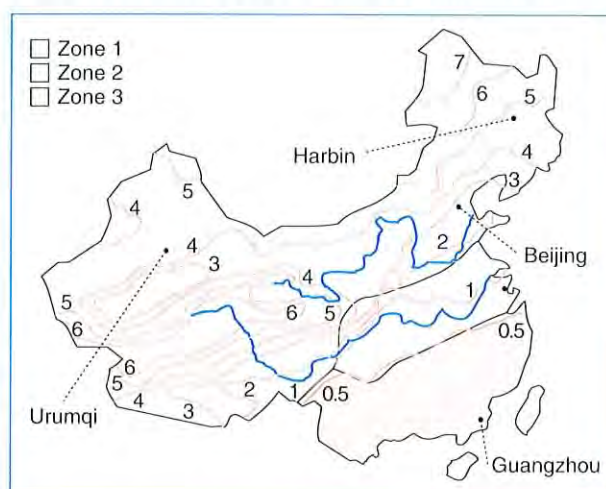
Bulgaria

In the centrally planned economy an energy saving programme was pursued from 1980 to 1990. Under this programme a significant number of heat pump plants were realized. A range of Bulgarian water-to-water heat pumps, and air-to-air space conditioners were developed. A fair amount of heat pump experience was gained, notably on geothermal-source heat pumps. Know-how to manufacture, install and maintain heat pump equipment remains.

When the political system shifted from centrally planned to market oriented in 1990, the ensuing uncertainty led to a recession which has hampered further developments. All energy and environmental programmes were stopped, and it appears that the present government has not yet started any new ones. The only market segment currently developing is the air-conditioning market, where today about 1000 reversible heat pumps are installed.

China

China represents an enormous and fast growing heat pump market. In the past, under the centrally planned economy, heating was only provided in the North (Zone 1 on the map), in general through district heating schemes. More recently, in the new economic climate, a heat demand is developing in the booming central and southern parts of China, in particular Zone 2. Already China is the second largest market for room air-conditioners (after Japan), and the market for heat pumps runs in parallel with the air-conditioning market. About 30% of all air conditioning equipment is of the heat pump type. It is estimated that 1.2 million small residential heat pumps were sold in the period 1991-1993, and it seems likely that annual sales will exceed this number soon. A Chinese study predicts that in the next 10 years, heat pumps will be installed in 1/4 to 1/3 of all buildings, starting in offices, but rapidly spreading to the whole commercial/institutional sector, and then to residences. A significant development in the air-conditioning market is the rapid shift from window systems to split systems.



The main factor pushing the residential heat pump market is the ongoing economic growth in China, which increases the demand for living standards and comfort. Concerns about the consequences of energy consumption are starting to stimulate the use of heat pumps in industry. The growing attention for energy saving options, along with the unreliable power supply, has led to some market penetration of absorption chillers driven by waste heat. The most significant impediment for more rapid heat pump penetration appears to be the power generation system, which cannot keep up with the rising demand for its services.

are highlighted, such as the decrease in the specific heat demand in buildings, the growing need for forced ventilation and heat recovery, the rising efficiency of power generation, and the growing attention for process integration and the use of waste heat in industry.

Policies

Given the basic factors, the heat pump market can be influenced strongly by governments and utilities, which in many countries support heat pumps. Governmental energy policies typically aim to maintain an economic and secure energy system with minimum environmental impact. Utilities will seek to

provide a reliable and cost-effective energy supply, to satisfy and retain customers, and to address society's concern for energy conservation and environmental protection (this may be enforced by regulations or voluntary agreements). For governments, heat pumps can be an option to support, as they can save resources and thus benefit the environment. For utilities, heat pumps offer the additional benefit of helping to attract or retain customers, and in some cases aiding load levelling.

However, support is often restrained, for instance because of poor experiences with heat pumps in the past, the ongoing concern about the availability of working fluids that are both safe and environmentally

sound, and the real or perceived competition of other energy saving technologies.

There are a number of heat pump policy instruments available, each with its own specific drawbacks and advantages. Successful heat pump programmes tend to be a mix of economic stimuli (e.g. financial incentives, special energy tariffs, lease arrangements, governmental energy price policies) and information campaigns (including promotion, education and demonstration projects). Other important policy instruments are the support for research and development work, and regulations (for instance on energy efficiency or ventilation requirements). Close collaboration between governments and utilities is generally a prerequisite for a successful heat pump programme.

Technology

Heat pump technology continues to develop, and significant potential remains to improve heat pump performance, reduce initial costs, and widen the applicability of heat pumps. The search for safe and environmentally sound working fluids is currently dominating many country's research programmes. A review of working fluid research programmes confirms the perception that in North America and Japan the emphasis is on HFCs, whereas in Europe naturals such as ammonia, propane and CO₂ also receive extensive attention. Heat pump efficiencies show an upward trend, where an SPF of over 3 is achievable for electrically driven air/air systems, 4 to 4.5 for ground

source systems, and 4.5 to 5.5 for the most advanced systems. Gas fired heat pumps with Primary Energy Ratios of 1.3 to 1.6 are available.

Markets

The international heat pump market is highly diverse, and remains dominated by the US and Japan. Of the 55 million heat pumps currently installed worldwide, over 9 million are in the US, and almost 40 million are in Japan. In both countries, the market is driven by the space conditioning demand, and nearly all of the heat pumps can provide both heating and cooling. Electric air-to-air units are dominant, although in the US and Japan a significant number of alternative systems are also in use. In central and northern Europe heat pumps are often used for heating only purposes. Less than 400 district heating heat pumps are installed worldwide, and only in Sweden have they achieved a strong market position. It is estimated that there are roughly 7000 industrial heat pumps installed worldwide. Figure 1 shows the heat pump stock of 1992 for each market sector.

One indication of the significance of both the current heat pump market and the remaining potential, is the share of the total heat demand currently met by heat pumps. Considering the total heat demand of the countries reviewed in all relevant sectors (residential, commercial/institutional, district heating, industry), less than 2% is met by heat pumps. In individual countries the share typically varies between 0 and 3%, and never exceeds 5%. Table 2 highlights the findings

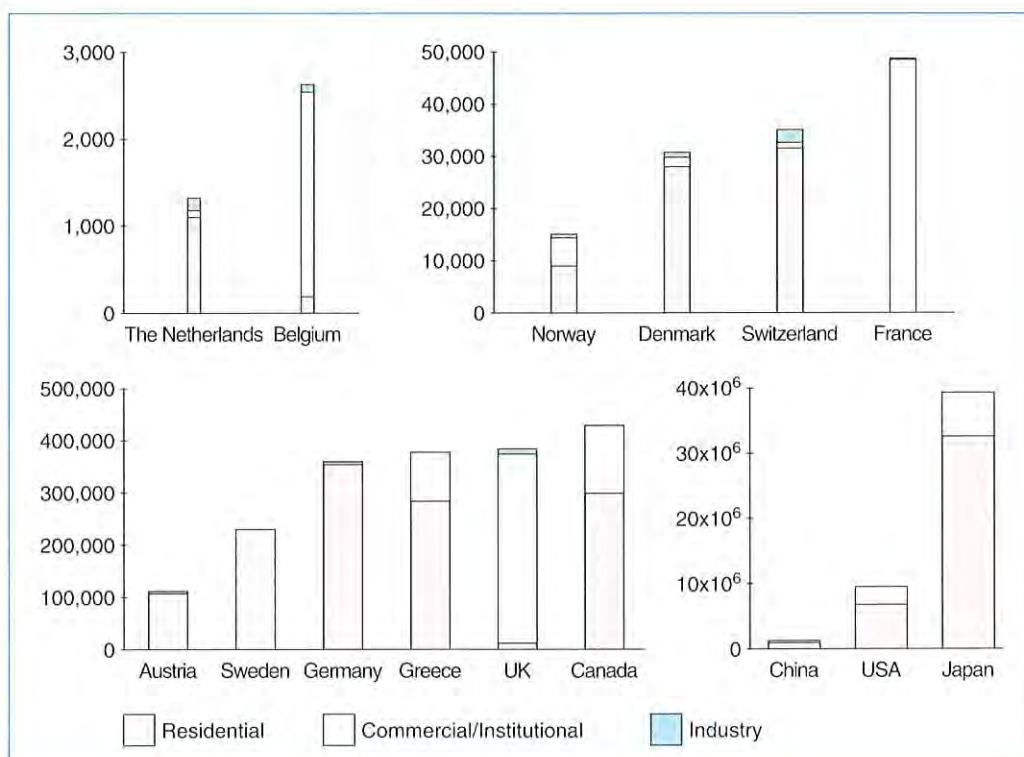


Figure 1: Heat pump stock, 1992.

- Czech Republic** The Czech heat pump market is very small, and is expected to remain so. The sharply rising energy prices may stimulate the use of energy saving technologies, but heat pumps are unlikely to benefit first. Their high first costs are a major impediment, aggravated by the fact that the Czech climatic conditions make a back up heating system in general necessary (temperatures down to -20 °C are common in winter). The suitability of the heat pump option is currently being assessed in the light of the new economic boundary conditions. Some 15 heat pumps of small capacity and a few larger ones are being tested in a variety of industrial plants. Indeed, the industrial sector is seen as the most promising for heat pump use.
- Israel** Data on the actual number of heat pumps installed in Israel are scarce. An increase in the penetration of air-conditioning is reported, but no data are available on numbers, or on the share of heat pumps. As an energy saving option, heat pumps must compete with solar systems, which are very popular in Israel. Israel is among the world leaders in development and utilization of this technology. Every new house must have a solar water heater. There is a strong general emphasis on energy saving, and this may be beneficial for heat pumps. Israel also wishes to develop its geothermal energy resources, although they are not abundant.
- Republic of Korea** In the residential sector, the demand for air-conditioning is rapidly increasing. However, equipment is in general cooling-only; the heat pump ratio is estimated at only 1%. This ratio may rise, but probably very slowly. Only the south of the country, which has relatively mild winters, appears to be a potentially significant heat pump market. In industry, heat pumps are not applied at all today, in spite of the vast amounts of industrial waste heat. With the current low energy prices, investments in heat pumps are unlikely. Decisive government support is necessary for the development of the industrial heat pump market.
- Mexico** The heat pump market is as yet non-existent. Air-conditioners are used to some extent, but nearly all of them are cooling only. Only one industrial heat pump was reported. It is installed in a water purification plant, and uses a geothermal heat source. Heat pump research is limited to the development of a solar absorption heat pump for food and medicine preservation, and a compression heat pump for agro-industrial applications. In spite of the limited current use a high market potential is recognized, to some extent depending on the economic development in the coming years. In northern Mexico there are areas with a heating requirement at night whilst during the daytime temperatures rise to 50 °C. In other parts of the country reversible heat pumps can meet the hot water and space cooling demand. Absorption units may be used in the extensive non-electrified market (20 million Mexicans do not have electricity). Industrial heat pump opportunities are highlighted for drying and distillation.
- New Zealand** Most homes have no cooling demand, and only modest heating demands, which may drop further in response to tightening building codes. Coupled with relatively cheap energy (hydropower, firewood in rural areas), the economics of heat pumps are not favourable. There is some interest in the use of heat pumps for air-conditioning and heating of large buildings. The government does not support heat pumps, although hot water heat pumps are recognized as appropriate in certain applications. Some power utilities are supporting heat pumps, notably in response to competition from natural gas.
- Poland** The fundamental economic and political changes since 1990 have had a considerable effect on the Polish heat pump situation. Since 1990, industrial activity decreased, and with it the industrial energy demand. Building construction activity also dropped sharply. As a consequence both the industrial and buildings heat pump markets are subdued. The current total heat pump stock is estimated to be about 1000 units. The government does see heat pumps as an energy saving option, but not as a priority. Experience with heat pumps in Poland is very limited. Some studies have suggested that neither for industry, nor for the very large district heating sector, the economics for the use of heat pumps are favourable. However, at least two district heating heat pumps are under construction, and opportunities are identified in areas with a geothermal heat source. With doubts about the significance of the heat pump option for industry and district heating, the main potential markets appear to lie in the residential and commercial/institutional sectors. It is difficult to predict how this will develop.

Total societal heat demand

Heat demand in buildings

	Total (TWh/yr)	Covered by heat pumps (%)	Total (TWh/yr)	Covered by heat pumps (%)
USA	7765	3.5	3252	8.2
Japan	1411	2.8	411	9.5
Sweden	270	3.7	138	7.2
Norway	53	5.0	39	3.9
Switzerland	84	1.6	68	2
Canada	956	0.6	321	1.2
Germany	1703	0.1	1143	0.15

Table 2:
Heat demand and percentage covered by heat pumps.

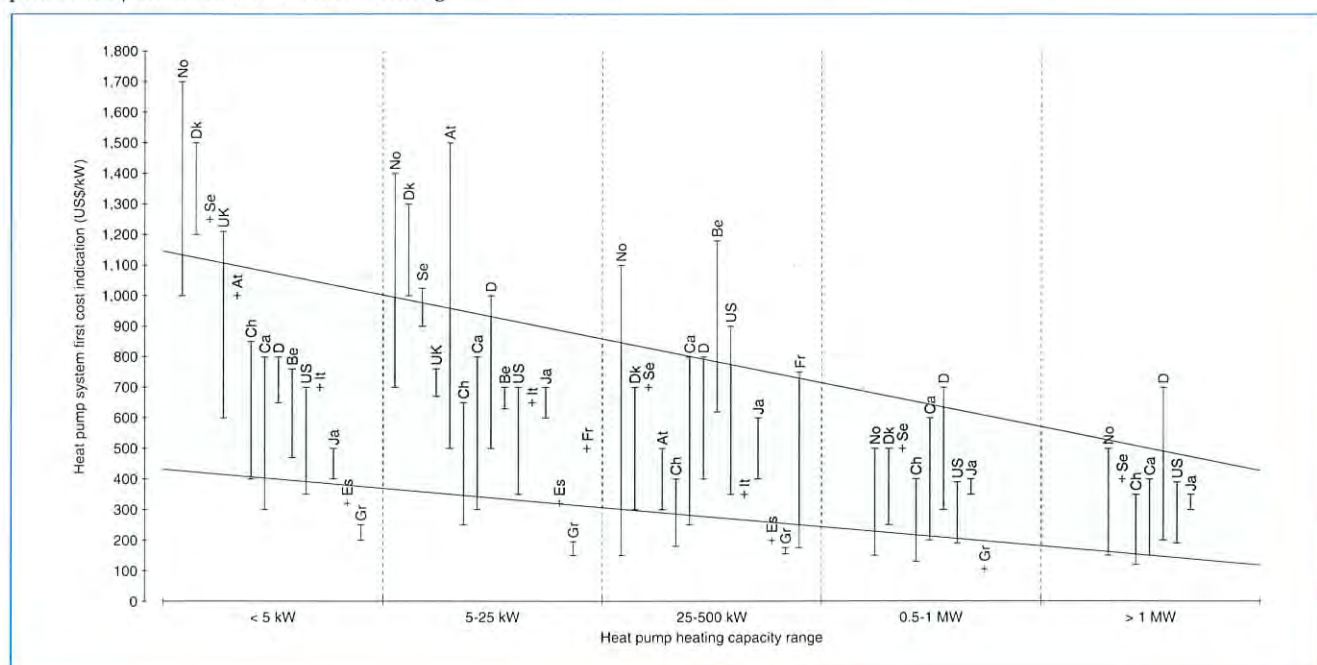
for a number of countries. In the US and Japan, about 7% of the heating demand in homes, and about 13% in commercial buildings is covered by heat pumps. Most of the heat pumps are installed in the southern parts of these countries, where cooling is the predominant load. Consequently the vast amount of reversible heat pumps meet a relatively small part of the heat demand: to supply a larger share of the heat demand the penetration of heat pumps in colder regions must increase. Norway, Switzerland and particularly Sweden are the only heating-mainly markets where space heating heat pumps have achieved a notable market penetration. It is significant that these three countries all have a non-fossil fuel based electricity system.

Heat pump sales have in general been restrained in the years 1989 to 1992, mainly due to the poor economic climate, and low energy prices. Because of the low energy prices, the relatively high heat pump investment costs act as another important market constraint, especially in heating-only markets. Figure 2 shows typical heat pump system investment costs.

Bound to grow

It is widely recognized that international collaboration and information exchange can accelerate the development and market penetration of heat pumping technologies. This has already led to a number of collaborative programmes, organizations

Figure 2: An indication of the range of heat pump system investment costs. The length of each vertical line represents the cost range for that country for heat pumps in one of five capacity ranges. The precise horizontal position of these lines has no meaning.



Portugal

The heat pump market is currently in its infancy. Yet it is national policy to develop renewable energies and energy saving technologies, including heat pumps. Some specific promotion initiatives were taken in recent years, such as the European Valoren programme. This programme led to the installation of heat pumps in some swimming pools. Up to 25% of the heat pump investment cost is subsidized by the government. The recent sharp rise in energy prices may act as a further stimulus for the heat pump market, although other technologies, notably solar systems are more likely to benefit. New national regulations, enforcing a rational use of energy in buildings, are expected to favour heat pumps, although it is too early to predict the significance of this.

Slowakia

Heat pump utilization in Slovakia is extremely limited. The residential heat pump market does not yet exist, and only very few heat pumps are used in commercial buildings and industry. Some opportunities are identified in the tourist sector. The government supports energy efficiency measures, and stimulates the use of renewable and waste heat flows. However, support for heat pumps is unlikely to be an early priority. Furthermore, government resources are limited, and its support for energy saving measures can hardly be executed through investment grants or promotion programmes. There is also a general lack of experience in the heat pump field.

Energy prices have gone up significantly, and this could stimulate energy efficiency measures in general, and perhaps the heat pump market with it. It is expected that geothermal and ground water source heat pumps have a high potential in Slovakia, mainly in the industrial sector. There is keen interest in international information exchange on this technology.

Turkey

At this stage the heat pump market is hardly developed at all. An important factor that could stimulate the heat pump market is the growing demand for space conditioning in response to economic development and urbanization in a warm climate. Other potentially positive factors are the fact that electricity is to a significant extent generated by domestic and clean hydro-power, and that there are growing concerns about environmental pollution. However, heat pumps are not yet seen as the most cost-effective technology to fight pollution. There is a trend towards extended use of natural gas, and solar systems are viewed as an important option.

and actions, notably within the IEA, the IIR and the European Union. This collaboration must continue, if heat pumps are to make a globally significant impact on energy use and its environmental consequences.

The 'International Heat Pump Status and Policy Review' contains a wealth of information which aims to stimulate international collaboration, to assist government and utility policy makers, and last but not least to provide useful information for the heat pump market players. Perhaps the best way to describe the intentions of this report is to quote the words that Mr Louis Lucas, Director of the IIR, used in the foreword: "I trust that this report will help promote trade and improve the exchange of technical information on heat pumps, of which the scientific interest, economic importance and environmental significance is bound to grow over the next decades".

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HPC Seminar***International Heat Pump
Status and Policy Review*****25 August 1995*****The Hague, The Netherlands***

One day seminar within the 19th
International Congress of Refrigeration
organized by the IIR (International
Institute of Refrigeration)

Be there!

Contact the HPC for a registration form.



Bibliography

Consequences of (H)CFC Replacement in HVAC Applications

Published by the IEA Heat Pump Centre; Order No. HPC-WR-13; January 1995; 234 p. Price NLG 60.

Proceedings of the workshop held in Gothenburg, Sweden on 7-8 September, 1994. Twenty papers address many issues including the technical, safety and economic consequences of switching to refrigerant alternatives.

Utilities Perspectives on Heat Pumps for Retrofit and New Applications in Buildings

Published by the IEA Heat Pump Centre; Order No. HPC-WR-14; January 1995; 340 p.; Price NLG 60.

Proceedings of the workshop held in Baden, Switzerland on 26-27 September 1994. Some 30 papers discuss a range of topics relating to measures that can boost the market for heat pumps in buildings.

Heat Pumps in Cold Climates

IEA CADDET Energy Efficiency Newsletter, No.1 March 1995. Distributed quarterly and free-of-charge in member countries of this IEA information centre. Contact the HPC for ordering information.

Seven articles, including one from the HPC, discuss a variety of heat pumping technologies for a range of applications in regions where heating, rather than cooling, is the predominant energy load for buildings.

Design and Optimization of Heat Pump and Combined Heat and Power Systems under MS-EXCEL

Programs and manuals (in German) available from INFOENERGIE Brugg, Switzerland; Fax: +41-56-412-015; Price CHF 1040.

Titled "W-calc", this computer program operates with Microsoft EXCEL 4 or 5 to allow the design and optimization (including economics) of a building heating system using heat pump or CHP technology.

PinchLENI

PC or MAC program can be ordered from Mr Daniel Notter of LESO-EPFL, Lausanne, Switzerland; Fax: +41-21693-2722. Price CHF 1600 (CHF 500 for universities) with manual in English, French or German.

Based on a graphical procedure, the software package PinchLENI allows design engineers to carry out pinch analysis on thermodynamic systems with multiple heat flow paths at different temperatures. See the articles on pinch analysis in *IEA Heat Pump Centre Newsletter* Vol.12, Nos. 3 and 4.

Thermophysical Properties of the Environmentally Acceptable Refrigerants

The following publications are the result of the work of Annex 18 of the IEA Heat Pump Programme:

Handbook for the Analysis and Identification of Alternative Refrigerants

Contact the IEA Heat Pump Centre for ordering details.

Reviews the major chemical analysis methods and compiles analytical information on new refrigerants. Provides physical, spectral and chromatographic data based on measurements performed on 120 materials.

Thermodynamic and Physical Properties of R123 Extended Thermophysical Properties of R134a

Two booklets published by the IIR (International Institute of Refrigeration) as part of the series "Tables and Diagrams for the Refrigeration Industry"; codes BRO123 and BRO134a+; March and April 1995; 56 and 48 p.; Price US\$ 20 or FF 120 each.

These properties bulletins are the result of intensive work under Annex 18 to determine and select the best equations-of-state. The property formulations presented in these two booklets are intended to become de facto international standards.

Events

* Call for papers

EAIRAH 1995 International Conference and Exhibition
April 30 - May 3 1995 / Melbourne, Victoria, Australia.
Contact: Mrs Siew-Ling Teh, AIRAH, Fax: +61-3-328-4116

Indoor Air Quality, Ventilation and Energy Conservation in Buildings
May 10-12 1995 / Montreal, Canada.
Contact: Fariborz Haghighat, Centre for Building Studies.
Fax: +1-514-848-7965

Indoor Air Quality in Practice
June 19-21 1995 / Oslo, Norway.
Contact: Ms Lise Olaussen, Norwegian Society of Chartered Engineers. Fax: +47-2294-7502

1995 ASHRAE Annual Meeting
June 24-28 1995 / San Diego, California, USA.
Contact: ASHRAE. Fax: +1-404-321-5478

The Second International Conference on New Energy Systems and Conversions
July 31 - August 4, 1995 / Istanbul, Turkey.
Contact: KONGRESIST International Convention Management Inc., Elmadag, Cumhuriyet Cad. 193/6, 80230 Istanbul, Turkey.

19th International Congress of Refrigeration - For a Better Quality of Life (IIR Congress)
20-25 August 1995 / The Hague, The Netherlands.
Contact: Van Namen & Westerlaken Congress Organisation Services. Fax: +31-80-601159

Tsinghua - HVAC '95- 2nd International Symposium on Heating Ventilation and Air Conditioning
22-25 September 1995 / Beijing, China.
Contact: Prof. Yi jiang, Secretariat of the Symposium.
Fax: +86-1-254-5093

International Symposium on Two-Phase Flow Modelling and Experimentation
9-11 October 1995 / Rome, Italy.
Contact: Dr Tommaso Setaro, ENEA Casaccia.
Fax: +39-6-3048-3026

***1995 International Gas Research Conference**
6-9 November 1995 / Cannes, France.
Deadline for abstracts: 31 July 1995. Contact: Gas Research Institute, USA. Fax: +1-312-399-8170

Symposium on Heat Pump and Refrigeration Systems Design, Analysis and Applications
12-17 November 1995 / San Francisco, California, USA.
Organized within the 1995 ASME International Congress.
Contact: Dennis L. O'Neal, Texas A&M University.
Fax: +1-409-862-2762

***Refrigeration, Climate Control and Energy Conservation**
11-14 February 1996 / Melbourne, Australia.
IIR Meeting of Commissions E2/E1 and B1/B2. Co-sponsored by the HPC. Deadline for abstracts: 14 July 1995.
Contact: Mrs Siew-Ling Teh, AIRAH. Fax: +61-3-328-4116

1996 ASHRAE Winter Meeting
17-21 February 1996, Atlanta, USA.
Contact: ASHRAE. Fax: +1-404-321-5478

***Frigair '96**
6-8 March 1996 / Johannesburg, South Africa.
Deadline for abstracts: 30 May 1995. Contact: FRIGAIR '96, Melanie Campbell. Fax: +27-11-442-5927

1st UAE Conference on Air Conditioning in the Gulf
14-18 April 1996 / Al Ain City, United Arab Emirates.
Contact: ACG96, UAE University. Fax: +971-33521

Purdue International Compressor Engineering Conference
21-26 July 1996 / West Lafayette, IN, USA.
Contact: Prof. R. Cohen, Purdue University, Ray W. Herrick Laboratories, West Lafayette, IN 47907, USA.

Natural Working Fluids in Refrigeration and Air Conditioning
2-8 September 1996 / Aarhus, Denmark.
Contact: Mr M. Arnvig, Danish Refrigeration Association.
Tel: +45-42-88-4622

Research, Design and Construction in Refrigeration and Air Conditioning in Eastern Countries
10-14 September 1996 / Bucharest, Romania.
Contact: Prof. F. Chiriac. Fax: +40-312-6880

***International Absorption Heat Pump Conference**
17-20 September 1996 / Montreal, Canada.
Contact: Darius Nikampour, EDRL, Fax: +1-514-652-5177;
Email: Darius.Nikampour@cc2smtp.emr.ca

IEA Heat Pump Programme

International Heat Pump Status and Policy Review
25 August 1995 / The Hague, The Netherlands
One-day HPC Seminar within the
19th International Congress of Refrigeration

Annex 22 Workshop on Natural Refrigerants
16-18 October / Trondheim, Norway

***5th IEA Conference on Heat Pumping Technologies**
22-26 September 1996 / Toronto, Canada

Contact the HPC for registration information

Available from the HPC

<i>Title</i>	<i>Publication type</i>	<i>Order No.</i>	<i>Price (NLG)*</i>
International Heat Pump Status & Policy Review	Analysis Report (Vol. 1, 2A & 2B) National Position Papers	HPC-AR3 HPC-NPP**	250 40
Consequences of (H)CFC Replacement in HVAC Applications	Workshop Proceedings	HPC-WR-13	60
Utility Perspectives on Heat Pumps for Retrofit and New Applications in Buildings	Workshop Proceedings	HPC-WR-14	80
Heat Pumps - An Opportunity for Reducing the Greenhouse Effect	Brochure	HPC-BR1	free
Heat Pumps - Better by Nature	Brochure	HPC-BR2	free
The HPC Portfolio	Brochure	HPC-BR3	free
The Behaviour of HFC-134a, HFC-152a and HCFC-22 in Evaporators	Annex 17 Report	HPP-AN17-1	100
Working Fluid Safety	Annex 20 Report	HPP-AN20-1	100

New publications

Next Issue of the Newsletter

Heat Pump Market Forces - June 1995



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National Team Contacts

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 its 24 participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

IEA Heat Pump Programme

Set up by the IEA in 1978, the IEA Heat Pump Programme carries out a strategy to accelerate the development and use of heat pumps, in all applications where they can reduce energy consumption for the benefit of the environment. Within the framework of the programme, participants from different countries collaborate in specific heat pump projects known as Annexes.

IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC), itself an Annex. The HPC contributes to the general aim of the IEA Heat Pump Programme, through information exchange and promotion of HPC products and activities, or for general enquiries on heat pumps and the IEA Heat Pump Programme. For more information contact your National Team or the address below.

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