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IEA Heat Pump Centre

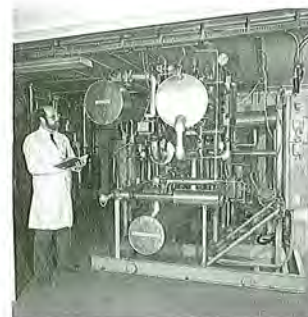
NEWSLETTER



heat pump
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Front Cover: High Temperature Heat Pump Test Facility used for testing R-123 at NRC, Canada.

International Energy Agency

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

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

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Editorial

"Programmes and activities to find CFC replacements" is the topic of this newsletter. Much has already been written and said about the CFC issue and the substitutes required. It is hard to add any new information to this without risking duplication. And yet, this issue deserves to be universally considered on a broad and continuous scale because it affects the environment, and the individuals living in it, now and in the future.

It is almost impossible to present a comprehensive state-of-the-art as far as CFC replacement is concerned within the scope of this publication, which covers all national programmes and activities. Other organisations will do this at regular intervals. Therefore, this issue deals with the CFC situation in a number of countries varying between large markets of refrigerant using equipment (Japan) and smaller markets (Netherlands).

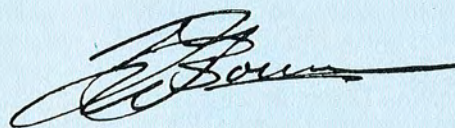
It is encouraging to see that Japan is now taking an active role. Industry has started to develop so called "third generation" alternative refrigerants that hardly, if at all, harm the environment. These include refrigerants for high efficiency heat pumps that use waste heat.

The articles prove that national policies on CFCs vary, as exemplified by Austria, where certain CFCs are still allowed in existing installations as long as these CFCs are available in the market.

In the Netherlands, as in Canada, a cooperative government/industry approach for CFC regulations is being pursued. As a result, detailed action plans have been developed, proving that industry has taken up the challenge of finding CFC replacements. An example of such a plan is presented in this newsletter.

Developing new refrigerants is one way of tackling the CFC problem. The alternate route is provided by the development and application of new cycles. This will be covered more fully in Newsletter Vol. 9, No. 4.

A next "global" strengthening of the Montreal Protocol in 1992 is underway. The HPC feels honoured to have been invited to contribute to this important task, which will provide us with additional support to enable us to work for a cleaner future.



Jos W.J. Bouma
General Manager HPC

Control on and Countermeasures against CFCs, etc., in Japan

*K. Maruo

Foreword

CFCs, now being recognized as representative substances that deplete the ozone layer, were introduced for the first time to the world in 1930 by Midgley as a safe refrigerant. For more than 60 years since that time, because of their outstanding safety and stability, CFCs have been utilised extensively, not merely as a refrigerant, but also as a safe, non-flammable aerosol propellant, plastic foam blowing agent, as well as for washing and substitution drying of electronic components, lenses, precision machinery parts, etc., metal degreasing, or as a cleaning agent for dry cleaning. Thus, CFCs have been heavily used for creating a comfortable living environment, thereby contributing to the economic development. However, since Dr. Ronald et al. presented a paper in "Nature" in 1974 on the depletion of the ozone layer, research has been carried out in various areas, and CFCs have been strongly suspected of the possibility that they are taking part in the destruction of the ozone layer in the stratosphere. In September 1987, the "Montreal Protocol on Substances that Deplete the Ozone Layer" ("Montreal Protocol") was adopted, and control on specific CFCs and specific Halons was concretely drafted, followed by control on chloric solvent as a source of airborne chlorine. At the 2nd Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, held in London in June 1990, an amended bill was adopted stipulating the phase out of CFCs and Halons by the end of this century and control on even 1,1,1-trichloroethane and carbon tetrachloride. Thus, the circumstances surrounding the control of CFCs, etc., are becoming increasingly severe. As a member of

the Parties, Japan must take steps towards the global environmental preservation in the future, putting up with inconveniences in some form or other. Primarily, it is necessary to reduce the quantity of CFCs used, while, at the same time, developing and introducing alternatives and alternative technologies.

Countermeasures by the Government

In December 1980, Japan declared, before the OECD, that it would freeze the CFC-11/12 production capacity, and has also endeavoured to reduce the use of aerosol CFCs. Furthermore, complying with the adoption of the "Vienna Convention for the Protection of the Ozone Layer" in March 1985, and of the "Montreal Protocol on Substances that Deplete the Ozone Layer" in September 1987, Japan enacted and promulgated the "Law for the Protection of the Ozone Layer through the Control of the Specified Materials" ("CFCs Control Law") in May 1988. It then announced the "Basic Matters (upper limits of production and import quantities after the control, etc.)" and "Guidelines of Emission Control and Rationalized Use of Specified CFCs" in January 1989, thus commencing the control of specified CFCs from July 1989. Complying with the amended bill of the Montreal Protocol, in March 1991, the revision of the "CFCs Control Law" was enacted after deliberation at the 120th Regular Session of the Diet (Parliament), and decided that it be implemented as the "Ozone Layer Protection Law". Responding to the revision of the Montreal Protocol, the revision of the Ozone Layer Protection Law mainly included the addition of other CFCs 1,1,1-trichloroethane and carbon tetrachloride (i.e., substances listed

in the Annex B of Montreal Protocol) to the list of substances to be controlled, changes in the method for calculating the production quantity (specifying the quantity used as a stock material of any other chemicals), and monitoring of production, export and import of specified substances (i.e., those listed in the Annex C of Montreal Protocol).

Countermeasures by the Industry

In the meantime, by joining the Fluorocarbon Program Panel (FPP), a special programme implemented by the Chemical Manufacturers Association (CMA) in the USA, from 1973, the Japan Flon Gas Association (JFGA), an association of manufacturers, has contributed funds to the programme, together with the major overseas CFC manufacturers, and has endeavoured to make basic scientific findings, such as possible influences of CFCs upon the ozone layer. Furthermore, at the instructions of the Ministry of International Trade and Industry (MITI), the JFGA prepared a manual for reducing the use of CFCs, with a view to smoothly implementing the control, and distributed its copies to users. Thus, the JFGA has endeavoured to enhance public awareness of the need for reducing CFCs. In order to actually implement the control, the Conference for Promotion to Decreasing CFCs was organised centering around the JFGA, and the JFGA co-operated in events such as the "Intensive Month for Decreasing CFCs" in July 1989. The Conference was reorganised in June 1990, into the Japan Industrial Conference for Ozone Protection (JICOP) in which a body of 1,1,1-trichlorofluorethane users also participated. The conference developed various activities

powerfully, such as cooperation in the "Month for Ozone Layer Protection" programme, various surveys, seminars, and distribution of information.

Development of the Alternatives

As a consequence of efforts made concertedly by the government and the public, use of CFCs has been steadily reduced to date without much confusion. From now on, however, since it is anticipated that the control programme may be implemented earlier than scheduled, alternatives must be placed on the market as urgently as possible. By pursuing development of their own manufacturing methods, Japanese CFCs manufacturers are preparing themselves for installation of new manufacturing equipment, while participating in the programme for Alternative Fluorocarbon Toxicity Testing (PAFT), a consortium for toxicity testing, in cooperation with overseas alternatives manufacturers. They have also taken part in the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS), thus conducting investigations into influences upon the environment of each alternative's decomposing mechanism and products of decomposition in the air, etc. As alternatives for CFC-113 which has been used as a cleaning solvent, HCFC-225ca/cb, pentafluoropropanol, etc., were unveiled by Japanese manufacturers. This reflects the fact that the quantity of CFC-113 used as a cleaning solvent has occupied about half the CFCs consumption in Japan.

In order to commercialise alternatives, it is necessary to study thermophysical properties, solubility and swelling on plastics and elastomers, and other characteristics. As a study project entrusted by the MITI, measurement of thermophysical properties and tests on chemical resistance and gas transmissibility of high polymers were conducted. Furthermore, a data book on thermophysical properties of

HCFC-123 and HCF-134a has been published jointly by the Japan Association of Refrigeration (JAR) and JFGA for the first time in the world.

Development Situation in Each Field

The quantity of CFC decreases and the current state of alternatives and alternative technologies introduced in each field are outlined below.

• Refrigerants:

Until CFCs are replaced by HFCs and HCFCs, the refrigerant field is thought to be a field where it is most difficult to reduce the consumption of CFCs. HFC-134a is available as an alternative for CFC-12. HFC-123 is currently being developed as an alternative for CFC-11. As for HFC-134a which is specially thought to be promising when used for refrigerators and automobile air-conditioners; polyalkylene glycolic or polyester lubricating oil will be adopted as a new lubricating oil. As for small disposable containers, the High Pressure Gas Control Law will be revised in the near future, and HFC-134a disposable containers will also be commercialised. HCFC-123 will be adopted as an alternative for CFC-11 used for centrifugal chillers. As for recovery/recycling of CFC-12 used for automobile air-conditioners, the industries concerned have set about a study on how to create an effective social system.

• Blowing Agents:

Blowing agents are used for making plastic forms such as cushions, heat insulating material, etc. At present, apart from that for rigid forms such as heat insulating material, efforts are being continued to lower the rate of CFC use by means of existing technologies and by improving them. For rigid polyurethane forms, HCFC-123 and -141b are drawing attention as alternative blowing agents. HCFC-123 is non-flammable and its ODP is small. HCFC-141b, on

the other hand, has a short flammable region and its ODP is fairly large, but the form made with it excels in physical properties and economy. Since both have merits and drawbacks, selection is being delayed. The possibility of using a HCFC-123 and HCFC-141b mixture is also discussed. In the case of polystyrene foam and polyethylene foam, the existing HCFC-142b, HCFC-22 blowing agents, etc., are going to be put to practical use as alternatives.

• Aerosol Propellants:

In Japan, flammability and flame length of aerosol products have been specially disputed. However, due to the revision of the law, it has become possible to use petroleum gas and dimethylether; they are rapidly replacing aerosol products mainly in the domestic field. In the industrial field, etc., however, there is still a deep-seated demand for non-flammable or not easily flammable aerosol products. Additionally, since 1,1,1-trichloroethane has been put under control, non-flammable HCFCs will have to be used in some cases. Even when flammable HCFC-142b, HFC-152b, etc. are used, they can be changed into a non-flammable propellant by mixing with non-flammable HCFC-22, HCFC-123, etc.

• Cleaning Agent:

In Japan, about half the quantity of CFCs under control is occupied by CFC-113 which has been widely utilised as a safe cleaning agent in such fields as electronic components, precision machinery parts and lenses that are bolstering Japan's economy. At present, prospective alternatives for CFC-113 are HCFC-225ca and -cb, since their properties most closely resemble those of CFC-113, and are thus capable of being used as drop-in agents. However, their use has just begun to be studied in the PAFT IV tests, and it will require four to five years for them to be commercialised. Furthermore, in the revised Montreal Protocol, it

was decided to phase out 1,1,1-trichloroethane in 2005. Thus, the situation has become even more serious. In Japan about 180,000 tonnes of 1,1,1-trichloroethane is consumed, and has been heavily used in many fields, including metal degreasing. Since its control was suddenly decided when demand for it as an alternative for CFC-113 was steadily growing, it is necessary to urgently establish countermeasures. As new non-CFC cleaning agents, terpenic Bioact-EC7 and pentafluoropropanol as a non-flammable alcohol have been proposed. Since both do not contain chlorine, they do not affect the ozone layer. However, they cannot totally replace the use of CFC-113, as they have a variety of merits and drawbacks.

However, since CFC-113 was put under control, major manufacturers are thoroughly reviewing their cleaning processes, and positively developing cleaning methods using non-CFCs, or non-cleaning processes. Also, by improving the methods for using the existing cleaning equipment, making the equipment more airtight, recovering/recycling more CFCs diffused in the air, and by other means, more reductions in use of CFCs have so far been achieved than expected. In the future, however, many hurdles will have to be cleared, including effective countermeasures to be taken by smaller users, and measures to be taken in association with the use of 1,1,1-trichloroethane. When manufacturers introduce CFC-free or CFC saving type cleaning equipment, they are benefited with financial provisions, such as various types of low interest loans, and treasury provisions, such as special depreciation.

Search for Next Generation Refrigerants

When adopting the revised Montreal Protocol, a resolution was made that measures be examined for phasing out HCFCs, which will

have been positively developed as alternatives for CFCs, by 2040, and if possible, by 2020. Safe refrigeration and air-conditioning equipment is indispensable for manufacturers, processing and transportation of foodstuffs and medical supplies. Safe heat mediums are also indispensable for effective utilisation of energy, in conjunction with the greenhouse warming effect upon the earth. As a step towards phasing out CFCs by the end of this century, and as a step towards phasing out HCFCs by the first half of the next century, studies in search of next generation refrigerants were inaugurated as a national project jointly carried out by the Research Institute of Innovative Technology for the Earth (RITE) and the National Chemical Laboratory for Industry, entrusted by the New Energy and Industrial Technology Development Organisation (NEDO). It started in October 1990. The programme aims to develop new alternative refrigerants for high efficiency heat pumps used for a waste heat utilisation systems, i.e., new substances which do not affect the ozone layer at all, and have a small global warming potential.

Conclusion

CFCs, which have been developed and widely utilised as safe substances, have been found to seriously affect the global environment because of the very properties which render them safe and stable in use. This will be an important lesson to be remembered when we consider a desirable course of development of forthcoming substances. Adoption of the Vienna Convention and Montreal Protocol may be said to be epoch-making in that, differing from the conventional approach to pollution and environmental problems, civilised society has made a decision to prevent the global environmental changes which may occur in the future, at the sacrifice of its current convenience. For industries not merely in Japan but also in the world at large, it is a tough

challenge to comply with the control on CFCs and to achieve a phase out by the end of this century. However, it is desired that, by racking their brains, both manufacturers and users will successfully develop alternatives which exert less influences upon the environment, and establish technologies for effectively utilising alternatives. These alternative technologies, however, should not be mere alternatives, but be superior to conventional technologies, so that they can serve as a springboard for further development.

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Towards Development of CFC Alternatives

*A. Sekiya

Summary

Since it was found that chlorofluorocarbons (CFCs) currently in use destroy the ozone layer in the stratosphere, and tend to produce a greenhouse warming effect, it was decided to totally abolish them by the end of this century. Consequently, in order to solve the CFC problem, it has become most important to develop pollution-free CFC alternatives.

It is desirable that future alternatives be compounds balanced in terms of their influence upon the environment; their physical properties; their toxicity which should be low; and the way of synthesising which should be easy. Research and development of these compounds have already been initiated.

Current State of CFC Alternatives

At present, in order to preserve the global environment, CFC manufacturers are actively developing various types of alternatives. Representative alternatives include hydrofluorochlorocarbon HCFC -123, and hydrofluorocarbon HFC -134a. Since these compounds contain hydrogen atoms, their life in the atmosphere is shorter than that of CFC thus destroying the ozone layer less than CFCs and producing a lesser greenhouse warming effect.

If CFCs, which are still in use, are regarded as "first generation" compounds, prospective alternatives such as HCFCs and HFCs being developed by manufacturers may be classified as "second generation" compounds.

Third Generation Alternatives

The second generation compounds exert less influence upon the environment than the first generation CFCs, but they are not free of problems. Since HCFCs contain chlorine atoms, they can destroy the ozone layer, although the effect is low. HFCs do not destroy the ozone layer, but can produce a greenhouse warming effect.

Accordingly, it has become necessary to find more pollution-free alternatives. As part of the second generation alternatives, it is possible to develop HFCs which produce a lesser greenhouse warming effect. Unexplored future alternatives, which will exert less influence upon the environment than HCFCs and HFCs presently developed by manufacturers, could be classified as "third generation" CFC alternatives.

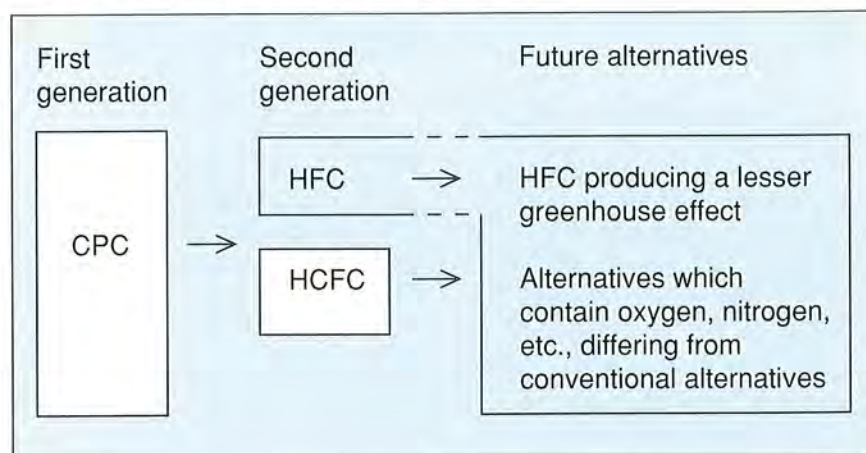
Now, as third generation CFC alternatives, what type of target should be aimed for?

A promising target is an organic fluorine compound containing oxygen, nitrogen, sulfur, silicon, etc. In order to maintain the excellent characteristics of CFCs, a compound must contain fluorine. Also, in order that a compound be able to dispense with chlorine atoms it is necessary to improve the affinity for oils and fats, a characteristic of CFCs due to chlorine atoms. For this purpose, it becomes necessary to examine the possibility of introducing oxygen, nitrogen, etc. The direction in development of alternatives is illustrated in Figure 1.

Development

In view of the ongoing destruction of the ozone layer, the long-term influence of the current CFC use which will extend to the next century, and the long time span required to develop alternatives, it is necessary to search for third generation alternatives as urgently as possible. At present, however, companies in Japan are hurriedly developing second generation alternatives, and have set about development of third generation alternatives only very recently.

Figure 1: Direction in Which Alternatives Evolve.



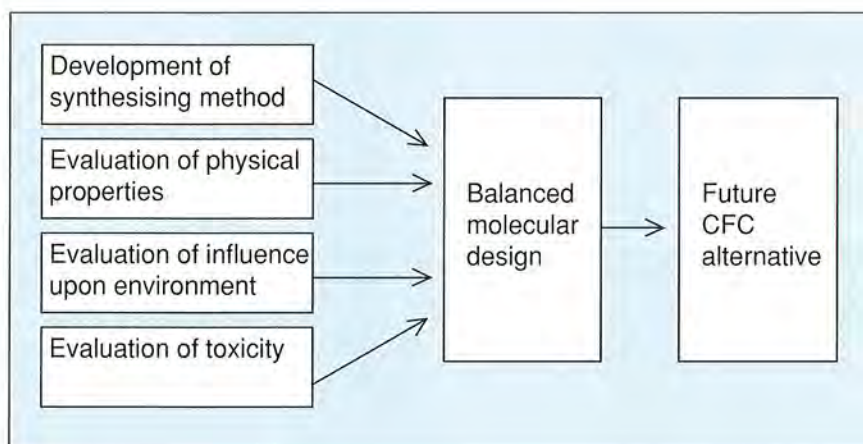


Figure 2: Development of a New Alternative.

Conclusion

As pollution-free future CFC alternatives, development of a HFC which produces a low greenhouse warming effect, as well as research and development of third generation alternatives, are underway. In the future, many of the basic data on various types of compounds will be unveiled, and a desirable course of CFC alternatives will gradually be determined.

In the USA, Prof. Adcock (Tennessee University) announced an ethereal compound containing fluorine at a meeting of the American Chemical Society held in August, last year¹⁾. The Research Institute of Innovative Technology for the Earth and The National Chemical Laboratory for Industry of Japan are presently engaged in research on synthesising various types of compounds containing fluorine, systematically examining their physical properties, and extracting prospective compounds which are most suitable as third generation CFC alternatives. As a method for synthesising an ethereal compound containing fluorine, for example, a synthesising method²⁾ has been developed which, by means of direct fluorisation, produces perfluoro-ethylmethylether at a high yield rate. Additionally, by examining the fluorination reaction of dialkylether containing chlorine, reactions have also been developed³⁾ for replacing chlorine atoms, by fluorine atoms.

As for hydrofluorocarbons (HCFs), in order to search compounds which produce a low greenhouse warming effect, partial selective fluorination reactions have been developed⁴⁾. Moreover, believing that instantaneous judgement of the greenhouse warming effect exerted by those synthesised compounds is helpful to future molecular design, a simple estimation method⁵⁾ for the

greenhouse warming effect has also been developed.

In order to develop a new alternative, it is necessary to develop its synthesising method, evaluate its physical properties, estimate its influence upon the environment, test its toxicity, and thereby select a target compound which is balanced, with respect to the above criteria so that the alternative may eventually be developed (see Figure 2).

In these circumstances, "Research and Development of New Refrigerants for Compression Heat Pumps" started in the latter half of 1990 as a project for developing 'so-called' third generation CFC alternatives. With a view to facilitating utilisation of waste heat, the project is going to develop new refrigerants replacing CFC-114, while taking into account the global environmental problems. The New Energy and Industrial development Organisation (NEDO) has entrusted the project to be carried out by the Research Institute of Innovative Technology for the Earth (where researchers despatched from ten private enterprises are working together on the project), in collaboration with the National Chemical Laboratory for Industry, as a five-year project.

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CFC Issues in Canada

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Summary

This article provides a brief overview of the impact to date of the Montreal Protocol and its implementation in Canada. It includes a review of the regulatory effects and measures being taken by government and industry to address related problems. A summary is also given of current R&D programs aimed at investigating environmentally acceptable alternative refrigerants.

Regulatory Activities

Modifications to the Montreal Protocol which were approved at the 1990 UNEP meeting in London have established the basis for an accelerated CFC elimination program. Canada and several other countries have set a target date of 1997 for total CFC phaseout. Regulatory changes are currently being prepared by Environment Canada (EC) to implement revised Protocol objectives in the areas of production, importation, and end uses of designated CFCs. EC has also recently issued "Canada's Green Plan" - a policy document on environmental issues which, amongst other environmental concerns, identifies objectives for dealing with both ozone depleting substances and greenhouse gases.

Emission Control Strategies

In dealing with ozone depleting substances the prime objective is emission reduction, and the principal effective strategies

identified by government and industry to accomplish this include:

• Development of Alternative Compounds

Industry has been challenged to identify and develop environmentally acceptable refrigerant compounds as alternatives to the fully halogenated CFCs. The proposed substitutes (Table 1) are now in various stages of development and evaluation. Many other alternatives including refrigerant blends are being studied in R&D programs (see below). The world's first commercial scale plant for the production of R-123 is now in operation at Maitland, Ontario.

• Equipment Design and Work Practice Standards

Refrigerant and equipment manufacturers as well as contractors and refrigerant wholesalers have jointly worked

together with the Heating Refrigeration and Air-Conditioning Institute of Canada (HRAI) to develop a set of equipment design and work practices. These industry standards have been adopted by the federal government and are also expected to become part of provincial regulations. HRAI also has an active industry training program in place, with funding support from Environment Canada.

• Recovery and Reclamation

Recovery, reclamation, and reuse of CFCs was recognized at an early stage as one of the most expedient approaches to significant reductions of CFC emissions. The technology required is relatively simple and currently available. Mandatory regulations for recovery/reclamation are now in effect in at least two provinces and others are expected to follow soon. A national reclamation infrastructure has been established by Du Pont Canada. In addition there are approximately 25 companies marketing small units for contractors and others who wish to do their own in-house reclamation.

• Other Initiatives

Industry has taken some initiatives in areas not specifically required by regulations. These include the development and provision of more efficient purge systems by equipment manufacturers such as Carrier, York and Trane. Small returnable refrigerant containers have also been introduced into the Canadian market to replace the disposable units which were a significant source of emissions.

Table 1: Proposed Alternatives to Commonly Used CFC Refrigerants.

CFC	Alternative Refrigerant
R-11	R-123
R-12	R-134a
R-113	R-123
R-114	R-124
R-115	R-125
R-502	R-22, R-125

The new returnable unit has the same convenience advantages and in addition the outer crate is made of recyclable plastic instead of cardboard. These measures are expected to reduce emissions by several hundred tonnes per year.

Prototype testing of ternary blends for automotive air-conditioning after-market use is being carried out in a joint program between Du Pont Canada and an automobile air-conditioning equipment manufacturer.

have been involved in a joint R&D program with Du Pont Canada Inc. and another federal government department, Energy, Mines and Resources Canada (EMR) to investigate the thermodynamic performance of new environmentally acceptable refrigerants. The thrust of this ongoing program so far has concentrated on comparing the capacities and coefficients of performance (COPs) of some of the alternative refrigerants with those of the CFCs which they are intended to replace. Most of these tests have been conducted in a small water/water heat pump test facility (Figure 1). Measurements have been carried out over a wide range of evaporating temperatures covering the application areas of refrigerator/freezers, automobile air-conditioning, and heat pump systems.

Long term fluid stability is being investigated at NRC in a special purpose steam generating heat

Demonstration Projects

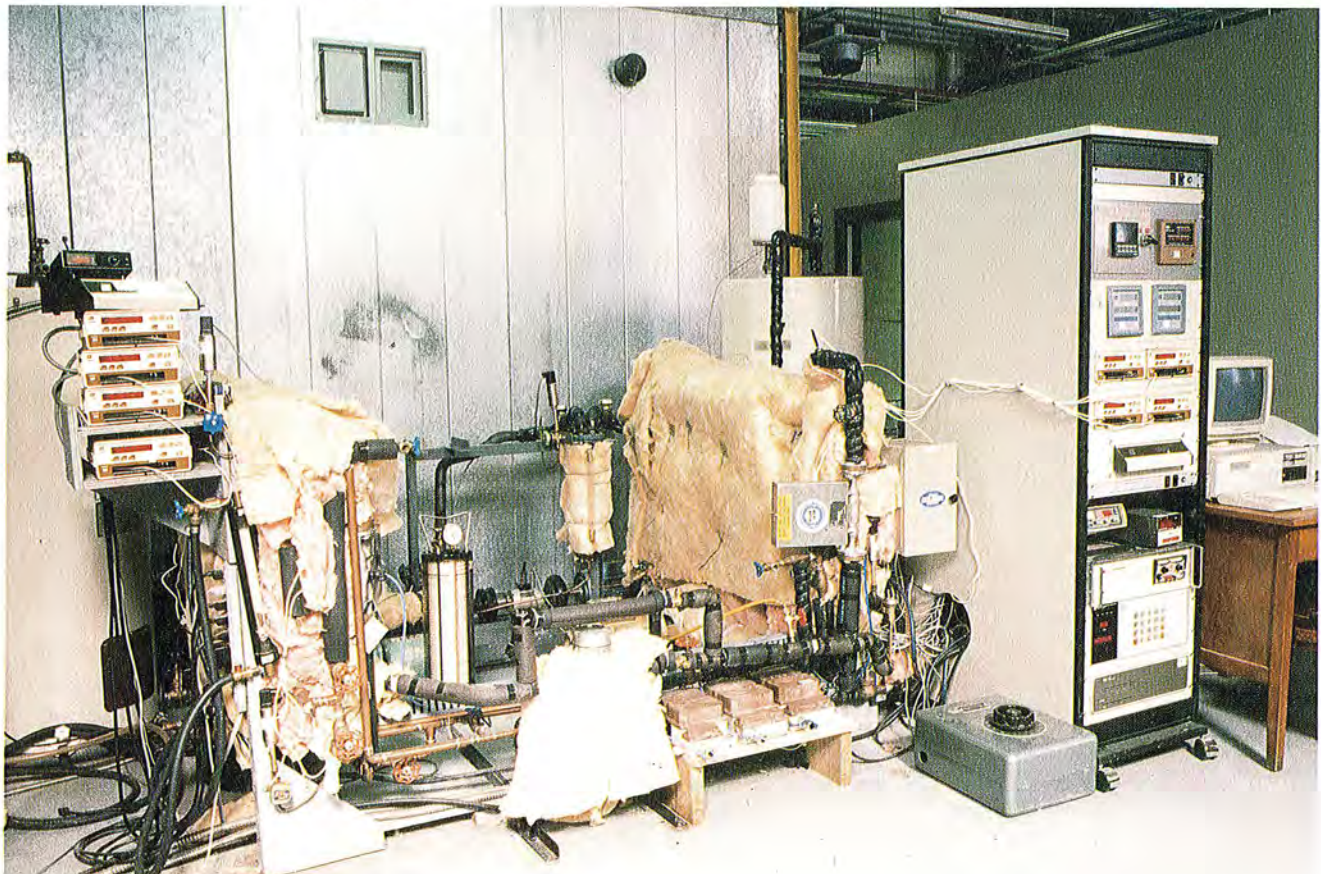
The use of R-123 as a replacement refrigerant in large chiller applications has been successfully evaluated during the past 18 months in an existing chilled water system at a federal government building located in Ottawa. Following on this favorable experience R-123 has recently been installed in several other building cooling systems on a trial basis, and Public Works Canada is developing a master plan to handle all existing chilling equipment in government buildings.

Research and Development

Canada is also involved in the worldwide R&D effort to identify environmentally acceptable working fluids as satisfactory substitutes for CFC refrigerants. The main focus for this activity is at the National Research Council Canada (NRC), which conducts an active in-house test program and also provides coordination of related work undertaken at other Canadian research institutions.

Since 1988 staff of the Institute for Mechanical Engineering at NRC

Figure 1: Water/water Heat Pump Test Facility at NRC.



pump test unit. The objective of this work is to assess the potential of some refrigerant/oil combinations as possible high temperature (150°C) working fluid substitutes in industrial heat pump system applications. Heat pumps are expected to be one of the major technologies to be employed in reducing fossil fuel consumption and greenhouse gas emissions.

As a part of this collaborative program NRC is also conducting strategic research on alternative refrigerants, particularly in the areas of two-phase heat transfer and key fluid transport properties measurement. For this purpose a new test loop has been built to measure heat transfer coefficients and pressure drop characteristics for fluid flows in various heat exchanger tubing configurations. Also, with additional assistance from the University of Hannover and an associated German consulting company, a viscosity measurement facility is currently being constructed at NRC for the purpose of measuring liquid viscosities of pure and mixed refrigerants, and oils.

Thermal conductivity measurements of some HFCs and HCFCs are now being carried out by the Thermal Conductivity Research Group at the University of New Brunswick, using a transient hot wire instrument. In addition to pure refrigerants, measurements will be conducted on two and three component blends and the effect of oils will also be studied.

At the University of Moncton, experimental and numerical studies are being conducted to predict the dynamic performance of selected binary and ternary refrigerant blends in vapour compression systems, particularly in heat pumps. A study is also being done to establish the performance of new non-CFC refrigerant mixtures as potential working fluids in absorption cycles.

The use of non-azeotropic refrigerant mixtures as potential substitutes for CFCs requires a reliable knowledge of the mixture

properties. To fulfill an important part of that need, the Centre de Recherche Industrielle du Québec (CRIQ) has designed and built a vapour-liquid equilibria (VLE) apparatus dedicated to measurement of properties required for application of the relevant equation of state. Some tests have been done on pure refrigerants and binary mixtures, and measurements on ternary blends are scheduled to begin soon.

Conclusion

Canada is pursuing a cooperative government/industry approach towards the development and implementation of CFC regulations, and is adopting a proactive approach to its environmental obligations. Government, universities, and industry are involved in carrying out coordinated and effective R&D programs to investigate the behaviour of alternative refrigerants. These measures are enabling Canada to maintain its commitment to an early phaseout of CFCs and to remain in the forefront of this important area of technology.

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Effects of CFC Regulations on Heat Pumps in Austria

*H. Halozan

Introduction

The Montreal "Protocol on Substances that Deplete the Ozone Layer" was the first worldwide agreement for protecting the environment. This agreement was also signed by Austria and therefore has an effect on manufacturing, marketing and operating heat pumps.

As a result of the Montreal Protocol, regulation 301 of the Austrian Minister of Environment, Youth and Family of May 17, 1990, specifies that production and marketing of the fully-halogenated chlorofluorocarbons (CFCs) is forbidden as of January 1, 1991. Substances which are used for heat pumps and which are subject to this regulation include the CFCs R11, R12, R113, R114 and R115 and the mixtures R500 and R502 which also contain CFCs.

Exceptions to this regulation are, however, provided for:

- heat pumps and air conditioners manufactured or imported up to January 1, 1992;
- small heat pumps with a maximum refrigerant charge below 1 kg (especially small hot tap water heat pumps) and high temperature heat pumps with condensing temperatures above 55°C manufactured or imported up to January 1, 1994, and
- the continued operation of existing heat pump units and systems as well as units manufactured or imported to Austria before the above mentioned deadlines using those refrigerants.

Additional exceptions after the above mentioned deadline dates are possible if no alternatives for

CFCs for special applications will be available.

Effects of the Regulation

This Regulation has different effects on existing plants and plants under construction, and it has also created some psychological effects.

Existing Plants

In agreement with the regulation, existing plants can continue to be operated with the above mentioned CFCs and mixtures containing CFCs. Refrigerants required for these plants can also be used in the future, until an economic solution for changing to an environmentally acceptable refrigerant becomes possible.

It may turn out, therefore, that the limitation for future operation with CFCs is not the Regulation but the availability of fully halogenated hydrocarbons. Some companies may not only stop production of these refrigerants but also halt recycling; this will be the end of such plants.

New Plants

In the case of new plants the situation for heat pumps is a little confusing when taking the present situation in the market into consideration. The number of environmentally acceptable refrigerants which are available on the market, and which have been tested for long term operation, is limited:

- R22 is the refrigerant which is presently favoured for more or less all heat pump and refrigeration applications. It was already used as the main

refrigerant for residential heat pumps and air-conditioners; it is used for refrigeration systems as a substitute for R12 and R502, using improved compressors and newly developed two-stage compressors; and for larger systems with centrifugal compressors it is used even for high temperature applications, while changing from the presently used 30 bar technique to a 40 bar technique.

- The DuPont mixture R22-R152a-R124, the only real 'drop-in' substitute for R12, is not yet available because R124, the substitute for the former planned R114 in this mixture, is not yet available.

The problem of these alternatives is that R22 is also under discussion. Efforts are being made to phase out R22 by 2040, in Germany even by 2000. This German intention of course has an influence on the Austrian market.

- R134a and R152a are chlorine-free fluorohydrocarbons, but the absence of chlorine, an advantage from an environmental point of view, may create other problems:
 - Chlorine-free refrigerants must not be used in compressors or circuits which have previously been operated with a chlorine containing refrigerant, as this leads to copper strip-off in the copper piping and corrosion of the winding of the electric motor.
 - Chlorine-free refrigerants need special oils; chlorine acts as an additive for the existing oils improving their lubrication capability. New oils with improved lubrication capabilities are extremely

hygroscopic and have not yet undergone long-term testing. Selection of the wrong type of oil can lead to a remarkable decrease in the efficiency of the compressor.

- Presently - according to remarks of compressor manufacturers at the Meeting of the Austrian Association for Refrigeration and Air-Conditioning of October 30, 1990 in Vienna - no long-term tested heat pump compressor for R134a and R152a is yet available. It will take at least two years before heat pump compressors for these chlorine-free refrigerants will be available on the market.

Tests with R134a and R152a are presently going on in Austria, and it is now becoming more and more a search for the best oil. In the case of R134a, additional improvements of the compressor are necessary in order to achieve at least the same COP as with R12. Another possibility which exists may be the use of mixtures with chlorine-containing refrigerants, where the chlorine containing component acts as a blend to improve the lubrication capability of the oil.

- Ammonia is an "old well-known" refrigerant. Its disadvantages are flammability, toxicity, high electric conductivity and non-miscibility with oil. Open compressors must be used, which leads to leakage of ammonia.

In this context one has to remember that CFCs were the basis for hermetic systems, and that hermetic systems are the reason for the worldwide market penetration of small and medium-sized refrigeration, air-conditioning and heat pump systems. Large systems with open compressors are no problem; however, in the case of small systems, problems may arise when safety regulations are considered.

There is one compressor manufacturer in Austria producing a hermetic compressor with a separating hood, i.e., the winding of the electric motor is outside of the refrigerant circuit, even though the refrigerant cycle still remains closed. A few parts of this compressor had to be modified to achieve material compatibility with ammonia. At present this compressor is being tested with ammonia, first results look promising. Additional modifications for heat pump application will be necessary, such as possibly two-stage compression.

Non Regulatory Effects

When taking the Austrian Regulation 301 into consideration, no urgent problem with respect to the use of CFCs in heat pumps seems to arise. Time until January 1, 1994 is available to change the design and refrigerant of hot tap water heat pumps and high temperature heat pumps. But there is still a psychological problem: people are presently afraid of installing a system which uses CFCs because of their reputation of contributing to the depletion of the ozone layer.

Ozone depletion was stressed so intensively in the media that everybody thinks he understands the problem. What some people were afraid would happen, has really happened: the ozone discussion, which resulted in regulations, has more or less obscured the global warming problem. And when in Germany the Enquete Commission for the Protection of the Atmosphere of the Earth talks about global warming, it only talks about the global warming potential of CFCs and HCFCs such as R22 and even HFCs such as R134a, and not about increased greenhouse effects caused by burning more fossil fuels due to the reduced efficiency of heat pump systems using alternative refrigerants or even by avoiding the future use of heat

pumps. In fact, such effects are much larger than the effects caused by the emission of refrigerants from heat pumps.

Conclusion

The encouraging effect of the Montreal Protocol was that it resulted in the first worldwide agreement to protect our environment. The negative effect was that CFCs utilised in closed heat pump cycles were also banned. The argument of closed cycles was not accepted for CFCs although it is generally accepted for toxic and/or flammable refrigerants. This means that, in the next decade, the main emphasis will be on changing the refrigerants and not on improving heat pump efficiency which could contribute to reducing the greenhouse effect which is a more severe problem than ozone depletion.

With respect to ammonia and water and ammonia/water mixtures there are many possibilities for advanced systems, but development, market introduction and penetration is not a task which can be accomplished in the next three years. It is a task for the next twenty years to develop reliable and highly-efficient systems which are fully acceptable from an environmental and safety point of view.

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The Netherlands CFC Action Programme

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Summary

A description is given below of the approach which is followed in the Netherlands to eliminate the use of CFCs. A project which involves cooperation between the government and industry has been set up and is called "CFC Action Programme" consisting of two phases.

The first phase (1990-1995) comprises:

- *voluntary reduction of CFC use by industry;*
- *supportive regulations.*

In the second phase further regulatory measures are planned to be taken (if necessary), culminating in a total ban by the year 1997.

General Policy

General background

The Dutch policy for the phase out of CFCs can be characterised as follows:

- full support of UNEP Montreal Protocol and subsequent revisions;
- full support of European Community (EC) measures to reduce the consumption of fully-halogenated CFCs (EC Council Regulation No. 594-91 of March 4, 1991).

A national programme under the name 'CFC Action Programme' has been set up to meet these objectives. This action programme has been drawn up in close cooperation between private industry, representatives of local and provincial authorities, and the national government. These

organisations endorse this programme and are committed to implementing it.

The action programme covers the period from 1990 to 2000 and its implementation falls into two parts. During the first period (1990-1995) the emphasis is on voluntary reduction by industry of the consumption of substances mentioned in the Montreal Protocol. The results of these voluntary reductions will be presented each year in an annual report. Supportive regulations on the application of CFCs in refrigerating equipment, of halons in fire-fighting equipment and on the prudent use of CFC 113 as solvents and cleansing agents will stimulate the activities of private industry during this period. A ban on the use of building materials containing ozone depleting substances will also be announced.

In the period 1995-2000 the voluntary reduction by private industry will be consolidated by a total ban. It is not intended that exceptions should be made, apart from medicines available only on prescription.

Voluntary measures are required in anticipation of international developments. As soon as the steps undertaken threaten to lag behind

international agreements, sanctions will be imposed.

Voluntary Reduction Scheme

In the period 1990-1995 private industry will reduce the use of CFCs and halons in the Netherlands on a voluntary basis, along the lines of the reduction scheme shown in Table 1.

Annual Report

To be able to follow the progress made in phasing out the use of ozone depleting substances in the Netherlands, an annual report will be drawn up before 1 May every year by an external accountant who will be granted leave to inspect the books of producers, importers and industrial consumers. The data in the annual report will be published in such a way that information on individual business is not traceable. If available, data which have already been checked externally will be used. Data about developments concerning alternative chlorofluorocarbon compounds and the latest scientific data on the hole in the ozone layer and its possible consequences will also be included in the annual report.

Table 1: Reduction Scheme.

Annual consumption in tonnes (10 ³ kilogrammes)	1986	1990	1992	1994	1995
Aerosols	≤4700	≤2600	951	6	6
Foams	6360	5100	3050	300	0
Refrigeration	800	600	150	60	0
Solvents/cleansing agents	1400	1000	500	200	50
Total CFCs	13260	9300	4651	566	56
Halons	445	300	100	10	0

Committee

A committee has been set up in which private industry, local and regional authorities, environmental and consumer organisations, the Ministry of Economic Affairs and the Ministry of Housing, Physical Planning and Environment will be presented. This committee, known as the CFC Committee, will be responsible for making decisions on the adjustment of the action programme in the light of current developments. Depending on the way the uncertainties develop the reduction targets for later years may also be adjusted. The committee will also advise the Minister of Housing, Physical Planning and Environment on the allocation of the resources that will be made available for the implementation of the programme. A project planning agency has been established by the committee for the day-to-day performance of its duties. The committee will give its views on the progress made at least once a year in the annual report, and will also be responsible for the preparation of the CFC annual report. As part of this committee, three working groups have been set up to deal with specific sub-areas such as refrigeration.

Supportive Regulations

In 1991 a regulation directed, towards sustaining the voluntary activities of private industry will come into force. It concerns the refrigeration sector and the fire-fighting industry, and the utilisation of CFCs as solvents and cleansing agents. The aim of the regulation for the refrigeration sector is to ensure that only competent personnel, who work in accordance with national regulations, install and maintain refrigeration equipment containing substances which could be harmful to the ozone layer. In addition, the use of CFCs in refrigeration equipment will be limited and the utilisation of CFCs in refrigeration systems will be subject to standards.

HCFCs and HFCs

According to the estimates available, the replacement of CFCs may be achieved as follows:

- 30% of the market will be replaced by HCFCs;
- 10% of the market will be replaced by HFCs;
- 30% of the market will disappear as a result of savings;
- 30% will be replaced by other alternatives.

In conjunction with the lower ozone depleting potential the replacement of CFCs along these lines means a reduction of the total ozone depleting potential by about 99%. The greenhouse warming potential will be reduced by about 96% in relation to CFCs. If stringent conditions are attached to HCFCs the replacement of CFCs may be endangered.

Furthermore, the short atmospheric life of HCFCs (2-20 years) in relation to CFCs (60-400 years) according to computer modelling means that careful use of HCFCs for an interim period will not delay the recovery of the chlorine concentration (about 2075) in the stratosphere at the level of the antarctic 'hole' in the ozone layer.

In the CFC action programme, industry is called upon to handle HCFCs cautiously. The annual report will indicate the quantities of HCFCs and HFCs consumed in the Netherlands in relation to their consumption worldwide. The areas of application for which these substances are used will also be indicated.

Total Ban

The announcement in the Bulletin of Acts, Orders and Decrees in 1991 of a total ban, to be effective from mid 1997, on the production or import of products which are harmful to the ozone layer or the use or stocking for trading or production purposes of products which contain these substances, will clarify the termination of the consumption of CFCs and halons. The production and use of CFCs is expected to be regulated by means of a European regulation in early 1991. European regulations have a general scope, are binding in their entirety and are directly applicable in each Member State, so that separate national regulations for this purpose are unnecessary.

Refrigeration and Heat Pumps

Government and industry have agreed on the reduction scheme shown in Table 2 for the refrigeration and heat pump sector:

These reductions will be achieved as follows.

1990

CFC-11 will no longer be used for cleaning condensers.

A start will be made on reusing refrigerants and phasing out the use of CFC-11, 12 and 115 for new commercial refrigeration and air conditioning systems.

1992

CFC-11, 12 and 115 will no longer be used for new commercial refrigeration and air-conditioning equipment with a capacity of 500

Table 2: Reduction Scheme for the Consumption of CFC 11, 12 and 115 for Commercial and Industrial Refrigeration.

	1986	1990	1992	1994	1995
Refrigeration	800	600	150	60	0

watts or more. CFCs 11 and 115 will be replaced by HCFC-22 until other replacements are available. Recycling of refrigerants will be fully realised after 1991. The first step towards making existing equipment more leak resistant will be completed.

1994

The need for CFC-12 for existing installations will be minimised by continuing efforts to make existing equipment more leak resistant and by retiring equipment with higher losses.

1995

The refrigerants necessary for filling up existing equipment will be provided entirely by reuse of recovered material. Careful management of the existing stocks of products and equipment is required since it is a way of reducing the consumption of newly produced CFCs. The reduction of consumption through reuse of CFCs from refrigeration systems is essential to reach the above mentioned reduction scheme for the refrigeration sector.

In cooperation with industry steps are being taken towards the establishment of a certification programme for refrigeration engineers. The aim is to introduce the programme in 1991.

In 1991 statutory regulations will come into force which oblige owners of refrigeration equipment to have these installed and maintained by certified installers. A certified installer will lose his certification if he does not work in accordance with certain technical regulations which among other things, provide for the recovering and recycling of refrigerants.

Also, for every refrigerating system all relevant information as to maintenance, tapping and filling up with refrigerant will have to be logged. These technical requirements are being developed by the industry with the support of the Institute of Environmental and Energy Technology of TNO (IMET-TNO).

The Organisation for the Education of Refrigeration Engineers (SKO) will undertake to translate the regulations into examination requirements for repairmen and installers of refrigeration equipment, and to organise refresher courses. The Metal Industry Training Organisation is responsible for organising SKO courses for refrigeration engineers, repairmen and senior staff.

The Dutch Association of Companies in the Field of Refrigeration and Air-Conditioning (NVKL) will draw up a plan aimed at informing the industry about the new regulations. The Ministry of Housing, Physical Planning and Environment will financially support this activity.

When called upon to repair these appliances, importers and suppliers of refrigerators and freezers for domestic use will recover the refrigerant and return it for recycling on a voluntary basis.

Under the auspices of the CFC committee, a joint working group of government and industry will be set up for the implementation of this programme for the refrigeration sector and to carry out supporting research and development activities.

Supporting R,D&D Programme

The Ministry of Housing, Physical Planning and Environment supports CFC phase out by funding various research, development and demonstration programmes. Topics include the following:

- feasibility of alternative refrigeration cycles;
- DME as an alternative refrigerant;
- CFC emission prevention in commercial refrigeration;
- consequences of HFC-134a use for evaporator design;
- recovery of CFC-12 from scrapped domestic refrigerators;
- knowledge transfer to industry;
- demonstration of HFC-134a applications.

IMET-TNO has been involved in many of these projects.

The government funds for the CFC phase out programme for the years 1991 through 1994, and the breakdown for 1991 are shown in Table 3.

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Table 3: Government Funds Allocated for CFC Phase Out; 1991-1994 (in million Dfl. [1 Dfl. is approximately US\$ 0.55]).

Year	Total in Million Dfl.	Topic	Breakdown 1991 Million Dfl.
1991	3	General activities	0.6
		Research in support of policy formulation	0.8
		Demonstration and research	0.6
		Infrastructure for recycling	0.5
		Improvements/replacements of refrigeration equipment and dry cleaning machines	0.5
1992	6		
1993	8		
1994	10		

Sorption Technology Heat Pumps

**S.I. Freedman, W.A. Ryan, C.E. French, and G.H. Myers*

Summary

The Gas Research Institute (GRI) is conducting a large development program on gas-fueled heat pumps for service in the residential and light commercial sectors. A previous paper¹⁾ described GRI and the research, development, and field test effort on the natural-gas-engine-driven systems. This paper describes the progress being made on the various sorption: absorption, adsorption, and chemi-sorption-based heat pump systems.

Introduction

One of the largest programs that GRI is conducting is that of the development of gas-fueled residential and commercial heat pumps, chillers, and year-round heating and cooling systems. The portion of the program dealing with sorption-based systems includes short-term projects concerned with new heat exchanger and burner design for the improved performance of commercial systems, the development of new systems, and applied basic research.

Sorption heat pumps all share the same well known cycle. Absorption systems operate on a continuous basis using a pump to achieve the pressure differential, while adsorption and chemi-sorption systems are batch processes that pressurize themselves while cycling.

Sorption heat pumps do not require high power-consuming mechanical compressors to compress the vapor from low to high pressure; consequently, they only require a minimum of mechanical power for liquid heat transfer fluid circulation, working liquid compression in the case of absorption systems, valve actuation, and the inevitable heat exchanger fan operation. Some sorption systems provide winter heating directly from the gas burner without heat pumping. These will be included here as they perform a space conditioning function similar to that of heat pumps, providing year-round space conditioning. When in the summer cooling mode, their operation is that of a thermodynamic heat pump. Commercialization of heat pump systems will result from the successful completion of these projects.

It is worthwhile calling attention to the fact that in the United States, a large amount of heat pump operating

time may be spent performing the air-conditioning function. Those units that do not have COPs over 1.0 during the winter are expected to cost less than those having the higher level of winter performance. In the United States, electricity costs are high in most areas during the summer in order to pay for the capital invested in those summer peaking power generation plants. The heat pump products aimed at lowering the cost of residential air-conditioning are expected to find market acceptance primarily in the United States, while those that have winter COPs greater than 1.0 are hoped to have markets in other IEA nations as well.

Terminated Development

Four years ago, the overall GRI heat pump program, including both sorption and engine-based systems, was described²⁾. At that time the GRI program included two sorption-based development projects in its program, the dual-cycle absorption and the double-effect absorption systems. The dual-cycle system consisted of a single-effect water-ammonia topping system that used the heat rejection of the topping cycle absorber to provide the heat for the LiBr water-solution bottoming cycle vapor generator. The system was composed of two complete absorption systems thermally coupled in a novel heat exchanger. The double-effect system used sodium thiocyanate-ammonia as the cycle fluid and resembled a double-effect water-ammonia system except for the absence of a vapor rectifier. Both of these systems were pursued to a point where preliminary system and component designs could be subjected to analyses to estimate manufacturing cost, installed cost, and operating economics.

Figure 1: The Current Dometic Production Unit.



Table 1: Status of Sorption Systems Development at GRI.

System	Working Pair	Developer	Status
Double-effect	NaSCN/NH ₃	Columbia Gas	Terminated
Dual-Cycle	H ₂ O/NH ₃ &LiBr/H ₂ O	Battelle Columbus Labs	Terminated
Adsorption	Carbon/NH ₃	Wave Air	Active
Adsorption	Zeolite/H ₂ O	Zeopower	Active
Improved Absorption (AHE Cycle)	H ₂ O/NH ₃	Dometic	Active
Chemi-sorption	Salt/NH ₃	Rocky Research	Active
Double Effect	LiBr/H ₂ O	Battelle Columbus Labs	Active
Regenerative	H ₂ O/NH ₃	RA Technology	Evaluation

The results of these analyses, were used to compare the heat pumps under development with both an electric heat pump and the combination of a typical gas furnace and electric air-conditioner.

Both the dual-cycle and the sodium thiocyanate-ammonia double-effect systems under investigation showed performance (heating and cooling COPs and capacity) reasonably close to that initially expected, but both showed manufacturing costs (at 50,000 units per year) believed to be too high to be attractive. These high manufacturing costs correlated with product weight. It is believed that the high cost was a major cause of the lack of interest of manufacturers in becoming involved in further technology and system development activities.

Current Development

The sorption systems (heat pump and year-round space conditioning) under development at GRI at this time are those listed in Table 1 as being active. These involve two different adsorption working pair systems, an improved absorption-heat exchanger (AHE) system, a double-effect lithium bromide system, and a chemi-sorption system.

The adsorption and chemi-sorption systems are solid-vapor systems and perform the cycling from condensation to evaporation on a batch basis by switching between static beds of the solid materials involved. In these systems, the only pumps involved are the heat transfer fluid circulation pumps. The improved ammonia absorption system has a modest pressure solution pumps. The solution pump for the lithium bromide system is of low pressure.

Absorption Systems

The technology improvement project with Dometic on the improved ammonia-water chiller will increase the COP to the point where the product is attractive in competition with other high COP systems. Operating costs for the unit will be decreased further by incorporating higher efficiency pumps and motors. It is expected that manufacturing cost increases will, at worst, be slight and may even decrease. It is to be noted that as the COP of a chiller increases, the size and cost of its heat rejection section decreases. The improved unit will be very similar in appearance to the current product shown in Figure 1.

The new double-effect LiBr-water system, developed by Battelle Columbus Labs, is an air-to-air air-conditioner with solution heating capability for winter use. The cooling COP is expected to be 1.0 at the ARI 95°F (35°C) condition when the unit reaches production. Heating efficiency will be in excess of 80 percent. The unit is intended as a competitive first-cost system for gas cooling and heating, based on known system chemistry, low pressure system pumps, and a generally low technical risk approach. Preliminary cost estimates indicate that in production, its manufacturing cost can be competitive with electric heat pumps. The new patented low NO_x burner may find other uses, both in new sorption systems and in general purpose applications. Individual components of the new design have been bench tested, and a complete system breadboard is currently being tested. Avoidance of salt crystallization is a concern. As the machine uses direct expansion of the refrigerant to cool the house air, the absorber is not at as low a temperature as is needed with water chiller systems. In the event of salt crystallization, the machine can redissolve the precipitate.

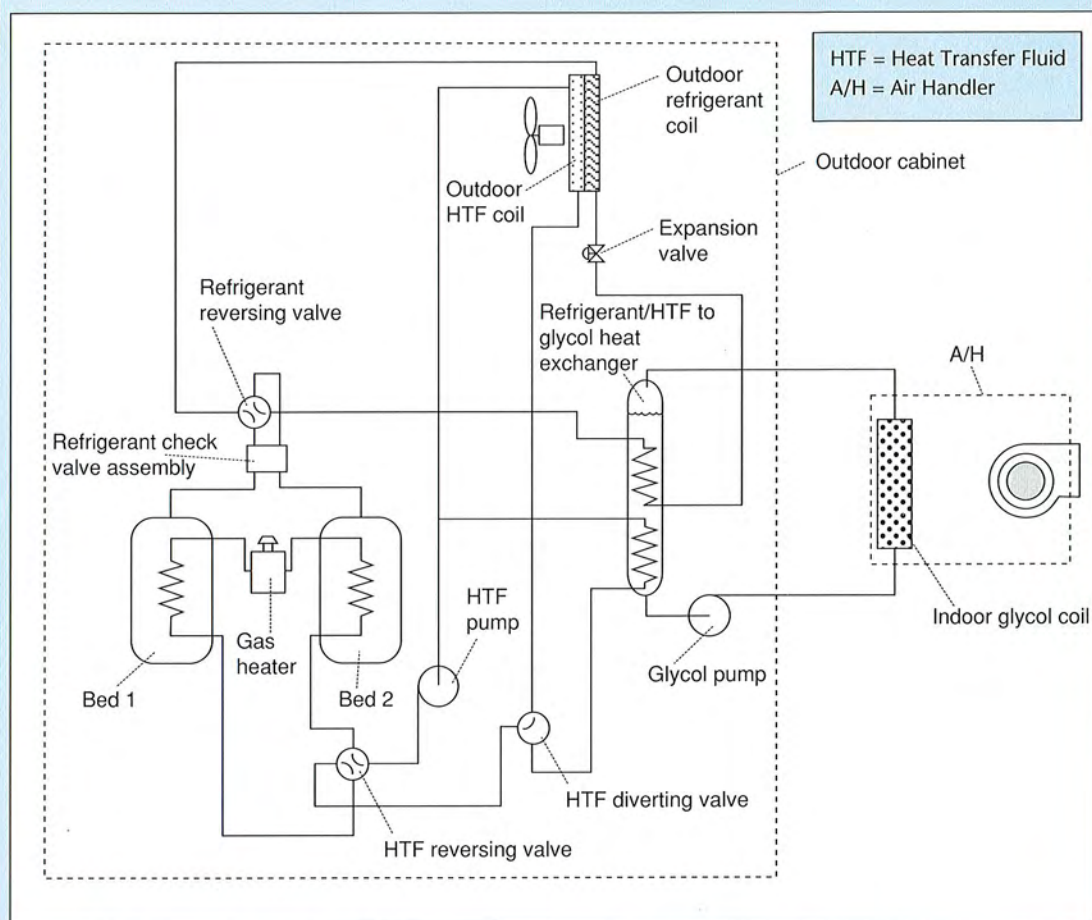


Figure 2: Adsorption Heat Pump Fluid Diagram (Wave - Air Corporation, Atlanta, Georgia, USA).

In addition to the work under way on an improved Dometic product, GRI is evaluating the regenerative cycle originally conceived at Lawrence Berkeley Laboratories (LBL). While the cycle shows the potential for operating in an air-conditioning mode with an ARI 95°F (35°C) day, COP of 1.1, questions remain as to whether such operation can be achieved with a simple, inexpensive regenerative heat exchanger and what the technical and economic issues to be faced in a practical system are.

Adsorption and Chemi-Sorption Systems

The Wave Air, Zeopower, and Rocky Research systems are in various early development phases. Their sorbent heat exchanger internal designs involve proprietary features. They are expected to be similar in size, or slightly larger than conventional (electric) heat pumps.

The refrigerant, bed heat transfer fluid, and air handler heat transfer fluid circuit diagram for the Wave air adsorption heat pump is shown in Figure 2.

Circuit diagrams for the other solid-vapor systems, the Zeopower adsorption and the Rocky Research chemi-sorption, have similar features. Refrigerant is evolved from one bed by heating it with fluid from the heater

located between the beds. The refrigerant is condensed and then expanded to provide cooling (in the air-conditioning mode) with the vapor returning to the other bed of solids where it bonds (by adsorption or chemi-sorption) to the solid with heat release.

The heat transfer fluid circuit shuttles heat between the beds with the fluid heater adding the differential temperature needed to drive the process. In the winter heating mode, the process is reversed; and the high pressure/high temperature refrigerant is used to provide heat for the air handler through its fluid loop, with throttled refrigerant picking up heat upon evaporation in the outdoor unit.

The key technical issue in the three solid-vapor systems is the heat transfer rate between the solid and the fluid in the internal heat exchanger. The two important material properties are sorption heat per unit volume of sorption material and the thermal conductivity of the sorption material. These material properties, along with the design of the sorption material heat exchanger, determine the temperature drop between the location in the sorption material where the phase change heating is occurring and where the heat appears in a fluid usable in a heating (or cooling) system. The research and development activities on these projects are directed towards two

objectives, increasing the thermal conductivity of the sorption material and designing a heat exchanger to minimize the sorption material-heat transfer fluid temperature drop while still being inexpensive and durable over the long time periods and large number of temperature (and pressure) cycles typical of heat pump service. The chemi-sorption work is currently in the laboratory stage of obtaining the P-T-X (Pressure-Temperature-Quality) data on the leading salt refrigerant combinations and beginning work in reactor-heat exchanger configuration concepts. Single-effect, double-effect, and cycles with new configurations are being evaluated for use with various salt-refrigerant combinations in chemi-sorption systems.

In a similar manner, the improvements in the single-effect ammonia absorption system all involve improved heat exchanger design. Efforts are under way to improve the burner-vapor generator heat transfer interaction in order to apply the heat exactly where in the generator it is most effective, to minimize flue losses, and to improve the internal heat transfer between streams at different temperatures within the cycle.

Conclusion

In summary, one can say that the key to all the sorption systems is being able to accomplish the required heat transfer interactions at competitive cost.

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Experiences from Air-Based Heat Pumps in Cold Districts

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Summary

Most of the small and medium-sized air-based heat pumps in Norway are equipped with air coolers with narrow fin spacing (1-3 mm) which require frequent defrosting. In the southern and western parts of the country where there is a mild coastal climate, these heat pumps perform well. There are some air-based heat pumps in colder parts of the country, on the other hand, that have not functioned satisfactorily. Experience shows that heat pump evaporators, which mainly operate at outdoor temperatures within the ranges of 0 to -10°C and in high relative humidity, require increased fin spacing compared to the standard units developed for the air-conditioning market.

Experiences Gained from Prototype and Demonstration Plants

SINTEF Refrigeration Engineering has been involved with prototype- and demonstration plants which have received grants during the last decade from the Norwegian government. Sixteen air-based heat pumps have been investigated, and half of these are standard units developed for the air-conditioning market. The characteristic feature of these heat pumps are finned tube air coolers with narrow fin spacing (1-2 mm), which require frequent defrosting.

Most of the standard units were installed during the period from 1983 to 1986 in greenhouses in the south-western part of Norway. The heat pumps, with condenser capacities from 20 to 60 kW, are in operation during the tomato growth season between February and October. During this period outdoor air temperatures are rarely below 0°C in this part of the country. This means favorable operating conditions, and the experience gained from these air-to-air heat pumps is very good.

However, one air-based heat pump which uses an air cooler with narrow fin spacing, has not performed satisfactorily. This air-to-water heat pump was installed in 1981 in Trondheim, mid-Norway. The heat pump operates with R22 as the working fluid. The heat pump was operating satisfactorily for about five years. However, during the last few years, there have been problems with refrigerant leaks every year. The first leaks were discovered on the high pressure side of the

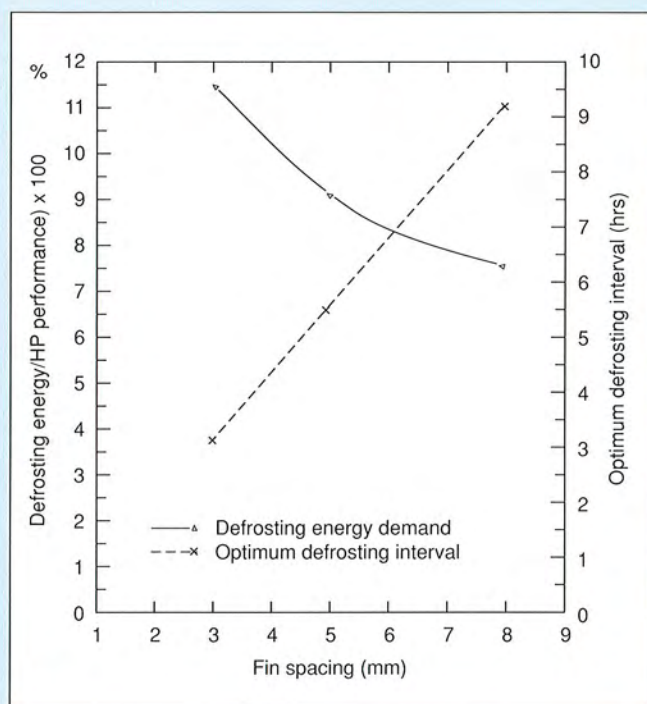


Figure 1: Defrosting Interval and Defrosting Energy Demand Versus Fin Spacing.

heat pump (pressure gauge, expansion valve for defrosting and hand stop valve). In 1989 a leak occurred due to a broken capillary tube, and finally, in 1990 a crack was discovered in a copper tube of the evaporator. It is not unlikely that this crack was caused by the rather severe operating conditions and the rapid defrosting which involve temperature changes in the material.

Experiences from larger heat pump installations (50-300 kW) show that evaporators mainly operating at outdoor temperatures in the range between 0 to -10°C, and high relative humidity (80-100%), should have increased fin spacing compared to the standard units developed for the air-conditioning market.

Evaporator Fin Spacing Influence on Defrosting Cycles

Compared to evaporators with small fin distance, concepts with increased fin spacing can be more effective as heat exchangers. The costs and space demand connected to larger fin distance must, however, be balanced by the corresponding lower running costs due to reduced energy demand for defrosting and more effective evaporators.

Practical experiments combined with system simulations have been carried out at SINTEF Refrigeration Engineering ¹⁾. This analysis shows that

the optimal defrost interval will increase approximately at the same rate as the fin spacing, see Figure 1. The additional energy demand for defrosting significantly increases as the fin spacing is reduced. Figure 1 shows results from the analysis which is valid for an outdoor temperature of 0°C and a relative humidity of 85%. If the fin spacing is increased from 3 to 8 mm the additional energy demand for defrosting is reduced from 12 to 7% of the total heat pump design performance.

The drop in heat pump performance due to the frost formation on the evaporators has to be taken into account when the nominal heat output for the installation is determined.

Depending on the fin spacing, the design capacity of the heat pump should be increased in accordance with the range indicated in Figure 1.

Economic evaluations must decide which fin distance should be chosen. From an "energy point of view" increased fin spacing is favorable, however, the investment combined with the running costs will have to determine the final choice.

Larger fin distances with correspondingly longer defrosting intervals may also reduce the risk of generating excessive material stress caused by frequent temperature changes in the evaporators.

Air-based Heat Pumps Designed for Cold Climate

In order to evaluate two different evaporator systems for air-based heat pumps, the Norwegian heat pump company, Aquaterm AS, has built two prototype heat pumps, both with fin spacings of 8 mm ²⁾.

At Gruben near the city of Mo i Rana, an air-to-water heat pump was installed in 1986. The heat pump has been in operation since spring 1987 and uses R22 as the working fluid. The heating capacity of the heat pump is 55 kW at -5°C outdoor air temperature and 45°C forward water temperature from the condenser.

The heat pump is equipped with a finned tube air cooler (evaporator). The tubes are connected to a liquid separator, and refrigerant circulation is by gravity (Figure 2). The evaporator is placed on the roof above the heat pump. For defrosting, the compressor is switched off, and liquid refrigerant is drained from the evaporator down to the condenser, where the cold refrigerant will evaporate, due to heat exchange with the heat distribution water. The refrigerant vapour will bypass the compressor and stream up to the evaporator, where it condenses and thereby melts the ice. The defrosting period is started by a timer, and is terminated by a temperature sensor placed at a fin at the bottom of the evaporator.

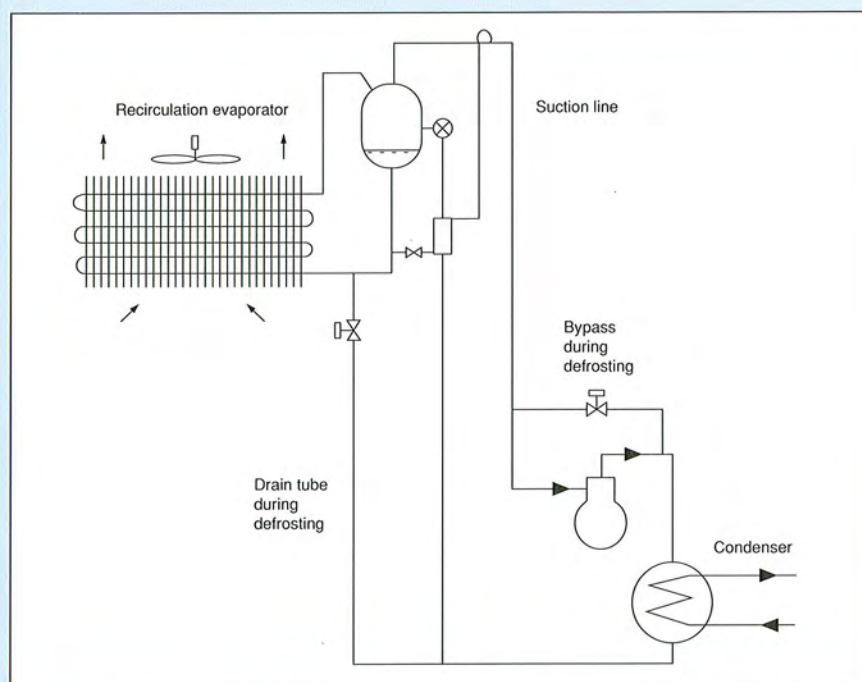
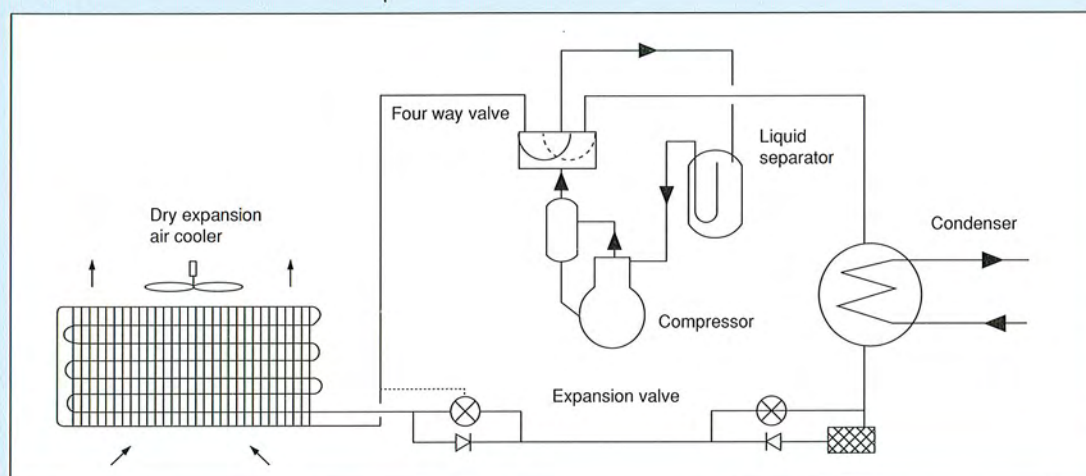


Figure 2: Air-to-water Heat Pump with Recirculation Evaporator.

The air-to-water heat pump has been in operation for about three years, and experiences gained are good, with the exception of some minor problems which were solved during the first year of operation.

The defrosting system is functioning satisfactorily, although defrosting normally takes about 15 minutes when defrosting occurs at six hourly intervals under the worst frost formation conditions. The self circulation defrosting system performs very efficiently producing up to 70 kW defrosting heat during the first couple of minutes or as long as there is ice on the tubes. As the defrosting heat has to be transported to the fins, the recirculation and production of defrosting heat decreases gradually until the defrosting cycle is

Figure 3: Air-to-water Heat Pump with Dry Expansion Cooler.



terminated after about ten minutes. Finally, it takes about five minutes to transport the liquid refrigerant back to the evaporator before the compressor starts again. Since the recirculation evaporator system is quite expensive, and the defrosting system requires the evaporator to be placed above the condenser, the heat pump manufacturer, Aquaterrm A/S in Molde, also offers a more conventional reversible air-based heat pump with dry expansion cooler, Figure 3. This heat pump system is equipped with a cheaper evaporator, but due to the suction line liquid separator and the four-way valve, the pressure losses in the suction line are considerably higher compared to those in the recirculation type system.

Conclusion

The reversible heat pump principle is well known as shown in millions of air-to-air heat pump installations in Japan and the USA. The main difference is that the Aquaterrm air-to-water heat pump is specifically designed for cold climates, by equipping the evaporator with a much wider fin spacing.

References

- 1) O.M. Nesje, B. Byggstøl: "The influence of the Evaporator Fin Spacing on Defrosting Cycles and Front Velocities in Electrically Driven Air-Based Heat Pumps". XVIIth International Congress of Refrigeration, Vienna, 1987.
- 2) G. Eggen, P.E. Frivik: "Medium-sized heat pumps for cold districts". 3rd IEA Heat Pump Conference, Tokyo, 1990.

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News and Views

Refrigerants/CFCs

CFC Information Database

An international online computerised database that provides information on CFC substitute processes, materials and technologies has been established by the Industry Co-operative for Ozone Layer Protection (ICOLP), Washington, D.C. It also contains information on legislation, government and industry contacts, conferences, and suppliers. OZONET is accessible over more than 90% of the world's business telephone lines in 750 cities and 35 countries. The Co-operative funds the database and users pay for the time used. ICOLP is a non-profit organisation created in 1988 to co-ordinate the global exchange of CFC information. Contact: David Bergman OZONET-Administrator, Lincoln Wood, Illinois, USA.

Tel.: +1-708-677-2850, Fax: +1-708-677-9570.

(Source: ASHRAE Journal, January, 1991 and ICOLP.)

Brayton Cycle Solvent Recovery Heat Pump

A project developing equipment to capture and recycle volatile organic compounds (VOCs) and chlorofluorocarbons (CFCs) that result from industrial solvent applications is sponsored by the US Department of Energy's Office of Industrial Technologies in cooperation with the 3M Company and Nucon International. The recovery of VOCs is by a reverse Brayton Cycle. In principle, the main components are a turbo-compressor/expander unit, a

regenerator (low temperature chiller), and an electric motor-driven vacuum pump. The solvent laden gas stream is first dehumidified and cooled in the regenerator to a temperature at which a majority of the solvents condense (e.g. most solvent streams can be cooled to -45°C to condense more than 90% of the solvent). After cooling in the regenerator the temperature in the gas is lowered further by expansion in the expander to sub-atmospheric pressures. At this stage essentially all of the solvents are condensed. The cleaned gas is passed through the other side of the regenerator to recoup the heat, and then compressed back to atmospheric pressure with the vacuum pump and the turbo-compressor. The recovered solvent is fed back to the solvent using process (see Figure 1).

Two units are operational: the first unit is a 17,000 m^3/hour solvent laden air (SLA) system at a 3M Company magnetic disc plant in which activated carbon beds capture the VOC emissions. A Brayton system with inert nitrogen regenerates the adsorbers, and then the Brayton system condenses the solvents. The second unit is a 5,100 m^3/hour SLA system using the Brayton system to directly condense solvents from an SLA stream being discharged from a Pfizer Pharmaceutical plant that was designed and fabricated by Nucon International.

Two development projects supported by the US DOE are underway: the first project with 3M involves an advanced 13,600 m^3/hour Brayton system to be installed at a 3M adhesive tape plant. The second project with Nucon International involves a mobile Brayton regeneration system to service many dispersed adsorption concentrators at many different industrial sites in Los Angeles, California.

For further information contact: Paul E. Scheihing, Program Manager, Office of Industrial Technologies, CE-211, US DOE, 1000 Independence Ave., S.W., Washington DC 20585, USA; Tel.: +1-202-586-7234.

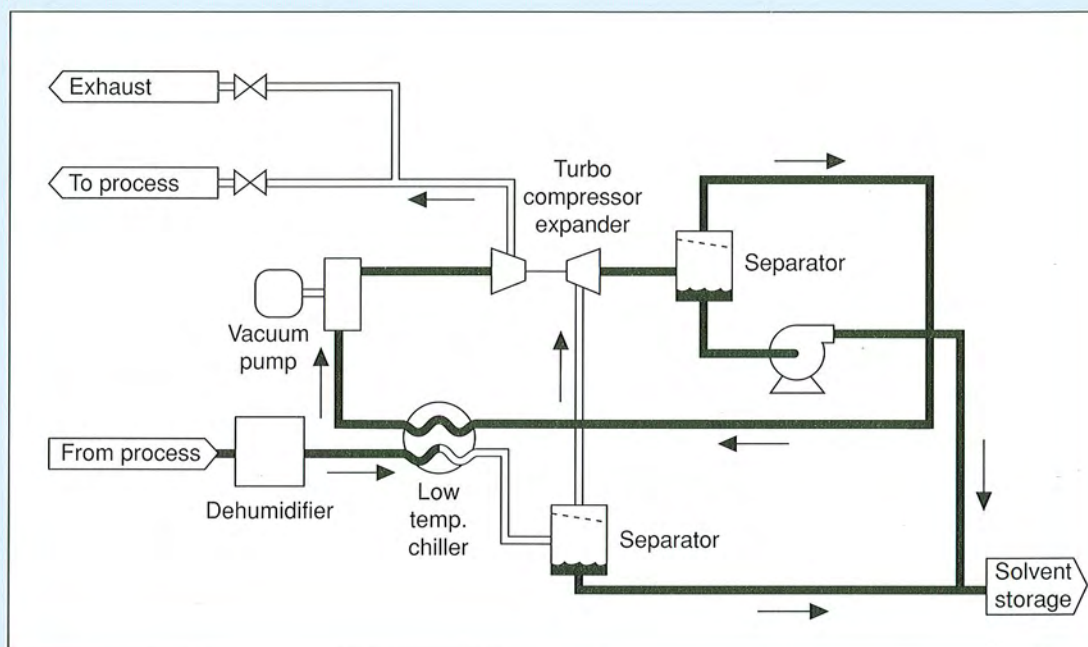


Figure 1: Braycycle Solvent Recovery Schematic Diagram.

IIR Informatory Note Emphasises Ammonia

In its 6th Informatory Note on CFCs and Refrigeration, the IIR states that, "of the many processes and systems being considered, there is one that merits careful attention: namely the more extensive use of ammonia compression machines". The note ends with the IIR highly recommending that world decision-makers request national laboratories and industrial companies to develop new ammonia refrigeration systems so that the operating range of these units can be extended with assurance of safety and financial profitability.

(Source: IIR 6th Informatory Note on CFCs and Refrigeration, November 1990.)

Encapsulated Ammonia Refrigeration Installation

The German firm Aero Tech of Frankfurt, in cooperation with other parties in Germany, has developed a concept for a compact ammonia refrigeration installation with hermetically closed containment. In case of a leak the total ammonia content is retained within the containment and absorbed in a fluid, e.g., water or glycol. Any release to the ambient, in case of a large spill, is via a safety system and remains below the smelling threshold of 20 ppm. This would also open the way to deploying this technique in buildings with unrestricted access to the general public, industry, and commercial cooling where, up till now, the use of ammonia was excluded. Application is possible for capacities between 10 and 1000 kW or larger. High energy efficiency and low ammonia inventory of the installation are additional development aims. The research project will be completed and ready for production at the latest in 1993. The project is being carried out within the framework of the research programme of the German Refrigeration and A/C Association (DKV) and supported by the Ministry of Research and Technology (BMFT). Project Leader is H.G. Schmidt of Aero Tech, Fax: +49-69-4091431.

(Source: HLH, April 1991 and Aero Tech.)

Refrigerant 134a to be Tested in Heat Pumps in Sweden

A full scale test with 134a will be carried out by Stockholm Energi AB together with ASEA-Brown Boveri Stal AB in an existing 25 MW heat pump unit in the plant Hammarby in Stockholm. The heat pump is equipped with a turbo compressor. The compressor rotor and the material in some of the seals must be changed.

Another test and demonstration project is planned by Lomma Energiverk together with STAL Refrigeration AB. 134a shall be tested in two 940 kW heat pump units with screw compressors. Previously this application was considered not to be possible due to the oil problems but these are now hopefully solved. The efficiency and the capacity of the heat pumps under various conditions shall be measured and some material tests are planned.

In the first case, the test runs begin during the spring 1991 and are planned to be finished before the end of 1992. The testing of the screw compressors is estimated to start in the autumn of 1991.

The costs of the project with turbo compressors are calculated to be 12.5 MSEK (approx. US\$ 2.2 million). The costs of reduced heat production and special risks are not included.

(Source: Swedish National Team.)

Prices for R123 and R134a

Du Pont has made the first new refrigerants commercially available under the trade name 'Suva'. Suva-123, which now costs US\$ 5 to 6 per pound (lb), will replace R11 which costs around US\$ 2.20 per lb. Due to CFC taxes for R11 and lower production costs for the alternative, their prices should cross in 1993. Prices should cross in 1995 for Suva-134a (US\$ 10/lb) and CFC-12 (US\$ 2.40/lb). Du Pont is currently developing alternative blends for R22, R124 and R152a.

(Source: The Air-Conditioning Heating and Refrigeration NEWS, February 11, 1991.)

Market News

HVAC Market Overview 1990

Japan

Figures apply to ref. year 1990, covering the period October 1989 through September 1990.

Room Air-Conditioners (small household split / window types)

Production increased by 4.7% to 6,701,000 units, and shipments went up 13.7% to 7,258,000 units. Of these shipments, 62% were heat pump types. Based on the shipment figures for the months October - December 1990 (60% increase), a growth of 5 - 10% is expected for the room air-conditioner market in ref. year 1991.

Packaged Air-Conditioners (all A/Cs other than room A/Cs)

Production in ref. year 1990 increased by 17.5% to 1,066,000 units. Shipments increased by 20.6% to 1,081,000 units. Heat pump types represent 66.4% of shipments.

Multi-systems for buildings have diffused rapidly in recent years. Systems of about 50 RT, combining 8 indoor units to one outdoor unit, have become available thanks to advanced control means, thus covering A/C demand in medium-size buildings.

Table 1 shows the statistics for room and packaged A/C in thousand units.

Table 1: A/C Shipments in Japan in Thousand Units.

Year	Room A/C		Packaged A/C
	Small household split type	Window type	
1985	3,422	1,559	562
1986	3,758	1,315	563
1987	3,914	1,284	632
1988	5,073	1,109	742
1989	5,356	1,028	896
1990	6,197	1,061	1,081

(Source: Compiled from JARN, January 25, 1991.)

Sweden

Table 2 shows the number of heat pumps sold as reported by SVEP, the Swedish Association of Heat Pump Manufacturers and Deliverers, with, in total 29 member companies, and approved by the authorities as official statistics. As can be seen heat pump sales doubled compared to 1989.

Table 2: Units of Heat Pumps sold in Sweden.

Year	Ambient air/ exhaust air	Ground coupled/ other water-water	Total
<1985	55,010	45,399	100,409
1985	13,127	5,818	18,945
1986	7,756	2,116	9,872
1987	8,160	1,524	9,684
1988	9,554	974	10,528
1989	11,897	1,096	12,993
1990	23,428	2,279	25,707
Total	128,932	59,206	188,138

(Source: Swedish National Team.)

Canada

Commercial A/C shipments declined from 11,125 in the 4th quarter of 1989 to 8,522 in the 4th quarter of 1990, a decrease of 23%. Year-to-date shipments dropped 18% from 42,117 in 1989 to 34,406 in 1990.

Residential A/C shipments dropped from 11,789 in the 4th quarter of 1989 to 8,639 in the 4th quarter of 1990, a decrease of 27%. Year-to-date shipments dropped sharply from 242,037 in 1989 to 129,774, a decrease of 47%.

'Residential A/C' means split A/C and heat pumps up to 5 tons; 'commercial A/C' means rooftops (combination heat/cool), packaged cooling and packaged heat pumps. No breakdown is given to differentiate between heat pumps and non-heat pump A/C.

(Source: Canadian National Team/News Release of the Heating, Refrigeration and Air-Conditioning Institute of Canada, March 4, 1991.)

USA

In 1990 shipments of air-to-air heat pumps declined 3.2% to 808,655 units and of water-source heat pumps 15% to 117,900 units. The decline is due to a decline of new home and building starts, a downturn in the economy and, especially, in consumer confidence aggravated by the war with Iraq, a situation which could not be balanced by the growing replacement market. Table 3 shows the statistics of unit shipments.

With respect to air-to-air heat pumps the forecast for 1991 is that growing replacements of cooling-only units with heat pumps will not be able to overcome early field inventory (at the factory and at distributors) completely. Shipments will be down 5% to 770,000 units. There are indications that 1991 will be the bottom of the new home starts cycle.

Table 3: Heat Pump Shipments in the USA .

Year	Air-to-air heat pumps	Water (ground)-source heat pumps
1985	820,623	135,200
1986	884,203	147,200
1987	918,432	138,500
1988	834,606	126,100
1989	835,424	138,700
1990	808,655	117,900

(Source: The Air-Conditioning, Heating and Refrigeration NEWS, April 1, 1990.)

Japanese Long-range Forecast

The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) has made a demand forecast for the period 1991-2000. Table 4 shows the numbers for small size, and medium and large size A/C's.

Table 4: Predicted Shipment Quantities in Thousand Units.

	1990 (result)	1995 (predicted)	2000 (predicted)	annual* average growth %
Small-size A/C				
domestic	5,932	7,062	8,786	3.5 - 4.5
export	1,339	1,000	1,000	-6.5 - 0.0
Medium-/large size A/C				
domestic	930	1,256	1,716	6.2 - 6.4
export	175	257	401	8.0 - 9.3

* Though not explicitly stated in the source, the first figure appears to apply to the period 1990-1995, the second figure to 1995-2000.

In 2000, shipments for small size A/Cs would amount to 1,130,580 million Yen (note HPC: approx. US\$ 8.4 billion) and for medium/large size A/C's to 757,177 million Yen (approx. US\$ 5.6 billion).

(Source JARN, March 25, 1991.)

US\$1.9 Million Ground-source Heating/Cooling/Heat Storage Plant

In Lincoln, Nebraska, USA three city- and county-owned buildings totalling 37,160 m² will be heated and cooled by a plant employing two Vilter Corp., Milwaukee compressors with a cooling capacity of 270 tons (948 kWth) each. The plant incorporates a 4,800 ton-hour (16,850 kWth) thermal storage capacity using three tanks for load levelling purposes. Plant capacity, which will be augmented by two existing centrifugal chillers totalling 550 ton (1930 kWth) and two gas-fired steam boilers totalling 400 horsepower (3,956 kWth), has been oversized with the view of supplying private customers in the future. Ammonia was chosen as the refrigerant for the Vilter compressors because of superior thermodynamic properties and low cost; and to avoid CFC phase out problems. The plant will use 55°F (13 °C) ground water stored in a sandstone aquifer with two 60 m vertical wells. From one well, 13 °C water will be taken to cool supply water in the summer and intermediate months by means of a titanium plate heat exchanger. Heat from the return water will be injected into the second well at around 75°F (24 °C). It is hoped that, in this way, around 18 to 21 °C water can be obtained for heat pump use during the heating season. During the summer, the Vilter compressors will make ice from 8 pm to 8 am. From 8 am to 4 pm they operate in conjunction with the existing chillers; and from 4 pm to 8 pm, the peak load hours, all compressors will shut off, and the ice will be melted to meet the cooling load. Payback on the new plant, to be completed mid 1991, should be approximately 5.6 years. Designer is the Omaha engineering firm of Dana, Larson, Roubal and Associates.

(Source: Energy Users News January 1991.)

New Heat Pump Purchasing Incentives in the Netherlands and Canada

As of January 1, 1991, heat pumps qualify for a grant of 25% of the investment in the Netherlands. The grant applies to all types of heat pumps and application areas, and is limited to Dfl. 300,000 (approximately US\$ 160,000) per installation. The scheme is managed by the Ministry of Economic Affairs. Excluded are heat pumps using Ozone layer depleting CFCs (Source 1).

Rebates given by the Canadian utility, Ontario Hydro, are CAN\$ 2,000 (approx. US\$ 1,700) or alternatively CAN\$ 1,000 plus a below prime rate loan for ground-source heat pumps; CAN\$ 1,000 or CAN\$ 500 plus a below prime rate loan for bivalent (dual fuel) heat pumps; CAN\$ 500 or a below prime rate loan for air-source heat pumps. The incentives apply to qualifying heat pumps for both existing homes using electrical resistance heating and new homes in areas not served by natural gas. Units must be installed by dealers who meet Ontario Hydro's standards (Source 2).

(Sources: 1. Grand Scheme Energy Saving and Renewable Energy 1991; Source 2. EPRI Heat Pump News Exchange Vol. 2 No. 4, winter 1990/1991.)

Environment

Taxes on CO₂ Emission on the Way in the European Community

The Commission of the European Community (EC) is in the process of drawing up a basis for decision-making as regards a future CO₂ tax. Regulations already exist for the emission of sulphur and NOx from large power stations above 50 MW. Regulations for small plants are on the way. The objective is to reach agreement on CO₂ tax before the World Environment Conference in 1992.

(Source: Scan-Energy (EC), 1991 No. 1.)

IEA

Announcement IEA HPC/Canadian National Team Workshop on Ground-Source Heat Pumps

A joint international workshop on Ground-Source Heat Pumps - Advancements toward Cost Reduction, will be held on 12 and the morning of 13 of August, 1991 in Montreal, Quebec, Canada. Preparation of the workshop is by Caneta Research Inc. The preliminary programme includes the following topics: New anti-freeze fluids; Direct-expansion systems; Ground-coil installation techniques and materials; Advanced heat exchangers; Improvements in the heat pump; Improved design and heat exchanger sizing methods.

Contact: IEA HPC.

Analysis "Impact of Heat Pumps on the Greenhouse Effect" contracted with ARGE-Wärmetechnik

IEA HPC contracted the above mentioned project with "Arbeitsgemeinschaft-Wärmetechnik" (Co-operative for Heat Technology), Graz, Austria. The Head is Prof. P.V. Gilli, and the Project Leader is Mr. H. Halozan. The project consists of a survey of available studies; and an analysis to determine the state-of-the-art of international knowledge on the subject, identify possible gaps in knowledge and possibilities to close such gaps. The project is scheduled to be completed by mid-November, 1991.

Heat Pump Promotion Activities of National Teams in Japan and the Netherlands

A training course on energy management was held between January 27 to February 16, 1991 in Tokyo by the Asian Productivity Organization and the Ministry of International Trade and Industry of Japan. The programme aimed to provide opportunities to observe energy management practices in Japan and to learn new technologies being developed for energy conservation. Nineteen people from thirteen Asian countries participated, most of them governmental specialists in energy management. As part of the programme the Heat Pump Technology Center of Japan (HPTCJ) lectured on heat pump technology in Japan, of which the Super Heat Pump R&D project, in particular, seemed to raise the interest of participants. The large heat pump-based District Heating and Cooling Plant of Hakozaiki was visited (see Newsletter Vol. 8 No. 4).

The Netherlands National Team together with Novem, on May 22 and 23, 1991 will be organising a Workshop on the future of heat pumps in the Netherlands. The first day is devoted to the use of heat pumps in industry; the residential and commercial sectors are addressed on the second day. The Workshop is designed to provide input data for the new policy regarding heat pumps which the Ministry of Economic Affairs intends to formulate.

Italian National Team Being Formed

Italy, whose participation in the IEA Heat Pump Centre collaboration was not definite up till now, has decided to partake and establish a National Team. The Italian National Team will be coordinated by ENEA who will also be the contact organisation with respect to the IEA HPC (contact: Dr. P. Coda). ENEA is established in Casaccia near Rome. Italy is a country with a fast developing space conditioning market. A first meeting between the Italian National Team, the IEA HPC and the Chairman of the Executive Committee took place on March 20, 1991.

International Contacts Sought

1. Collaboration within Euro-environ Context

Euro-environ is an initiative to stimulate international collaboration in the field of environmental technology. Within this context collaboration is sought for the following projects:

- **Solar heating and hot water supply using seasonal storage and heat pumps for small and medium-sized buildings.**

The proposed system consists of roof-mounted or wall-mounted solar collectors delivering their heat to an underground seasonal storage tank outside the building. During the summer heat is used directly from the tank. During the winter a heat pump utilises the remaining heat from the storage tank. Domestic or industrial waste heat can

be integrated into the system. The proposed system is intended mainly for use in urban areas where no room is available for ground coils or heating wells. The project consists of: a project study to determine the best layout and components; a simulation study; and a fully instrumented pilot project. Scientific and technical work will be carried out by EN-SOLAR.

Technical and financial cooperation is requested from manufacturers of solar collectors, compression and absorption heat pumps, stirling motors, heat exchangers and underground storage tanks.

Contact: Dr. Peter Case, EN-SOLAR, P.O. Box 57, Könizstrasse 25, CH-3000 Bern 21, Switzerland; Tel.: +41-31-263568; Fax: +41-31-262671.

- **Variable-capacity heat pump for windpower applications**

The purpose is to use the variable windturbine shaft work to drive a heat pump which abstracts thermal energy from the wind itself. A binary working fluid is used whose composition is varied in response to power availability. A 3.3 kWe, 10 kWth pilot plant has been built and operated using an electrical variable speed drive. The project involves development, construction and operation of a wind-driven prototype. The system is intended for desalination, drying processes, greenhouse heating, refrigeration, and A/C.

Collaboration and financial support is sought from wind turbine manufacturers, whose ultimate interest would be in marketing a package. Compressor manufacturers may wish to collaborate on load-matching for which development work has been carried out at Edinburgh University.

Contact: Dr. C.L. Pritchard, University of Edinburgh, Department of Chemical Engineering, King's Buildings, Edinburgh EH9 3JL, Scotland; Tel.: +44-31-667-1081, ext. 3358; Fax: +44-31-667-9238.

(Source: Eureka Secretariat, the Netherlands.)

2. Contact sought for manufacturing window-type heat pumps in India

Mr Chaudhuri of Urja Energy Journal in India is searching for contacts with firms interested in manufacturing window-type heat pumps in India (using their technology on an equity sharing basis). Contact: Mr Dipak Basu Chaudhuri, Urja Energy Journal, P.O. Box 3008, G-82 Sujana Singh Park, New Delhi - 110 003, India. Tel. and fax.: +91-11-611-536.



Bibliography

Codes/Guidelines

New British Standard

English

BS 7326: Specification for Rating and Performance of Heat Pumps with Electrically-Driven Compressors, part 1, 1990, Terms, Definitions and Designations: Price £ 10.20. Available from BSI Sales at Linford Wood, Milton Keynes, MK14 6LE, UK.

Systems/Installations

Stirling and Vuilleumier Heat Pumps: Design and Application

J. Wurm, J.A. Kinast, T.R. Roose, W.R. Staats, ISBN 0-07-053567-1 (English).

The book (252 pages) treats the design, application, and performance evaluation of integrated engine-refrigerator heat pumps. It contains a comparative analysis of six integrated Stirling and Vuilleumier heat pumps and their advantages in various applications; an overview of heat pump theory and Stirling heat pump performance analysis and component arrangements; in depth evaluation of the effect of key components on performance; listings and documentation of computer programs; a summary of current hardware development programmes. Publisher: McGraw-Hill, Inc., 1221 Avenue of the Americas, New York, NY 10020, USA.

Proceedings of the Third Workshop on Solar Assisted Heat Pumps with Ground-Coupled Storage

Editor: Jan-Olof Dalenbäck, 335 (English)

The workshop was held at Chalmers University of Technology in January 1989. It covered the following sections: components-analysis and performance; system analysis; system performance; national overviews (Sweden and Austria); and a computer workshop concerning an expert system prototype, and the simulation program MINSUN, developed within the IEA Solar Heating and Cooling Programme. Available from: GIT-ETA, Energiteknisk Analys Chalmers Industriteknik No. 1990: 3. Tel.: +46-31-721-145; Fax.: +46-31-721-152.

Geothermal Ground-loop Preinstallation Project at Walden Pond

EPRI, CU-6969, (English)

A new report describing mass installation of geothermal ground loops before home construction at the Walden Pond subdivision in Carmel, Indiana (see Newsletter Vol. 8 No. 2, p. 27) is now available. It details the role of project participants and provides information on system design, specifications and installation. Copies of the report can be obtained from EPRI Research Reports Center; Tel.: +1-415-965-4081.

ARI/ASHRAE

ARI Research Plan

revised 19 December, 1990 (English)

The updated ARI Research Plan identifies research programmes recommended by the air-conditioning and refrigeration industry, with primary focus on refrigerants, energy conservation, and building environment. The main objective is to encourage and guide research. Appendixes are: a specific plan for materials compatibility and lubricant research; a series of charts to show the status of alternative refrigerants and projections for their commercialisation; elaborations for selected research recommendations including objectives, rationale, suggested approaches, and estimated or recommended budgets and time required. Contact: Research and Technology Department, Air-Conditioning and Refrigeration Institute, 1501 Wilson Boulevard, Sixth floor, Arlington, VA 22209-2403, USA; Tel.: +1-703-524-8800, Fax: +1-703-528-3816.

New ASHRAE Publications

A sample compiled from the ASHRAE 1991 catalogue. Order from ASHRAE, 1791 Tullie Circle, NE, Atlanta, GA 30329, USA; Tel.: +1-404-636-8400; Fax: +1-404-321-5478. Quoted prices are for non-ASHRAE members. (English)

Standard 90.1.1989, Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings Applies to: building envelope; energy distribution; systems and equipment for auxiliaries; heating; ventilation; A/C; service water heating; lighting and energy management. Includes 2 software programs for Envelope System Performance, and Lighting Prescriptive and System Performance. Codes: 5 1/4 disk 86237; 3 1/2 disk 86238. Price US\$ 98.

Guideline 1-1989

Commissioning of HVAC Systems Code 86801. Price US\$ 30.

1990 Winter Meeting - Atlanta, GA

ASHRAE Transactions 1990, Vol. 96, Part 1 Code 82902. Price US\$ 170.

1990 Annual Meeting - St. Louis, MO.
ASHRAE Transactions 1990, Vol. 95, Part 2
Code 82892. Price US\$ 170.

An Annotated Guide to Models and Algorithms for Energy Calculations Relating to HVAC Equipment
Guide to literature. Aimed primarily at engineers who wish to develop their own simulation programs for analysing energy uses for all types of buildings.
Code: 90332. Price US\$ 45.

Marketing

Residential Heat Pump Marketing Guidebook

Electrical Power Research Institute (EPRI), prepared by Synergic Resources Corporation, Bala Cynwyd, Pennsylvania; EPRI CU-7106, Project 2417-9, December 1990; 200 pages (English).

The objective of the book is to guide utility staff in formulating, conducting, and evaluating residential heat pump marketing programmes. The book provides detailed information on how to develop, implement, and evaluate an effective residential heat pump marketing programme. It also presents a perspective on the heat pump market, a review on the customer decision-making process, and a brief overview of heat pump technology.

Refrigerant/CFCs

Series of Articles About Ammonia

1. **Forum: Ammonia as an alternative refrigerant**
R.A. Cole, R.S. Ohling, S.M. Miner; ASHRAE Journal December, 1990, pp. 27-44 (English).
In three articles, the authors discuss ammonia's advantages, disadvantages and potential new applications based on their years of experience with this refrigerant. The articles give a good overview of the pros and cons of the use of ammonia.
2. **The "Luft und Kältetechnik" Magazine**
Vol. 27 (1991), No. 1, pp.3-4 (German) contains four articles about ammonia.
 - NH₃ as a refrigerant - a new chance by D. Otto, Institute for Air and Refrigeration Technique, (ILKA) Dresden;
 - Components of Ammonia refrigeration installations and their specific construction by H. Dölz, ILKA;
 - Experience with NH₃ as a refrigerant, W. Jensen, Consultant;
 - Safety consideration of ammonia refrigeration installations from a chemical point of view, G. Pätz, ILKA.

Environment

Proceedings of Seminar 'Heat Pumps for Reduction of CO₂ Emissions'

(German)

Held in Mainz, Fed. Rep of Germany, October 17, 1990. Twenty experts from different fields discussed the importance of heat pumps with the objective to obtain as broad as possible a consensus on heat pumps as a technology for energy saving and hence for reduction of CO₂ emissions.

Available as report No. IZW 1/91 from Informationszentrum Wärmepumpen und Kältetechnik (IZW), Fachinformationszentrum Karlsruhe GmbH, 7514 Eggenstein-Leopoldshafen 2, FRG;
Tel.: +49-7247-808351; Fax: +49-7247-808666.

IEA

Basic Heat Pump Technology

NTF-Sintef, approx. 185 pages, (Norwegian)

In Norway a government funded four year (1989 - 1992) promotional and educational programme for a broader application of heat pumps is underway. The above book, made available by the Norwegian National Team, is used as educational material in course activities. It contains the following chapters: basic thermodynamics; heat pumps - important conditions; main components; heat sources and heat extraction systems; fields of application; cost analyses/ economic requirements.

A second book 'Heat Pumps for Space heating' is expected to be available soon. Contact the HPC.

Directories

Japan HVAC & R Directory 1991

(English and statistical information also in German, French and Spanish). Approx. 115 pages.

The 1991 edition has been published listing companies and association names, telephone and facsimile numbers, addresses and services as well as the latest industrial statistics.

Price: surface mail US\$ 30; airmail US\$ 34 to US\$ 36, depending on destination. Order from: JARN Ltd. International Sales and Marketing Division, Hosokawa Building, 1-16 Akasaka 1-chome, Minato-ku, Tokyo 107, Japan.



Conferences

*Call for papers

Course CFC Alternatives for Refrigeration - Status and Outlook

July 7-10, 1991/Davos (Switzerland).

This course is supported by the IEA HPC and will be lectured by five internationally recognised experts - D. Didion, J. Horvay, H. Kruse, W. Stoecker and H. Spauschus. Registration is limited to 60 participants. Course fee US\$ 600.

Contact: Ann Spauschus, Spauschus Associates Inc., Atlanta Technology Center/Suite 410, 1575 Northside Drive, N.W., Atlanta, GA 30318, USA.
Tel.: +1-404-351-3180,
Fax: +1-404-351-3226 or the IEA HPC direct.

XVIII Congress of the IIR : New Challenges in Refrigeration

August 10-17, 1991/Montreal (Canada)

Contact: Coordinator Steve Bettner. XVIIIth International Congress of Refrigeration, 3600 Casavant Boulevard West, St. Hyacinthe, Quebec, Canada, J2S 8E3
Tel.: +1-514-773-1105, Fax: +1-514-773-8461.

Building Simulation '91-2nd World Congress on Technology improving the Energy Use, Comfort and Economics of Buildings Worldwide

August 20-22, 1991/Sophia-Antipolis, Nice (France)
Contact: SCSi c/o Philippe Geril, Coupure Links 653, B-9000 Gent, Belgium. Tel. and Fax: +32-91-234941.

12th AIVC Conference: Air Movement and Ventilation Control within Buildings

September 24-27, 1991/ Ottawa (Canada)
Contact: IEA Air Infiltration and Ventilation Centre, University of Warwick Science Park, Barclays Venture Centre, Sir William Lyons Road, Coventry CV4 7EZ, Great Britain,
Tel: +44-203-692-050, Fax: +44-203-416-306.

Absorption Heat Pump Conference 1991

September 30 - October 2, 1991/Tokyo (Japan)
Organised by Japanese Association of Refrigeration and others. Contact: Absorption Heat Pump Conference 1991, Conf. Secretariat, Ms. Y. Miyazawa, Japanese Association of Refrigeration, San-ei Building, 8 San-ei-cho, Shinjuku-ku, Tokyo 160, Japan.
Tel.: +81-33-359-5231, Fax: +81-33-359-5233.

Post conference site visits, among others to largest district heating centre in the world.

Symposium Ground-coupled Heat Pumps in Europe

October 7-9, 1991/Giessen (Fed. Rep. of Germany)

Symposium language is German.

Contact: Institute for Applied Geo-sciences of the Justus-Liebig University, B. Sanner
Diezstrasse 15, D-6300 Giessen, Germany
Tel.: +49-641-702-8244, Fax: +49-641-702-4711

Meeting Customer Needs with Heat Pumps

October 15-18, 1991/Dallas, Texas (USA)

Conference and exhibition. Contact: Pam Turner, EPRI Conference and Travel

Tel.: +1-415-855-2010 or David P. Ross, Policy Research Associates, Inc., Tel.: +1-703-620-1008.

14th World Energy Engineering Congress

October 23-25, 1991/Atlanta, Georgia (USA)

Besides many non HVAC subjects, the congress also addresses the subjects HVAC system optimisation and thermal energy storage. Contact: Association of Energy Engineers, 4025 Pleasantdale Road, Suite 420, Atlanta, GA 30340, USA.

Tel.: +1-404-447-5083, Fax: +1-404-446-3969.

1991 ASHRAE Far East Conference

November 5-8, 1991/Hong Kong

Contact: ASHRAE Meetings Section, 1791 Tullie Circle NE, Atlanta, GA 30329, USA
Tel.: +1-404-636-8400, Fax: +1-404-321-5478.

1991 ASME Winter Annual Meeting, Symposium on Heat Pump Design, Analysis and Application

December 1-6, 1991/Atlanta, Georgia (USA)

Contact: Keith E. Herold, Department of Mechanical Engineering, University of Maryland, College Park, MD, 20742, USA
Tel.: +1-301-405-5268, Fax: +1-301-314-9477.

*1992 International Gas Research Conference

November 16-19, 1992 / Orlando, Florida (USA)

Conference will include papers on: space heating, cooling and dehumidification, heat recovery, and heat pumps. Contact: Gas Research Institute, Dan A. Dolenc, 8600 West Bryn Mawr Avenue, Chicago, Illinois 60631, USA.

Tel.: +1-312-399-8226;

Fax: +1-312-399-8170

Deadline for submission of summaries: July 31, 1991.

