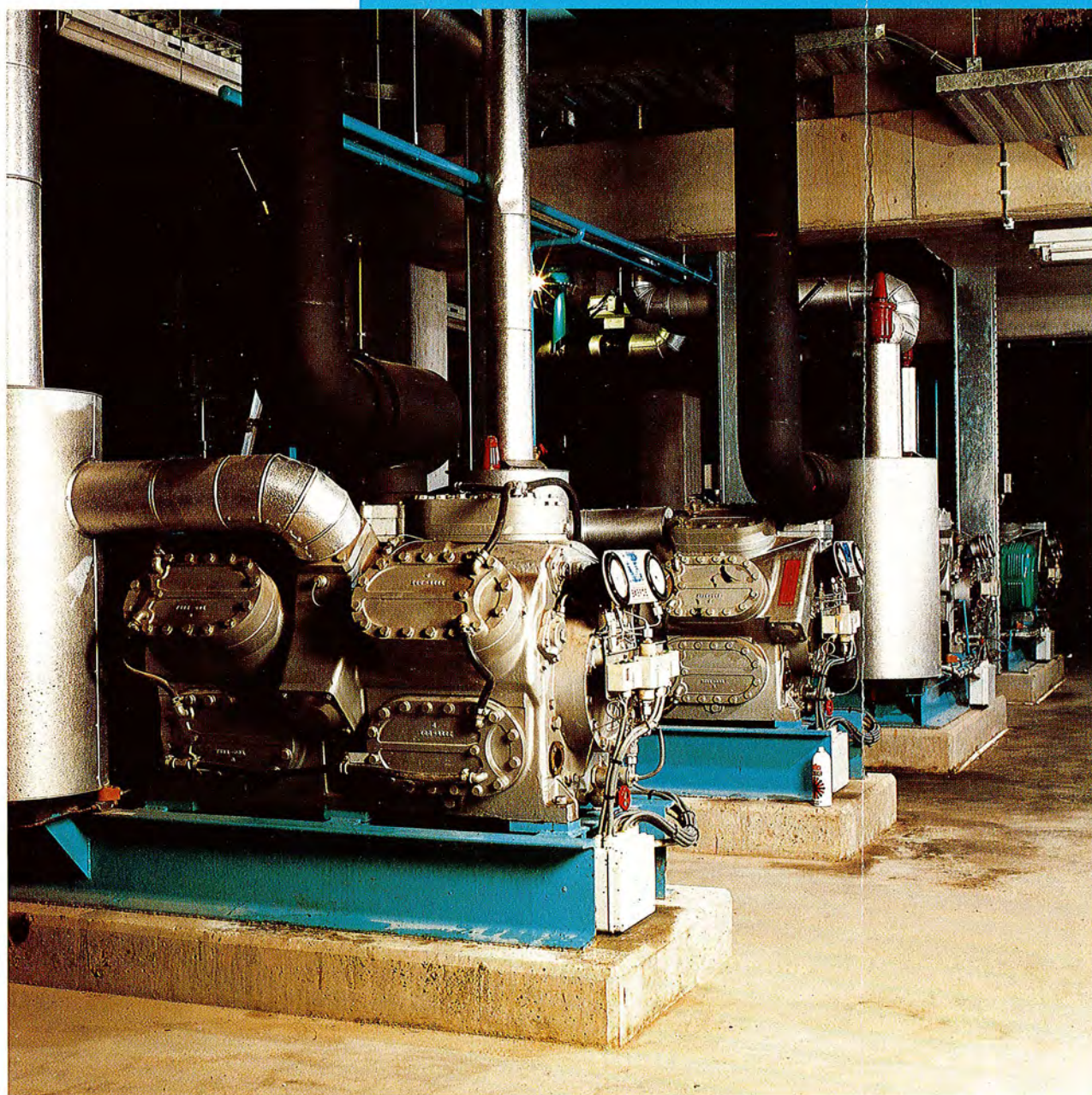


Vol. 8, No. 1, April 1990

IEA Heat Pump Centre

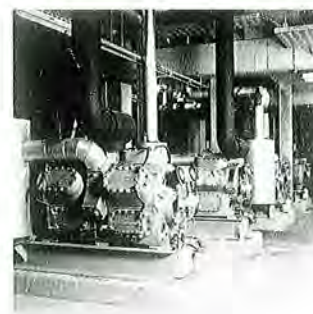
NEWSLETTER



heat pump
centre

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Front Cover

Heat pump compressor installed at Sports and Recreation Centre Glanerbrook in Geleen, the Netherlands (see page 26).

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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Editing:

Rosemarie Smith / Lisa White.

Design & lay-out:

Jo Engelen.

Illustrations:

Bureau van de Manakker, Maastricht.

Printers:

Hamers B.V., Sittard, the Netherlands.

ISSN 0724-7028

Editorial

As a result of a strategic reassessment of the IEA Heat Pump Centre (HPC), the participants opted for NOVEM (the Netherlands Agency for Energy and the Environment) to be the new Operating Agent for the HPC (Annex XVI) as of January 1, 1990 .

The HPC will act as a focal point for the whole Implementing Agreement (IA). It will not be solely an Annex of the IA, but will also deal with information related to heat pumps from other Annexes.

The participants also agreed to extend the scope of work of the HPC to include related air conditioning and refrigeration technology. Secondly, a new element in its task is to incorporate a market-oriented approach towards the target groups, and also address and involve the private sector. These ingredients will enable the Heat Pump Centre and its Operating Agent, NOVEM, to promote the penetration of heat pumps into the market. The National Teams have also been reorganised and revitalised and will represent the HPC in their member countries, offering support to the target groups. At the same time the National Teams will support the HPC in achieving its goals of promoting the use of heat pumps and of improving awareness of the HPC in the market place. Indeed, a new spirit can be found within the National Teams.

This issue of the Newsletter therefore deals partly with the new National Teams, their organizational structure and present situation of heat pumps in their respective countries.

You will also notice that the design and layout of the newsletter has been slightly modified. We wanted to begin with a fresh look whilst maintaining the quality of the articles. We hope, therefore, that we have succeeded in this and that we can also attract more readers whilst continuing to provide our existing readership with the quality articles and information they are accustomed to.

Together with the National Teams, the Executive Committee, and the new HPC Advisory Board we hope to make the HPC a success to the benefit of the participating countries and their heat pump community.



Jos W.J. Bouma,
General Manager HPC

The Heat Pump Centre Staff



Jos Bouma

Jos Bouma, General Manager of the IEA Heat Pump Centre, was born in Oldenzaal, the Netherlands in 1946. He attained his degree in Mechanical Engineering in 1975 at Delft Technical University and since has built up broad international (IEA and EC) experience in the field of heat pumps. Having worked for 10 years in the R&D field with TNO, the Netherlands Organization for Applied Scientific Research, he joined NOVEM in 1985 as a Project Manager dealing with industrial heat pumps. During this time he has built up industrial experience in energy conservation, especially in the field of food industry and heat pump applications.

In 1987 he became a Managing Director for NOVEM's 'Warmtepomp Nederland BV', a joint venture concerned with the operation of the Netherlands demonstration scheme for gas engine-driven heat pumps in the residential sector. He is a member of the Executive Committee on 'Decentralized Energy Generation', a group of utility and private experts who deal with the exchange of practical information on residential and commercial

heat pumps and cogeneration systems. Jos Bouma is also Secretary to the Executive Committee of the IEA IA for an R&D programme on advanced heat pumps.



Gerard Meijer

Gerard Meijer was born in 1936. He became Deputy Head for the IEA HPC in January 1990 and represents TNO. He graduated in Mechanical Engineering at Delft Technical University. He joined TNO in 1971 after having gained 7 years experience in the Netherlands and Switzerland in the development of nuclear reactor systems. He worked with TNO for 10 years in the field of sodium heat-transfer systems as an R&D Project Manager and as head of a 50 MW component test facility. Since 1982 he has worked in various fields of energy technologies. For 3 years he headed a department for energy policy studies.

He began working with NOVEM, on secondment from TNO in 1984, as Senior Programme Manager for the Dutch Coal R&D Programme. In the last 2 years he has been responsible for managing grant schemes for energy

saving demonstration projects - including heat pump projects - and for cogeneration studies. During this period he was also closely involved with the European Community energy demonstration programme.



Cees Hoedemakers

Cees Hoedemakers was born in Geleen, the Netherlands in 1948 and is Department Head of International Affairs for NOVEM.

He graduated from Eindhoven Technical University in 1974 as a Mechanical Engineer. He then began working in the oil and gas exploration and production field mainly for Royal Dutch Shell. This took him all over the world until he returned to the Netherlands in 1987. Then he began working with NOVEM as a Project Manager for CADDET. In 1989 he was appointed as NOVEM's Department Head of International Activities. His main responsibilities lie with the two IEA information centres currently with NOVEM, namely the IEA Heat Pump Centre and IEA CADDET (Centre for the Analysis and Dissemination of Demonstrated Energy

Technologies). Cees Hoedemakers is also General Manager of CADDET as well as Secretary to the CADDET Executive Committee.



Lucinda MacLagan

Lucinda MacLagan was born in 1959 in London, England. She graduated from law school in 1983, after which she moved to the Netherlands where she worked for Elsevier Publishers. After working her way to Editorial Manager she joined an R&D company to set up their documentation and library department. She joined NOVEM in 1989 and is currently responsible for the editing, production and distribution of all HPC and CADDET publications and related automation activities.



Jos Debie

Jos Debie born in 1957 in Geleen, the Netherlands, completed his studies in Technical Engineering and

Environmental Technology and is at present studying Computer Analysis. He was an engineer at the national chemical company DSM. In March 1985 he joined the NOVEM Buildings Department where he was involved in the computer programming of energy measurements in buildings. In May 1988 he moved within NOVEM to the Department of International Affairs where he is responsible for information systems development and office automation.



Rosemarie Smith

Rosemarie Smith is British and was born in 1962. She has studied French, German and Spanish and is currently studying Dutch. She began her career in Desk Top Publishing (DTP) in England, researching and offering consultancy to clients about DTP systems. Rosemarie joined NOVEM from Diva Medical Systems, in the Netherlands, where she worked as Documentation Specialist, responsible for editing and producing all the Company's literature. She joined NOVEM in January 1990 as DTP Specialist and Deputy Editor for the HPC and CADDET. Her responsibilities are layout and editing.



Katja Kersten

Katja Kersten was born in 1963 in Zevenaar, the Netherlands. She completed her secretarial education in Arnhem in 1983. She worked in Arnhem as a purchasing assistant until 1988. From 1988 to 1989 she joined NOVEM as Secretary for the Industrial Department in Sittard. As of January 1, 1990, she became Executive Secretary for the Heat Pump Centre and CADDET Executive Committees.



Marjan Berix

Marjan Berix, born in 1964 in Sittard, the Netherlands, studied Office Management at the College for Economics and Administration in Sittard from 1981 to 1983.

Following 7 years secretarial experience she became responsible for office management for the Heat Pump Centre in January 1990.

Introduction to IEA Heat Pump Centre Newsletter

L. Boxer

Deputy Director of IEA Energy Research Development and Technology Application



This issue of the IEA Heat Pump Centre Newsletter is not only important as it heralds a New Year - the 8th in a successful campaign to promote the wider application of heat pumps - but also because it introduces new faces in the operation of the Centre.

The subsequent pages will describe the new Operating Agent (NOVEM) and National Teams, but I would like to begin my short message with a tribute to the solid foundation already established by the outgoing Operating Agent, Fachinformationszentrum in Karlsruhe and particularly to Dr. Laue, who in recent years has made a sterling contribution in the orientation of the work of the Heat Pump Centre.

The heat pump community in general has had to face up to many changes in recent years. The softening of oil prices with the consequent waning enthusiasm for the kind of energy savings that heat pumps can offer, are factors which have lengthened payback periods and engendered a certain indifference towards innovation.

Paradoxically enough, the advent of environmental concerns and the new impulse they could give to energy conservation has not yet stimulated renewed interest in heat pumps. As you well know, part of the problem now is the current use of chlorofluorocarbons (CFC's), and one of the major challenges facing heat pump engineers and scientists today is the need to develop and exploit refrigerants which can be demonstrated as harmless to the environment. I am confident that this challenge will be met, if not fully in 1990 then soon after, and I wish the HPC every success in its endeavours which will continue to have the strong encouragement of the IEA.

Finally, I would like to pass on my good wishes to our new Operating Agent, NOVEM, who joins the Heat Pump Centre with a wealth of experience in the field, and in whom we can place our full reliance for preserving the continuity of excellent services to all participants and beneficiaries of the IEA Heat Pump Centre.



Introduction from the Chairman of the Executive Committee

Per-Erling Frivik



Welcome to the nineties and to the new Annex XVI which will continue the IEA Heat Pump Centre (HPC). As many of you readers will know, a strategic reassessment of the HPC has taken place during the last 18 months through a thorough process involving all member countries.

The major conclusions of the work were that:

- the heat pump has a significant role to play as an energy saving and CO₂ reducing device;
- since global energy and environmental issues are best attacked through international cooperation, the HPC should be continued;
- a much more active involvement is needed in the HPC from users and industry and vice versa.

The future direction of the HPC is reflected in the text of the new Annex, from which I will mention only the most important elements:

- expanding the scope of the heat pump technology, in the sense of the Annex, to include related air conditioning and refrigeration technology - for instance the CFC issue;
- strengthening of the national teams as such, as well as through involvement of users and industry;
- introducing special tasks and related funding in order to facilitate direct industry involvement;
- replacing the former Steering Committee of the HPC with a four-member Advisory Board.

From strategic measures and the HPC's programme of work, which is dominated by information exchange and topical workshops, I expect the HPC to fulfill the goal we are all working towards which is to give the heat pump its proper place in the future energy system. In addition, I hope that the HPC can be the focal point we need to develop the whole Implementing Agreement on Advanced Heat Pumps.

I also hope that most of the former participants in the HPC will continue their membership and that many new ones will join the new Annex. The more we are, the more we get done - this is true in relation to countries as well as people.

So, dear reader, are you prepared to involve yourself?

Since the participants during the reassessment process also decided to change the operating agent for the HPC, I would like to thank the former head of HPC, Professor Laue, and Fachinformationszentrum Karlsruhe for his efforts and enthusiasm in making the HPC a success and to wish the new head, Mr. J. Bouma, and NOVEM, Sittard the best of luck in keeping up the good work.

Introduction to the HPC Operating Agent NOVEM

S. Pietersz

General Managing Director of NOVEM

In the Netherlands as in many other countries, energy and environmental protection ranks high on the priority list, especially since the Government recently presented the National Environmental Policy Plan. This plan stresses the need for and importance of a well-defined policy in this area. In a small, densely populated, and highly industrialized country such as the Netherlands, one is faced daily with the necessity to confront energy and environmental problems in an internationally coordinated way. This applies not only to the subject of environmental legislation but equally to the development of technology and exchange of information.

Therefore we welcome the advent of the IEA Heat Pump Centre to NOVEM's (Netherlands Agency for Energy and the Environment) head office in Sittard. For NOVEM this is an extension of its international activities. As of 1988, NOVEM hosts the Centre for Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), the IEA organisation which promotes the exchange of information regarding demonstrated energy technologies.

NOVEM has a great deal of experience in the field of managing RD&D projects. In this realm the organization acts as an intermediary between government, the private sector and the R&D community. Therefore, the IEA HPC activities fit well within NOVEM's tasks and capabilities. TNO-MT (the Netherlands Organization for Applied Scientific Research) will provide technical and scientific support.

The principle goal and inherent guidance for NOVEM's RD&D management is to stimulate market introduction of energy saving techniques and to fuel diversification. Environmental acceptability of techniques is an explicit requirement. These tasks, which have been assigned to NOVEM by the Ministry of Economic Affairs, and in a number of cases, also by

The NOVEM building in Sittard, the Netherlands.



the Ministry of the Environment, are accomplished in close collaboration with the private sector, such as manufacturers, suppliers, installers and utilities.

Financial support from NOVEM takes the form of subsidies, venture capital and loan guarantees. Within the Residential Department NOVEM's activities are aimed at implementing energy-saving building methods. NOVEM's Industrial Department focusses its efforts on a number of energy intensive industries. NOVEM's long-term R&D Department is assigned to the study of renewables and long-term energy conservation techniques. Small and medium-sized industries are also one of the important target groups of NOVEM. Wherever possible, energy and environmental problems are confronted in a balanced way.

NOVEM's 1990 budget amounts to Dfl. 175 million (approx. US \$90 million); NOVEM has 220 employees spread over the 3 locations (Sittard, Utrecht and Apeldoorn).

I would like to wish the IEA HPC success with the start of its activities from the Netherlands.

Profile of TNO (the Netherlands Organisation for Applied Scientific Research)

TNO-MT is one of the eight Divisions that constitute TNO. TNO is a fully independent organisation, performing research on a cost-price basis in terms of

strict confidentiality. TNO-MT specialises in experimental research, studies and consultancy in the field of energy, environment and industrial technology.

Since the end of the seventies the TNO Heat and Refrigeration Technology Department has been engaged in heat pump research. Starting with strategic studies on possibilities for heat pump application and developments in the Netherlands, the scope of work has broadened extensively. In the past two years TNO has been involved in various fields:

- research and development of gas-driven absorption heat pumps and their control for residential use;
- experiments and simulation related to ground heat exchangers;
- evaluation of several heat pump demonstration projects in commercial buildings, greenhouses and industry.

More recently, studies on new thermal heat pump systems, incorporating membranes are in progress. Another important subject of study and consulting work is the heat transformer.

Since the start of the IEA Heat Pump Centre in 1982, the task of the National Team and representation of the Netherlands has been the responsibility of TNO. Therefore, the experience of TNO in heat pumps, RD&D, as well as knowledge transfer, will be beneficial to the new Annex XVI. □

The HPC National Teams

As mentioned in the Editorial, the majority of the National Teams have recently been reorganised and the following pages outline how each National Team would like to introduce themselves to you. You are well aware that the main objectives of each National Team are to achieve an improved awareness of the use of heat pumps in society and to co-ordinate the promotion of heat pumps as a viable, cost-effective, and environmentally attractive application. Secondly, the National Teams play an important role in collecting and transferring information from target groups to the Heat Pump Centre and vice versa. In future issues we hope to provide more detailed reports on each country's heat pump situation and applications. However, this article will provide you with an insight into how each National Team hopes to achieve the challenging goals already mentioned. The National Teams of the USA and Italy will be presented in future issues of the Newsletter since the process of reorganisation is still continuing.

Canada

W.K. Snelson

In the past Canada was an active member of Annex IV (the former IEA Heat Pump Centre) and was involved in related steering committee work and workshop participation. Currently, the National Team consists of the following 5 members who represent various areas in the field of heat pumps and related technology in Canada, including R&D, the Industrial and Residential Applications sectors:

M. Boulanger - Centre de recherche industrielle du Québec; R.L.D. Cane-CANETA Research Inc.; I.R.G. Lowe - National Research Council Canada; J.G. Smale - DuPont Canada Inc. and W.K. Snelson - National Research Council Canada.

The current members have been taken from the membership of the National Heat Pump Coordinating Committee (NHPCC). This committee consists of 10 members drawn from government, industry, utilities, and universities, representing a broad cross-section of interest in the Canadian heat pump community. The Committee meets about 3 times each year and provides an opportunity for the members and attendees to keep up to date with the various heat pump related activities taking place in each other's working organisations.

Clearly one of the main purposes of any committee such as the NHPCC, should be to avoid duplication of effort, particularly in areas of costly heat pump related research and development programmes. With this in mind, contacts made through the existence of the NHPCC, have enabled some joint collaboration projects to emerge, such as current test programmes related to CFC alternatives and mixed refrigerants investigations.

The NHPCC's main objectives are to:

- co-ordinate technology transfer
- review issues which have an impact on the industry
- discuss R&D priorities, such as new standards, CFCs
- provide opportunities for collaboration, for example, new refrigerant research projects
- consider IEA initiatives and make recommendations
- publish the NHPCC newsletter.

The NHPCC meetings usually include a report on recent IEA activities and also provide a forum for consideration of new initiatives in this area, such as participation in proposed new IEA annexes. Canada has already participated in several working annexes. The current ones are Annex XIII (State & transport properties of high temperature working fluids and non-azeotropic mixtures) which is currently winding down, and Annex XV (Heat pump systems with direct expansion ground coils) for which Canada is acting as Operating Agent.

Present Heat Pump Situation

The current R&D work with regard to heat pumps in Canada is carried out by the following groups: the National Research Council Canada (NRCC), the Centre de Recherche Industrielle du Québec, Varennes, the universities of Moncton, Concordia, Sherbrooke and New Brunswick and finally by three utilities - Canadian Electrical Association (CEA), Ontario Hydro Research Division and Institut de Recherche D'Hydro-Québec (IREQ).

The Canadian heat pump market can be split into two areas - Residential and Industrial. The Residential market deals with air, water and ground sources (of which 30,000 units were installed in 1987, including 4,000 ground source units). The industrial market handles dehumidification lumber drying (300 units have been installed up to 1987) and units for the pulp & paper, dairies and fish processing industries.

Looking to the future Canada has committed itself to supporting the activities of the new Heat Pump Centre (Annex XVI).

Norway

G. Eggen

The Norwegian National Team was established in February 1990 in order to coordinate the activities of the Heat Pump Centre and the various sectors working with heat pumps in Norway.

The main objectives of the National Team are:

- to promote the use of heat pumps wherever they may be reasonably used to save energy and to protect the environment;
- to collect and transfer information from heat pump research and demonstration projects in Norway to the Heat Pump Centre;
- to disseminate information from the Heat Pump Centre, its activities and products, to the various sectors working with heat pumps in Norway;
- involvement in selection of topics for analytical work and workshops, etc.

Present Heat Pump Situation

Norwegian authorities believe that the heat pump will be even more important in the near future and will also achieve a broader market penetration. This progress will be the result of several factors:

- improved heat pump systems will bring increased energy savings;
- use of heat pumps reduces CO₂ emissions compared to conventional heating systems;
- improved boundary conditions for heat pumps, e.g., increased oil prices, governmental grants to energy saving devices, etc.;
- a wider use of dual-mode heat pumps covering both heating and cooling purposes, resulting in very competitive heat pump systems compared to conventional heating systems.

Figure 1 shows an overview of the various heat pump RD&D sectors in Norway who are represented in the National Team. The National Team also hopes that cooperation with the IEA Heat Pump Centre will improve heat pump market penetration in Norway. Furthermore, the National Team will keep close contact with the Norwegian Society of Refrigeration, the Norwegian Refrigeration Constructors Association for Heat Pumps and the Nordic Expert Group for Heat Pumps.

Sweden

B. Bäckström

Sweden has taken part in the IEA Implementing Agreement on Advanced Heat Pump Systems since its inception and has been involved in many of the annexes, in some cases even as Operating Agent. The Swedish Council for Building Research (BFR) has,

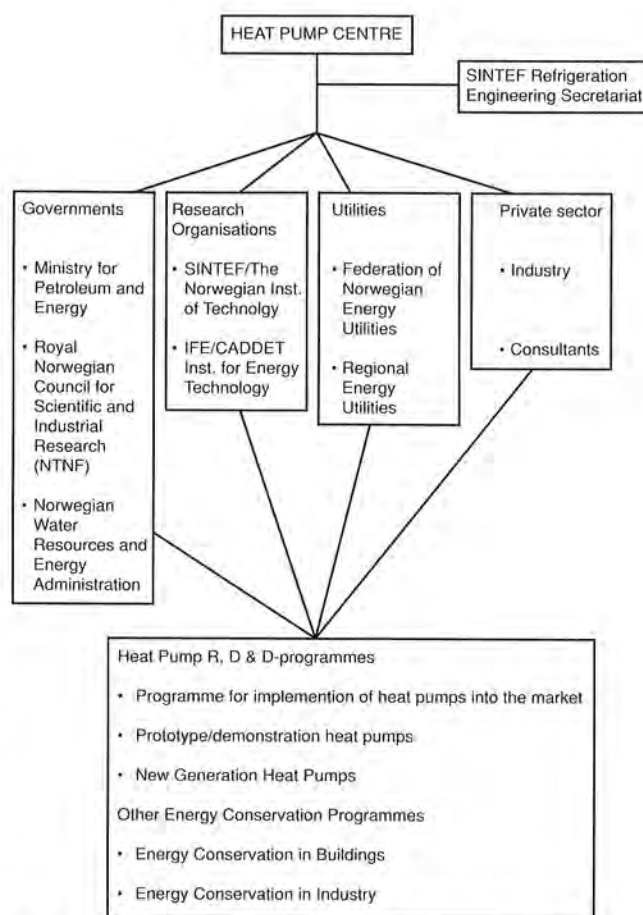


Figure 1: Norwegian National Team.

during the last decade, been responsible for a substantial part of the energy R&D programme including heat pumps. BFR has been funding a reference group - called BFR's Heat Pump Group - with representatives from technical universities, consulting engineers, contractors and manufacturers, all of whom are active in the field of heat pumps. The group acted as the Swedish National Team during the period when the IEA-HPC was operated by Germany (Annex IV). The group also evaluated the results of the RD&D projects financed by BFR during each 3 year period and proposed the R&D programmes for the forthcoming 3 years.

The group is still in operation, but as of January 1, 1990, a separate HPC National Team (NT) has been nominated. Some of the members are also members of the BFR's heat pump group, but the new NT includes representatives from the utilities and the Swedish Association of Heat Pump Manufacturers.

The daily work of the NT is carried out by a permanent Secretariat, Bernt Bäckström, Chairman of the NT, and Lil Falkensson, Information Secretary. The secretariat is hosted by Chalmers Industriteknik, a foundation with close connections to Chalmers University of Technology in Gothenburg.

Present Heat Pump Situation

In Sweden, heat pump technology has been the most successful of the various alternative forms of heating in competing with conventional methods. As a result, Sweden currently possesses a strong competence in heat pump technology, both in research and practical implementation. These resources will be extremely important in our unavoidable shift to a new energy profile in the future.

A comprehensive adjustment of the entire Swedish energy profile has to be made. Apart from the fact that Sweden's dependence on oil should be further reduced for economic reasons, there are now demands for actions in energy fields in order to reduce harmful emissions and greenhouse gases. Furthermore, Sweden's electricity consumption must be reduced in the light of the nuclear phase-out policy.

The heat output from all heat pump installations in operation in Sweden today is estimated to be 14 -16 TWh/year gross and comes mainly from a number of large plants. The total number of heat pump units in Sweden now exceeds 150,000. A large proportion have a capacity of less than 25 kW.

The capital cost of heat pumps, per unit of installed heating capacity is high, but is among the lowest of known energy-saving methods. The price of both electricity and fossil fuels is now expected to increase faster than other costs and that may contribute to a positive trend for the heat pump market in Sweden.

Funding

A significant level of expertise has been achieved over the last ten years in heat pump technology, largely due to governmental support of R&D and international cooperation.

It is suggested that, in future, BFR should shoulder an increased responsibility within the field of Energy Technologies in the Building sector, Heat Pump Technology and Solar Heating.

BFR is the contracting party in the Implementing Agreement on Advanced Heat Pumps and the HPC and is, together with the Swedish National Board for Technical Development, funding the Swedish activities.

BFR's proposed budget for the 3 year period 1990-93 is SEK 128 million (US \$~20 million), out of which SEK 25 million is proposed for the Advanced Heat Pump Technology programme. In addition to the R&D budget, SEK 66 million (US \$~10 million) will be available in loans to cover extra costs and risk capital for experimental and demonstration projects. Repayment depends on the results achieved. The Building Council also operates parts of the R&D programme of the National Energy Administration, i.e., introduction of natural gas.

Future Activities

The following are considered areas of primary importance for the next 3 years for the Swedish Heat Pump R&D Programme:

- CFC substitutes;
- Absorption heat pumps and heat transformers;
- Combustion engine-driven heat pumps;
- Use of heat pumps in existing electric resistant heated houses;
- New system technologies.

BFR will also support evaluations of test results and help coordinate other aspects such as indoor climate and environmental regulation. A national network of contacts is already well established. BFR hopes to continue supporting a good research atmosphere and encourage cooperation among universities, consultants, installers, local governments, real-estate companies, end users and others. The HPC National Team of Sweden looks forward to fruitful international team work.

The Netherlands

H.J.M. Knipscheer, A.G. Melman

From the beginning in 1982 the Netherlands has been participating in the Heat Pump Centre through the Netherlands Organization for Applied Scientific Research (TNO). The National Team (NT) has recently been reorganised in order to represent most of the parties actively involved in heat pumps in the Netherlands.

The Chairman of the NT is H.J.M. Knipscheer, Managing Director of Coman Consulting Engineers. He is an expert in the field of heating, ventilation, air conditioning and refrigeration, especially in designing and installing heat pump systems.

The Secretariat of the NT is headed by A.G. Melman from TNO. G.H. Bontius represents the Association of Electric Power Utilities. M. van Rij is a member on behalf of the Institute of the Dutch Gas Utilities. A.F.L. Hendrickx, Managing Director of Helpman Machinery Works, represents the manufacturing industry. Prof. A.L. Stolk represents the R&D community at Delft University of Technology.

The work of the NT is sponsored in part by NOVEM, within the framework of the Dutch RD&D programme in the field of energy. NOVEM is also a member of the NT and represents the government. The main activities in the coming year will be:

- the developing and maintaining of a contact network;
- promotional activities through publications and an annual seminar.

Moreover, the feasibility of a Dutch centre for heat pump technology will be examined.

Present Heat Pump Situation

In the Netherlands heat pumps are still seen as a promising possibility both for energy saving in a broad field of applications and for environmental protection. It is hoped that the development and penetration of heat pumps may benefit strongly from the recently launched National Environmental Plan of the Dutch government. However, the total number of installed heat pumps for residential, commercial and industrial use is rather low.

Approximately 100 gas-engine driven heat pump plants exist, of which 60% are used for greenhouse heating. Virtually no sorption heat pumps have been installed. As far as the residential sector is concerned, small heat pumps have not had any chance to penetrate that market due to circumstances in the Dutch energy market as follows:

- the relatively high electricity to gas price ratio (>4) which makes electric heat pumps unattractive;
- the strong position of less expensive gas-fired boilers;
- the absence of a domestic cooling demand.

Absorption heat pumps with a thermal capacity of up to 60 - 80 kW are currently not feasible due to their high costs. However, there is, in fact, an enormous market potential for smaller heat pump units which fall in the range of 2 - 40 kW for residential heating. In realising a hypothetical 10% share of the total residential market for heating devices, annual sales of 20,000 heat pump units for individual central heating systems and 2,000 heat pump units for collective central heating systems would be required. In view of this potential, there is a strong incentive for the further development of absorption heat pumps, featuring a high COP and low investment cost.

The market for larger users in the residential and commercial sector for space heating looks better from an economic point of view. Within the framework of the National Heat Pump Programme, about 15 projects have been accomplished in the eighties with an installed thermal capacity of about 7 MW in total. However, in some cases, the performance of gas engine-driven heat pumps has been disappointing.

In the field of industry about 30 heat pump systems have been installed. The total thermal capacity is more than 60 MW. Most of these are open cycle compression heat pumps, the largest one having a thermal capacity of almost 22 MW. A recent market study showed a total market potential of over 2,200 MW, of which 1,350 MW were for total open systems. By the year 2000, about 100 installations with a capacity of 400 MW could be realised, bringing the market penetration up to 30% and resulting in an annual energy saving of 200 million m³ of natural gas. Currently, as far as R&D is concerned, the most important industrial development is an absorption heat pump for a capacity range of 250 - 1000 kW.

Austria

H. Halozan

Since the beginning of the IEA Annex IV Heat Pump Centre, the activities of the Austrian National Team were carried out by ARGE (Arbeitsgemeinschaft) Wärmetechnik, a working team consisting of scientists working with Prof. Gilli from Graz University of Technology, Institute of Thermal Engineering. Good contacts were established with heat pump manufacturers, heat pump distributors, planners, and installers and also with a few utilities (such as OKA).

Currently, the National Team is trying to form a more formal collaboration with contacts in industry, utilities, and the Ministry of Science and Research, in order to establish a strong National Team which can really support the Austrian heat pump market and the Heat Pump Centre.

Present Heat Pump Situation

(See IEA HPC Newsletter, Vol. 7, No. 4, for more detailed information.) The heat pump market in Austria started in 1978 with heat pumps for the residential sector, which, in terms of sales figures, is the largest market segment. The common heat pump operation mode is heating only. The heat pump unit has to be integrated into a hydronic system, which is most commonly used as a heat distribution system.

The units installed in new buildings with low temperature distribution systems are monovalent water-to-water heat pumps, using ground water as their heat source. Bivalent systems were installed in existing buildings with medium or high temperature distribution systems. The type of heat pump most commonly used in these buildings was the air-to-water unit which utilised outside air as a heat source and which supplied 50 - 80% of the annual heating demand. The remaining heat was supplied by a boiler. The market was a retrofit market and was dominated by bivalent systems. Both types were economic when careful sizing, integration and installation were considered.

After the first drop in the market of heat pumps, the heat pump community had to decide on a new approach. Market niches have been created as a result of the hard but continuous work of utilities, heat pump manufacturers, heat pump distributors, planners and installers. In order to find new market segments, a lot of development work was carried out to expand the field of heat pump application in the residential sector and this development is still continuing. Development work has been carried out into:

- sanitary hot water heat pumps, the market introduction of which was very successful;
- ground coupled systems, at first with heat extraction by a brine circuit, and in more recent years using direct evaporation;

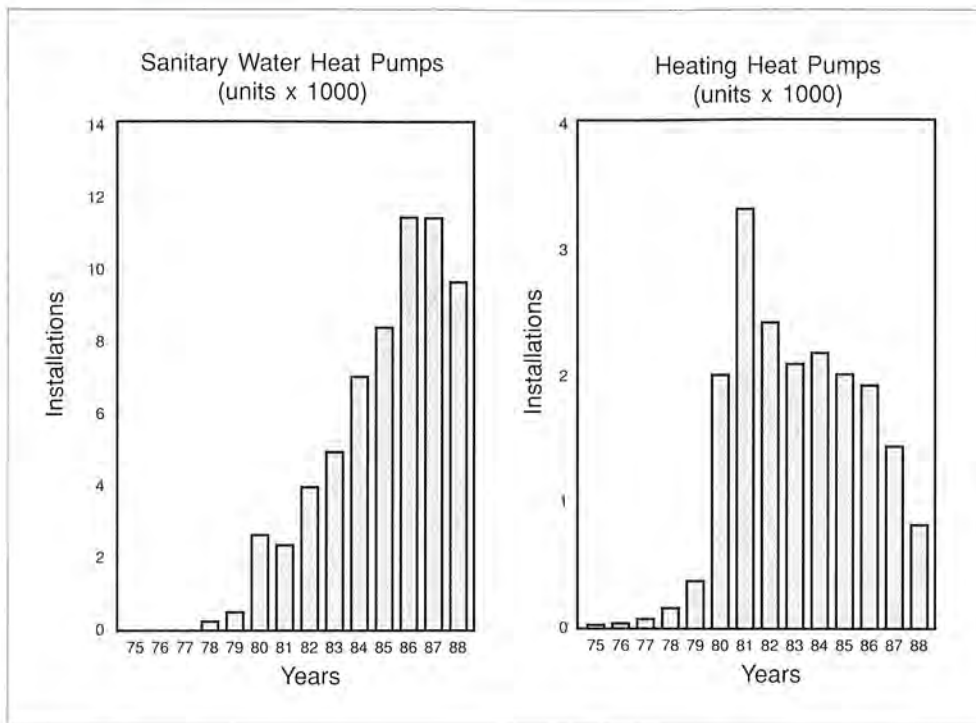


Figure 2: Number of Sanitary Hot Water and Heating-Only Heat Pumps Installed Between 1975 - 1988.

- commercial systems for heating, cooling and heat recovery in which category the Austrian firm, ELIN, has developed a system particularly suitable for hospitals and recreation centres.

Figure 2 shows the number of sanitary hot water and heating-only heat pumps installed over the years.

Funding and Promotion

Heat pump application in Austria is stimulated by the Austrian government through tax incentives and subsidies. Research on heat pumps is funded partially by the government and partially by the funds for scientific research and economic affairs. Local governments also support specific research projects. Industrial research is partially funded by the fund for industry.

Although the Austrian government supports energy saving measures to a certain extent, there is no dedicated party representing the field of heat pumps. Unfortunately only a few utilities (of which there are over 250) support heat pumps. Besides low costs for fossil energy and relatively high initial costs of heat pump systems, this lack of governmental emphasis is a primary reason that heat pumps have not been able to achieve a real breakthrough in the market.

Currently, the market situation is extremely serious: heat pump manufacturers and customers are confused by the CFC discussion and by regulations resulting from this discussion. Therefore, the Austrian National Team hopes that, together with the Heat Pump Centre, it can offer more support to the heat pump community and establish a stronger place for it in the market place.

Japan

*S. Nagamatsu, E. Miura**

NATIONAL TEAM ORGANISATION

The IEA Implementing Agreement on Advanced Heat Pump Systems (IA) for Japan is carried out by the National Team of Japan, which is composed of the organisations and agencies shown in Figure 3).

The Ministry of International Trade and Industry (MITI)

MITI is a branch of the Japanese Government which has jurisdiction over the IA in Japan. The Agency of Industrial Science and Technology (AIST) of MITI exercises general control over internal and international heat pump technology affairs.

Agency of Industrial Science and Technology, MITI

While promoting the R&D of basic technologies for state-of-the-art heat pumps, such as the Super Heat Pump Energy Accumulation System (SHP System), this agency is also in charge of international collaboration related to heat pump technologies. As it represents Japan in all IA Annexes in which Japan participates, it exercises general control over activities in close collaboration with other divisions within MITI.

IEA Advanced Heat Pump Systems Executive Committee of Japan

This committee was established in December 1982 within the AIST to aid the smooth implementation of

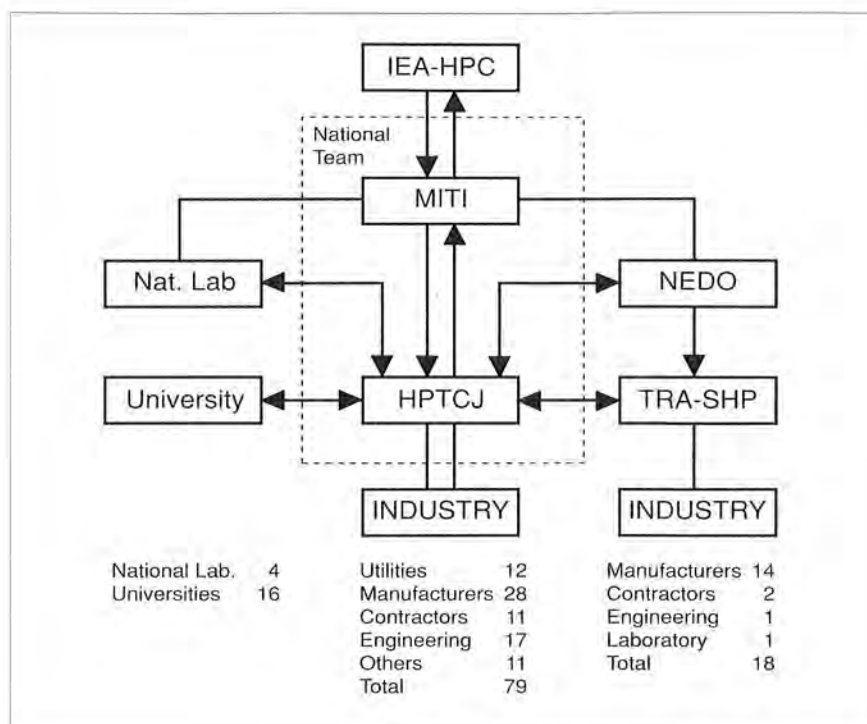


Figure 3: Organisational Flow-Chart of the National Team of Japan.

the IA. It serves as an Advisory Board whose aim is to carry out activities necessary for the IA, including research and exchange of information concerning matters relating to heat pump technologies.

Heat Pump Technology Center of Japan (HPTCJ)

The HPTCJ is a public service corporation established in June 1986, and aims at promoting the development and promotion of heat pump technologies as well as international collaboration. The HPTCJ co-ordinates the activities with specialists from universities, research institutes, utilities, manufacturers, general contractors, design/engineering companies and users. There are 79 supporting members.

IEA-Annex Steering Committees

These Steering Committees are set up within the HPTCJ to perform the tasks of each Annex of the IA, and supervised by the Executive Committee of Japan. These committees are responsible for preparing national reports, participating in workshop meetings, and are also engaged in other services relating to each Annex. At present, the following IEA-Annex committees are in operation: XIII, XIV, XV, and also Annex XVIII which will commence in April 1990. Due to the general nature of its work, Annex XVI, the IEA Heat Pump Centre, is operated by the AIST and HPTCJ.

Cooperating Organisations

The National Team of Japan is in close contact with the following two organisations which are engaged in the development of the SHP System:

New Energy and Industrial Technology Development Organization (NEDO)

NEDO is a technology development agency of the Japanese Government, established in October 1980 after the oil crisis, in order to promote the development and introduction of oil alternatives.

Technology Research Association of Super Heat Pump Energy Accumulation System (TRA-SHPEAS)

TRA-SHPEAS, consisting of 18 members, was established in April 1980 as a joint private venture in order to develop the SHP System.

NATIONAL TEAM ACTIVITIES OF AIST/MITI

R&D for State-of-the-Art Heat Pump Technologies

Since the fiscal year 1984, as part of the "Moonlight Project", AIST has conducted R&D on the SHP System. Four national research laboratories are performing the basic research, whilst NEDO and TRA-SHPEAS are working on the development. The total funds are 10 billion yen (US \$ 69 million). (See IEA HPC NEWSLETTER, Vol. 7, No. 4, Dec. 1989 for more detailed information.)

Development of Industrial Technologies for Global Environmental Protection

As a result the rapid expansion of socio-economic activities of human beings, global environmental problems, such as the greenhouse effect and destruction of the ozone layer, have become the most serious problems facing the world today. Therefore,

while setting up a comprehensive and efficient research system, the Japanese Government has decided to promote the development of new industrial technologies in order to combat global environmental problems such as the development of: carbon dioxide (CO₂) fixing, effective utilization technology, and environmentally safe substances (including third generation CFCs) beginning in 1990.

Government Support for Heat Pump Promotion

Since heat pumps have a large energy saving effect, their promotion is quite important. As such, tax and financial incentives related to energy saving have been provided, covering amongst others a variety of heat pump applied equipment.

Government Support for R&D by the Private Sector

The Government has provided conditional loans to stimulate energy conservation for the development of such projects as the Stirling engine-driven heat pump system and for advanced cold district heat pumps.

NATIONAL TEAM ACTIVITIES OF THE HPTCJ

The HPTCJ, commissioned by AIST, as Japan's secretariat, operates all Annexes of the IA. The HPTCJ also implements various activities promoting heat pumps in Japan with an annual funding of 151.9 million Yen (US \$ 1.04 million) including 55.4 million Yen (US \$ 382 thousand) from Government subsidies.

R&D of Fundamental Technologies

Development is being carried out of basic technologies for heat pumps and devices incorporating heat pumps, as well as research on the effect of widespread use of heat pump technologies. The centre promotes heat pump technology study forums with the help of experts from universities, research institutes and private enterprises.

International Cooperation & Information Exchange

International cooperation is based on the IA and bilateral cooperation. The HPTCJ is the Operating Agent for Annex XIV of the IA. In order to facilitate information exchange regarding heat pump technologies, the centre sends a study mission overseas once a year, and organises international seminars, inviting foreign experts, and also exchanges information and opinions with research teams visiting Japan.

Information Dissemination Activities

The centre holds an annual conference in 9 areas of Japan to promote heat pumps. Lectures are held to introduce marketing and operating experiences, and inspection tours of facilities are conducted to increase awareness in owners of buildings, builders, designers,

engineers, contractors, installers, area heat suppliers, industrial users, and local Government officers, about the advantages of heat pump technologies, while at the same time, creating a place for cross-industrial information exchange. There are 7 Promotional Area Steering Committees and a nationwide Promotional Executive Committee that run these activities. Additionally, the centre holds a quarterly lecture, not only for the supporting members but also for non-members, on such topics as state-of-the-art technologies, CFC problems, environmental problems, and other current issues.

Inspection Tour

The HPTCJ conducts an inspection tour twice a year, focussing on the latest heat pump technologies, visiting universities and research institutes, demonstration test facility companies which use heat pumps, district heating/cooling plants, etc.

Technical Information Services

The centre publishes periodicals, distributes reports, collects and offers information about new technologies and new applications, responds to inquiries, and various other documental tasks.

FUTURE TASKS

The National Team of Japan is resolved to actively promote the following:

Research & Development

- R&D on key technologies of heat pumps
- R&D on heating systems using heat pumps.

Promotion of the Introduction of Heat Pumps

- Demonstration of the SHP pilot system and other heat pump systems
- Supporting the introduction of heat pumps
- Heat pump promotional conferences.

Development to Preserve the Global Environment

- Development of advanced substitutes for CFCs.

International Co-operation

- Strengthening activities of the IEA
- Promotion of bilateral collaboration
- Transfer of technology to developing countries.

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Residential Variable Speed Technology

Lou Sulfstede, Texas

Although residential variable speed systems made an appearance in the early 1980s, those early products were very costly, had seasonal energy efficiency ratios (SEER) of only 10 to 12 (seasonal COP of 2.9 to 3.5) and could not compete with alternative means of achieving equivalent performance; hence were shortly abandoned.

Trane's XV1500 heat pumps and air conditioners, introduced in 1985, represent the first generation of variable speed equipment focussed on the economics, logistics, efficiency and performance demands of residential products.

The XV1500 SEER ratings range from 14.1 at 5 Tons (seasonal COP of 4.1 at 17.6 kW) to 16.9 at 2.5 Tons (seasonal COP of 4.95 at 8.8 kW) and Heating Specific Performance Factor (HSPF) from 8.6 to 9.4.

In 1978 and 1979, Trane, which was then the Central Air Conditioning Department of the General Electric Co., began assessing the benefits of variable capacity operation.

Technological innovations resulting from the 10 year development programme have scope far beyond the Heating Ventilation and Air-Conditioning (HVAC) industry. It precipitates production of a new class of fractional and integral motors for appliance applications, the Electronically Commutated Motor (ECM). The motor drives, or inverters, specified by Trane and jointly developed with General Electric Co. (GE), have become the

standard for residential equipment application in the U.S. The inverters were designed for specific interfacing and operation with HVAC elements and, as a result, have cost potential to compete with conventional systems.

The programme also produced a new class of simple to operate thermostats and controls with unprecedented benefits in comfort, equipment protection and performance. In addition, the system and interface designs partition the electronic elements so that installation and service follow conventional methods and techniques, without the need for special cables or equipment. These innovations are all part of the XV1500.

More variable speed heat pumps are currently sold in Japan than single speed, primarily because they are designed for maximum heating capacity, rather than cooling, to avoid the use of the available heating alternatives. In the U.S., systems are bigger, the cost of electricity is lower, the nature of the product and its logistics are different, and of course, the consumer has different rationale for buying a particular system.

The article as it is presented here is a shortened version. The full article which describes the system control and the variable speed motor in more detail can be obtained by contacting the author.

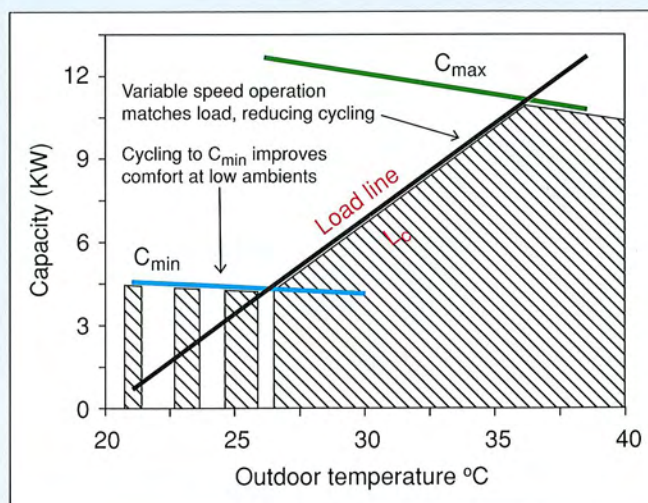


Figure 1:
Load Matching.

WHY VARIABLE SPEED?

A variable speed system adjusts its cooling or heating capacity to exactly match the heat gain or loss in the conditioned space. The advantages of load matching are greater seasonal efficiency and better comfort control.

Cooling Mode Operation

Figure 1 shows the principles of capacity production and structure load. In the cooling

mode, the system's ability to develop capacity at a constant maximum compressor speed and indoor airflow is shown by the line C_{max} . This line also represents the way conventional, single speed systems produce capacity. A second line, C_{min} indicates capacity developed by the same system that developed C_{max} but while operating at a slower, constant compressor speed and lower airflow. A variable speed system is able to develop any capacity within an envelope bounded by C_{max} , C_{min} and a selected range of condensing temperatures.

The load, or heat gain, of a dwelling is represented by the line L_c and can be seen to increase as the outdoor temperature increases.

A single speed system accomplishes capacity reduction by cycling on and off to 'duty cycle' or 'average-down', the system's peak capacity to match the load. In the variable speed system, the compressor and fan speeds are adjusted so that a part-load capacity which super-imposes itself on the load line of the structure is developed.

In Figure 1, the capacity can be reduced from maximum at C_{max} by changing compressor speed over most of the outdoor temperature range. At the mildest conditions,

the system capacity reaches a minimum at C_{min} and the unit begins duty cycling just as a single speed unit. However, the variable speed system cycles between off and lowest capacity C_{min} , rather than to full speed and maximum capacity as the fixed displacement compressor system would under light loads.

Heating Mode Operation

The load matching principle also applies to the heating operating mode. In heating, however, the ability to develop capacity at a constant maximum speed decreases as the outdoor evaporator temperature falls.

Cycling occurs during the mild outdoor conditions, averaging the capacity to the load. The speed of the variable capacity system's compressor is gradually increased, developing capacity, as the outdoor temperature gets colder, until it reaches maximum speed at the 'balance point' of the structure. Beyond this point, auxiliary heat is necessary to maintain the temperature in the heated space.

Efficiency

Load matching operation produces two contributors to an increase in efficiency over an equivalently sized single speed system.

The first is an increase in efficiency due to a reduction of cycling losses. The continuous operation of variable speed systems accounts for approximately 40% of the total efficiency increase over an equivalently designed single speed system (EPRI Dual-Fuel Rooftop Heat Pump Field Test Project ^{Ref. 1}).

The second reason for the efficiency advantage of variable speed systems is the heat exchanger unloading that occurs at all speeds. For loads less than rated, or at low speed conditions where the compressor capacity has been reduced and the mass flow of refrigerant through the exchanger is less than the rated flow rate, the heat exchangers are oversized and heat transfer improves. This effect accounts for the majority of the efficiency improvement.

Figure 2 shows the combined effect of both factors in the cooling mode over the seasonal outdoor temperature range. The COP at each outdoor temperature is plotted for a high efficiency single speed system and a variable speed system of the same rated capacity. As the temperature moderates, the variable speed system's COP reaches 5.8 before the effects of cycling cause it to flatten. The single speed system, on the other hand, suffers from cycling losses throughout the range.

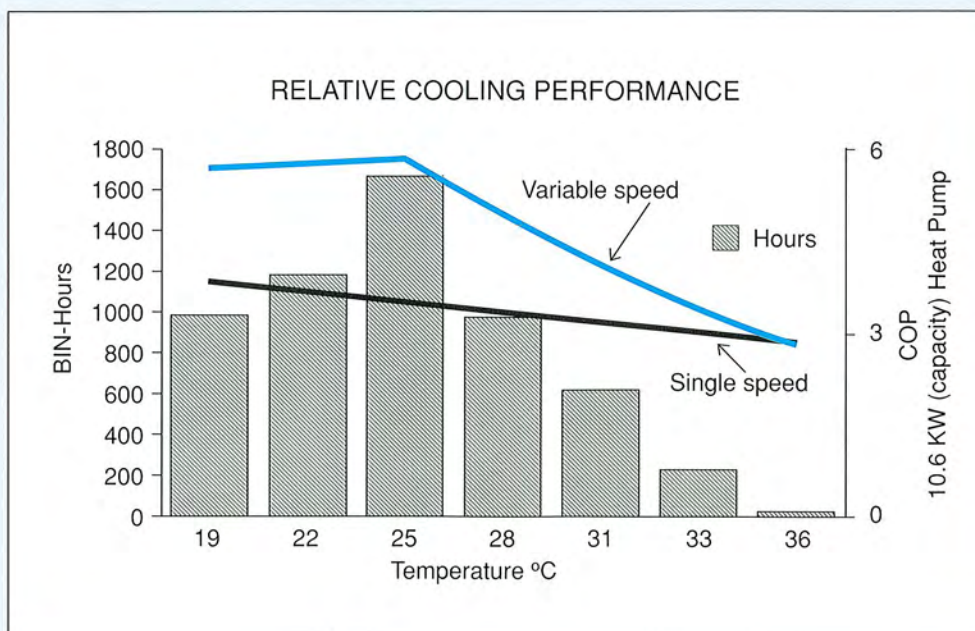


Figure 2:
Energy Efficiency Ratio
Enhancement.

Table 1: 2.5 & 3 Ton Performance.

System Capacity and Efficiency		
Product ratings		
	TWS 730	TWS 736
Cooling capacity (KW)	9347	11000
Seasonal COP*	4.81	4.45
Low speed COP (Peak)	7.6	7.0
8.3 °C Heating capacity	8790	10130
COP 8.3 (High speed)	3.2	3.1
COP 8.3 (Low speed)	4.0	4.0
-8.3°C HTG capacity	4680	5655
COP -8.3	2.2	2.2
HTG Seasonal COP*	2.55	2.58
50-70% Clg Run time @ COP>5		
* per ARI STD 240-81		

Table 2: 4 & 5 Ton Performance.

System Capacity and Efficiency		
Preliminary ratings		
	TWS 748	TWS 760
Cooling capacity (KW)	14064	16850
Seasonal COP*	4.41	4.15
Low speed COP (Peak)	7.0	6.4
8.3 °C Heating capacity	12690	16700
COP 8.3 (High speed)	3.28	3.01
COP 8.3 (Low speed)	4.02	3.90
-8.3°C HTG capacity	7470	9786
COP -8.3	2.33	2.22
HTG Seasonal COP*	2.75	2.53
50-70% Clg Run time @ COP>4.7		
* per ARI STD 240-81		

In addition, it's compressor speed cannot be adjusted to reduce refrigerant mass flow to unload its heat exchangers beyond that which can be achieved by the thermodynamic effects of reduced condensing temperature.

As can be seen in Figure 2, most of the season is spent at moderate temperatures where the variable speed system efficiency is highest. This, of course, is the fundamental reason why variable speed unloading has a dramatic effect on seasonal efficiency.

The heating and cooling rating of Trane's 2.5 and 3 ton heat pumps are shown in Table 1 and those of 4 and 5 ton in Table 2. Efficiencies are shown for heating and cooling at typical part-load conditions to aid visualization of seasonal effects.

Variable Speed Comfort

The long run times of capacity modulated systems put them in continuous control of comfort. In cooling, they have exceptional

humidity control since they are continuously running, generally at low capacity and airflow, dehumidifying over very long periods. In heating, smooth temperature control is characteristic of load matching operation and the resulting long run times.

Most of the heating and cooling seasons are spent at moderate conditions, below the design load. A typical application may spend 50% to 70% of the time at low to mid-speed and capacity. This enhances comfort by creating draftless and practically noiseless operation for most of the season.

The comfort enhancements of variable speed heat pumps make them attractive heating alternatives. They offer the means of modifying the operating characteristics that have been sources of complaint about heat pumps. In cooling, their exceptional performance in high latent load conditions provides unmatched comfort at very high efficiency.

The ability to adjust capacity and airflow provides modes of operation that were not previously achievable, or could only be attained with significant operating cost increases. The flexibility of variable capacity offers opportunities for tailoring the comfort control system on-site to the customer's preferences.

VARYING SYSTEM CAPACITY

The XV1500 adjusts its capacity by changing the speeds of the compressor, indoor blower and outdoor fan. Inverter driven brushless D.C. motors, also known as ECMs, run all three components. The microcomputer-based Thermostat and System Controller computes a value that is representative of the load and converts it to speed commands for the inverters, which operate their individual motors. The air handler, outdoor unit, system controller and thermostat operate as a unit and must be used together.

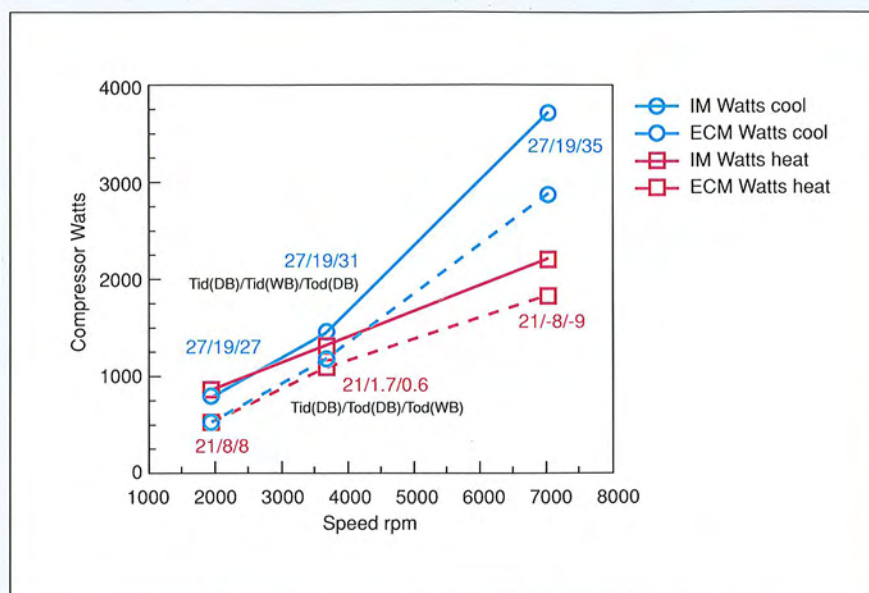
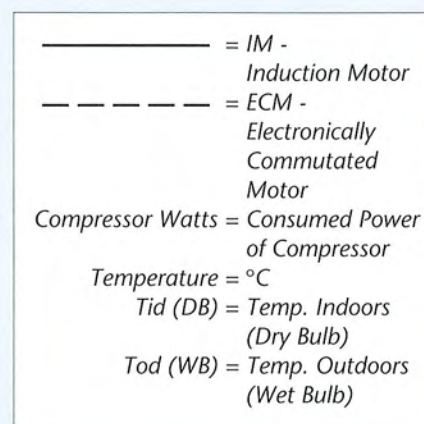


Figure 3: Comparison between an Electronically Commutated Motor and an Induction Motor.



SYSTEM DESIGN CONSIDERATIONS

ECM vs Induction Motors (IM)

Compressor performance with an Electronically Commutated Motor (ECM) is significantly better than with a variable speed induction motor (IM). Figure 3 shows compressor power with an ECM and with an Induction Motor over a common set of load conditions. As can be seen, ECM efficiency is higher over the entire speed and load range. It does not suffer from the induction motor's poor efficiency at low load and speed

since it is not subject to the harmonic losses typical of induction motors in variable speed operation. It also out-performs the induction motor at rated load, which is generally the point at which the induction motor was designed for maximum performance. Greater efficiency at the rated load helps offset the losses in the electronics which are near maximum at that condition, degrading Energy Efficiency Ratio (EER).

The ECM's efficiency also enhances the value of the inverter. In the same application as an induction

motor, the ECM's efficiency advantage is augmented by its higher power factor. The cumulative effect is the ability to deliver greater power to the load, or conversely, a reduction in the size of the power semi-conductors for a given load (Ref. 2). For a given system capacity rating, this results in a significant economic advantage for the ECM since the cost of the power electronics is primarily driven by the power devices.

The linear torque-speed relationship of the D.C. brushless motor generally simplifies the design and

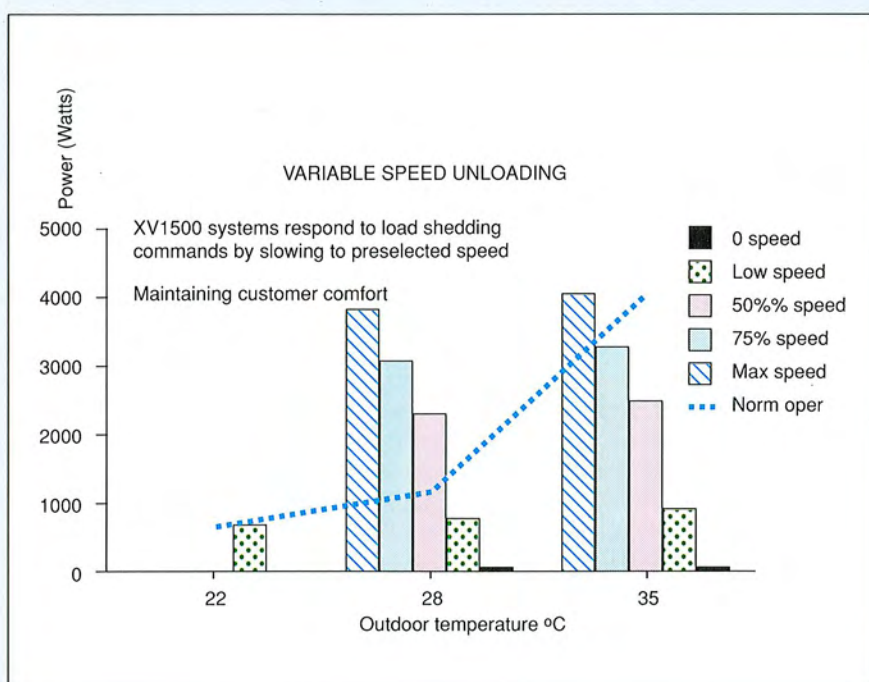


Figure 4: Load Shedding.

hardware content of the inverter. In effect, the speed of the ECM is determined by its voltage, the electro-motoric force (EMF), which is easier to control than frequency, the parameter that determines the speed of an induction motor. Furthermore, to maximize the performance of an induction motor requires a more complex and expensive design that includes p.w.m. and angle control. But even these enhancements cannot cause the induction motor to match the brushless D.C. motor's performance.

System Operation With Inverter Driven Motors

In addition to increased seasonal efficiency, several other advantages accrue from operating the system's motors with inverters. They stem from the intrinsic operating characteristics and self-protection designed into the drives themselves. Highest amongst these is the absence of locked rotor currents at system start-up. The inverter becomes the 'compressor contactor', but simply will not allow the 100 Amp locked rotor currents typical of single speed induction motors. Lower starting stress improves reliability.

Slowing a variable speed system reduces its power consumption at any outdoor or indoor temperature condition. Inverter driven operation therefore offers new opportunities for load management by the electric utility. The same load shedding controls currently used can interface with the XV1500 system controller to direct the unloading process. Figure 4 demonstrates the amount of power that can be shed at several speeds and outdoor temperature conditions in cooling operation. Variable speed controls make it possible to provide continuous, albeit diminished, environmental control during the power reduction period, maintaining a higher degree of comfort than the present method of complete system shut-down.

Power consumption by the system depicted in Figure 4 can be dropped by 1.5 kW, or 38%, with

a 50% percent speed reduction. By forcing the system to the lowest speed, 75% of the rated load power can be shed, yet over 3.5 kW of capacity remains, providing some degree of environmental control. From the manufacturer's point of view, this method of shedding is preferred over complete shut-down of the system since it minimizes discomfort and avoids long pull-down periods at high load after the shedding period. In addition, it insures that the system controller manages the reduction to prevent conditions it would otherwise report as faults.

Comprehensive system design allows the control system, the variable speed motors and inverters to combine for many value-added advantages in HVAC. Stall detection, controlled load shedding, stress reduction during the defrost cycle, overload protection, and customized airflow are several features that are intrinsic. The electronics in serving its prime objective provides extra value without adding complexity. Significantly, it adds these features for little or no cost, except for the one-time software design needed to incorporate the function into the intelligent computer-based controls.

Designing for Installation and Service

A massive, established sales and service network is in place serving the HVAC market. The success of variable speed systems is dependent upon the facility with which this logistical base can assimilate the concepts, technology, and needs of the product. It is imperative that the HVAC dealer is not intimidated by the technology and recognizes how similar it is to what he already knows. Training is a necessary element, but accommodating the sales and service network in the system design is fundamental. A 'user friendly' design philosophy that the electronics should be 'invisible' and the refrigeration system be 'conventional' is a reasonable approach to optimizing the design for this purpose.

Ideally, the electronics should improve reliability and serviceability and not require special care or consideration. To meet this criteria, the system must be designed so that the electronics are modular, that it protect itself from the common failure modes and operating conditions of residential HVAC, and that it be integrated with the standard system components. Several functional features are evident in the XV1500 reflecting this philosophy.

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A New Option for Commercial Space Heating: Introducing the Dual-Fuel Heat Pump

R.E. Hough & S. W Carlson / M. H. Blatt & J.P.Kesselring

Project History

The Electric Power Research Institute (EPRI), Palo Alto, California, initially commissioned an analysis of the Dual-Fuel Heat Pump (DFHP) concept in late 1986. The DFHP concept employs a gas furnace, rather than electric resistance heating, for supplemental heating. EPRI contracted with Lennox Industries, Dallas, Texas, to design and produce a limited number of 7.5-ton rooftop DFHPs for field testing and evaluation.

Each of the initial six units produced by Lennox was a combination air-source heat pump and gas furnace package. All heat pump and gas furnace components came from production units. Simple controls were added which integrated heat pump and gas furnace operation.

The gas furnace operated when needed to supplement the electric heat pump or when it was more economical to operate than the electric heat pump.

The DFHPs are designed to supply high quality occupant comfort by using four stages of heating and two stages of cooling. The four heating stages include two stages of heat pump and two stages of gas heat. The four stages operate separately or in combination, as needed, for greatest comfort and efficiency.

Background

The DFHP was developed to replace "gas-pack" or "gas-electric" units. These units consist of standard practice direct expansion (DX) air conditioners coupled with electric resistance heating, heat pump heating, or gas furnace heating to provide year round space conditioning.

The most common configuration for commercial building unitary HVAC systems combines the DX air conditioner section and gas furnace heating section in one package. A considerable number of these units are now nearing the end of their service lives. Approximately 115,000 units need replacing each year, which corresponds to the number of gas-electric installations anticipated for at least the next 5 years. Replacing an existing gas-electric unit with an all-electric heat pump would require approximately 30-50kW of electric resistance backup heat, with a corresponding upgrade of electric service to the unit. The service upgrade would increase the initial cost, making it difficult to economically replace gas-electric units with all-electric heat pumps. In contrast, a rooftop DFHP using a fossil fuel furnace for backup would use the existing electric and gas service and not require an upgrade to the electric service.

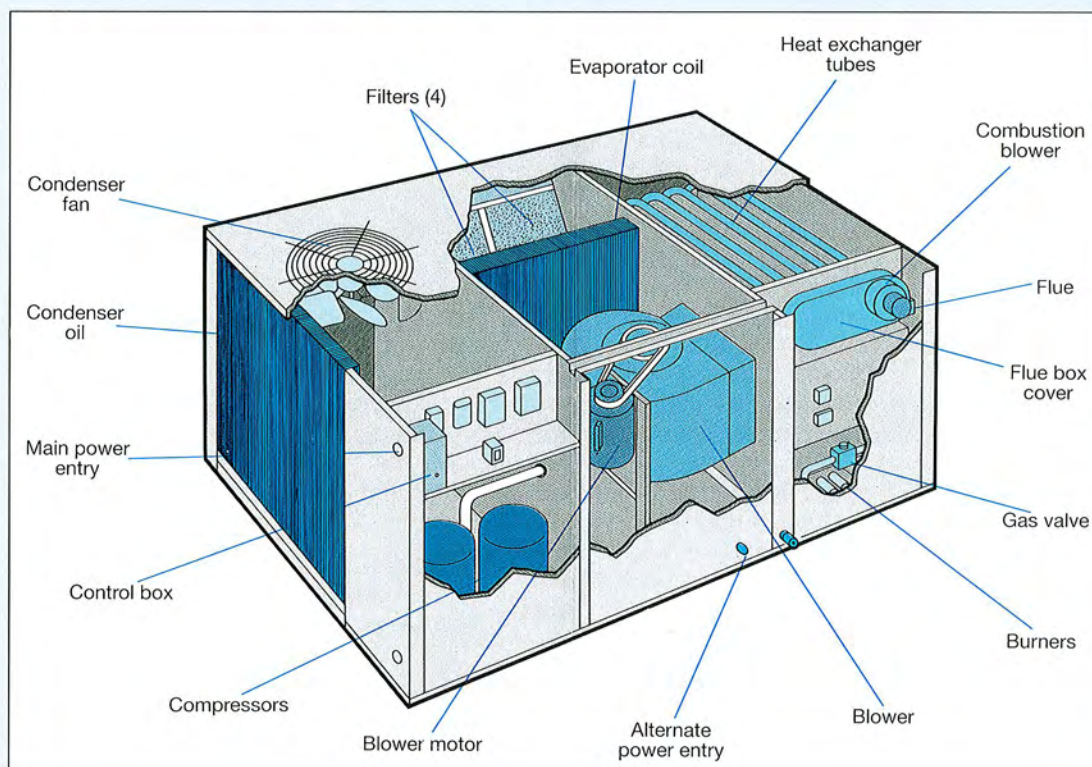


Figure 1:
Dual-Fuel
Heat Pump
Configuration.

EQUIPMENT DESCRIPTION

As shown in Figure 1, the unit is a single package configuration divided into three major sections:

- i. a two-stage air source heat pump with electrical controls,
- ii. a blower and filter section with two indoor refrigerant coils, and
- iii. a two-stage gas burner section with heat exchangers and combustion blower.

Performance Specifications

Rated performance for the prototype DFHP is presented in Table 1. The heat pump ratings are for dual compressor operation.

Controls

The controls include a standard heating/cooling thermostat capable of using up to four heating stages and two cooling stages. A timer and an outdoor temperature sensor are used with this thermostat to operate either the gas furnace or the heat pump, or both, depending on the operating economics.

Operating Economics

Utility rates, plus the DFHP's heat pump and gas furnace efficiencies, determine the economic break-even temperature. As shown in Figure 2, the break-even

temperature is the outdoor temperature at which operating costs for the heat pump and gas furnace are equal. Above this temperature it is more economical to operate the heat pump, and below this temperature the gas furnace is more economical to use. The thermal balance point temperature, or balance point, is based on building heating load and the heating capacity of the heat pump. Below the balance point, the heat pump cannot supply all the heating capacity needed for the building, so, it must be supplemented by the gas furnace, regardless of the costs of either fuel.

In economically favourable DFHP applications, the balance point is above the break-even temperature. In this case, and when the outdoor air temperature is also above the balance point, the heat pump is used as the primary heating source and supplies all the heating capacity. Between the balance point and the break-even temperature, the heat pump, still the cheapest heat source, must be supplemented by the gas furnace. Below the break-even temperature, the gas furnace is the most economical heating source and provides the total heating capacity. Figure 3 illustrates this concept. An outdoor temperature controller and a time-clock control help ensure that the DFHP operates economically. The easily adjustable outdoor temperature controller is set at the economic break-even temperature. It can be readjusted if gas or electricity prices change to keep the total space heating cost as low as possible. The time-clock control is used in areas with on-peak and off-peak winter rates or winter demand charges. The time clock controls the heat pump to account for high usage times of electric rates or high building peak electric demand charges.

Table 1 - Dual-Fuel Heat Pump Prototype Specifications

Cooling capacity 35°C (kW)	25.80
Cooling COP	2.43
High temperature (8.3°C.) heating capacity (kW)	25.80
High temperature (8.3°C.) COP	2.96
Low temperature (-8.3°C.) heating capacity (kW)	12.60
Low temperature (-8.3°C.) COP	1.90
Gas low output (kW)	12.70
Gas high output (kW)	46.90
Gas AGA thermal efficiency	80%

Figure 2:
Gas and Electric Heating
Costs in the DFHP System.

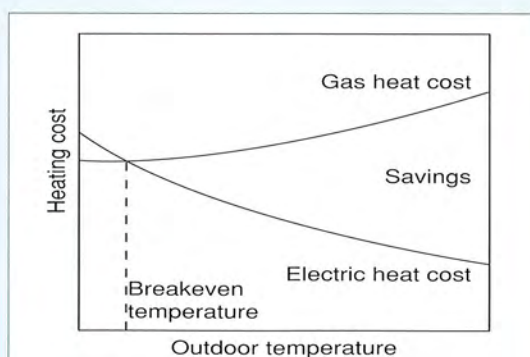
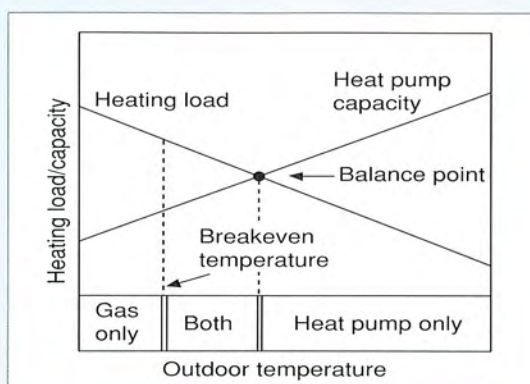


Figure 3:
Typical Dual-Fuel
Heat Pump Operating Modes.



Thermostat Control Staging Sequence

The thermostat used makes two heating configurations available depending on whether the thermostat is being used in the

occupied period (when the building space conditioning is maintained at a comfortable temperature for the occupants) or in the unoccupied period (when the building temperature is setback to a lower level to save energy).

During the occupied period two heat pump stages and the first gas heat stage are available. During the unoccupied period, maximum unit capacity (when two heat pump stages and two stages of gas heat are combined to form the third stage) is available to allow the unit to recover quickly from night setback.

APPLYING THE DFHP

Sizing

Sizing the DFHP follows the same approach as for the standard-practice rooftop gas-electric units. The heat pump is sized to meet the design cooling load and the gas furnace is sized to meet the total design heating load. The first units produced by Lennox will be 7.5- and 10-ton units intended for applications that include space conditioning for restaurants, convenience and food stores, office buildings, and retail outlets.

Basis for Control

Heating season operating costs with the DFHP, as compared with a gas-electric unit, depend on the local utility gas and electric rates and the outdoor profile for the heating season. A combination of low electric rates and high natural

gas rates is required for substantial savings using the DFHP. A substantial heating design load compared to the cooling design load and a relatively long heating season are also necessary. In all cases, economical operation of the DFHP is obtained by establishing equipment control setpoints based on the electric and gas rates.

FIELD TEST RESULT

Field testing was conducted for more than one year at five sites in the United States (Ref. 1). Data were collected, recorded and analyzed as required to meet project objectives. The results demonstrated that performance was in substantial agreement with the manufacturer's original specifications, and that proper conditions provided mutual utility/customer benefits.

Multi-Stage Operation

Use of the four stages of the DFHP varied during the field test of each application. Overall, the first heat pump stage met about half (44-58%) of the seasonal heating loads and the first and second stage of the heat pump provided 55% to 80% of the seasonal heating load. Use of the other stages varied considerably based on the weather distribution and heat pump lockout temperature setting. Applications with large portions of the heating load below the economic break-even temperature have larger amounts of gas-furnace-only operation.

Applications with large portions of the load between the economic

break-even temperature and the thermal balance point temperature had larger amounts of combined heat pump and gas furnace operation. Figure 4 shows the contribution of each stage in supplying the heating load.

The supply air temperature of the DFHP varies with the mode of operation, because the airflow through the unit remains constant. Table 2 shows the average supply air temperature for each of the operating modes. Note that the supply air temperature for operating the dual-compressor heat pump is comparable to the supply air temperature for low fire-gas operation. As the outdoor air temperature decreases the supply air temperature increases because more stages of the DFHP are operating. This provides better comfort levels for building occupants.

Seasonal Heating Energy Use

Replacing a gas-electric unit with a DFHP shifts heating input energy from natural gas to the heat pump. The amount of heating load that is shifted depends on the fraction of the heating load that is above the lock-out temperature. The relative output from the stages illustrated in Figure 4 shows that the heat pump supplied over half of the heating for each application at the test sites.

**BENEFITS:
BUILDING OWNER
OPERATOR AND ELECTRIC
UTILITY**

**Building Owner/Operator
Benefits**

- 1. The Dual-Fuel Heat Pump (DFHP) uses existing gas and electric service when installed as a replacement for rooftop gas/electric units.
- 2. Using simple controls, the DFHP automatically selects the unit that provides the lowest possible heating costs. If fuel prices change, controls are easily adjusted to continue this optimization.

Table 2 - Average Supply Air Temperature/Operating Mode

MODE	AVERAGE SUPPLY AIR TEMPERATURE (°C)
Stage 1: Single-Compressor Heat Pump	26
Stage 2: Dual-Compressor Heat Pump	32
Stage 3: Single-Compressor Heat Pump and Low-Fire Gas	46
Stage 4: Dual-Compressor Heat Pump and High-Fire Gas	58
Low-Fire Gas	33
High-Fire Gas	49
Defrost	25

3. The DFHP will provide increased occupant comfort from the four heating stages and two coolings stages - better than either the furnace or the heat pump alone.
4. The availability of two heat sources provides an alternative heat source in the event of natural gas shortages. This ensures that building operators can provide acceptable comfort levels even when no gas is available.
5. Standard off-the-shelf components ensure reliable operation.

Electric Utility Benefits

1. The DFHP gives electric utilities access to a market that was not previously available to them. The potential increase in electric energy sales ranges from approximately 700 to 1500 kWh/ton, depending on climate and electric and gas prices, with no increase in winter peak electric demand.
2. The DFHP reduces the electric utility summer peak demand

when compared to the unit it is replacing. Specifically the DFHP COP is 2.43 (EER is 8.3 Btu/Wh), and an old unit's COP is 2.05 (EER is 7.0 Btu/Wh).

3. The DFHP offers an improved electric utility annual load factor when compared to either the all-electric heat pump or the combination gas-electric unit. The connected electric load for a 7.5-ton DFHP unit is about 10 kW, compared with 50-60 kW for the standard all-electric heat pump of similar capacity. In addition, the 10-kW demand is not likely to coincide with the electric utility's winter peak period. Over the entire heating season, the DFHP may provide 75% or more of the electric use of an all-electric heat pump with no addition to the utility's seasonal peak demand.

supplemental gas heating that can be controlled to manage space heating operating costs. Electric utility companies benefit from increased winter electric revenues with no increase in seasonal peak load and reduced summer peak demand.

Reference:

- 1) EPRI Dual-Fuel Rooftop Heat Pump Field Test Project, Final Report, November 1989, The Fleming Group.

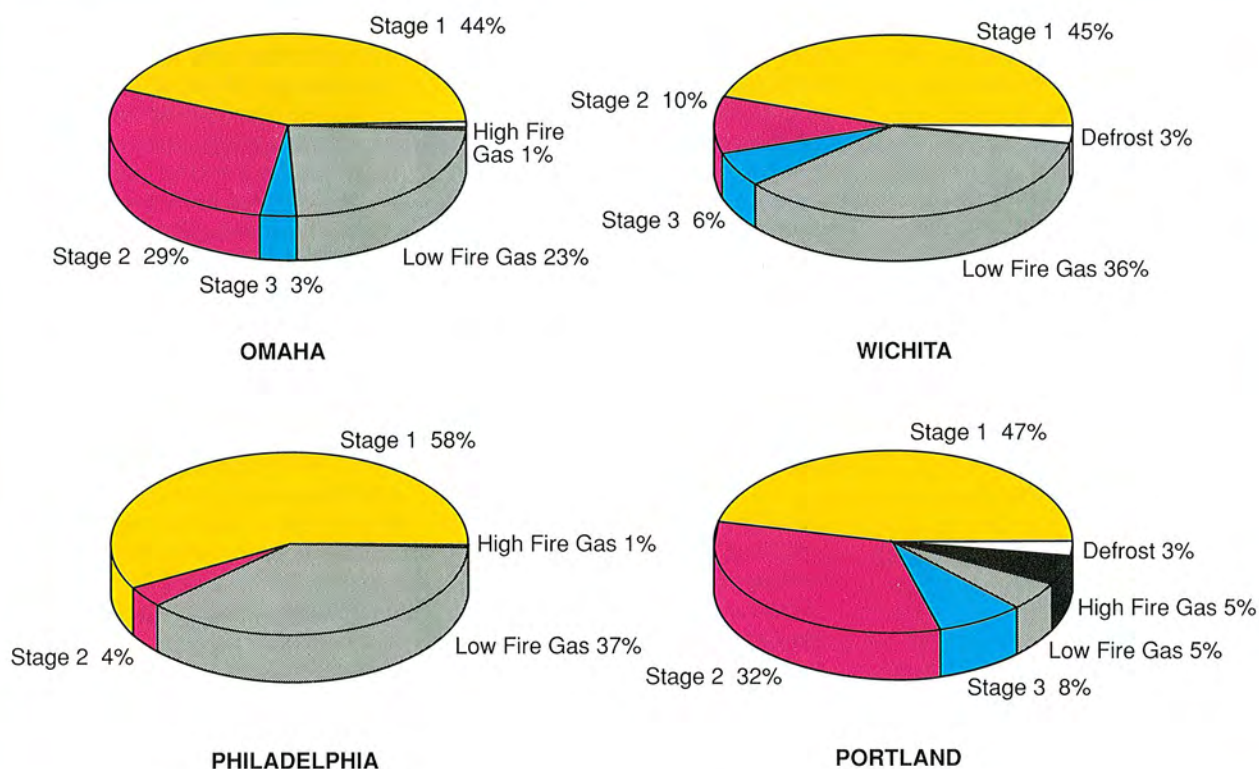
Robert E. Hough and Steven W. Carlson, The Fleming Group, East Syracuse, New York, USA.

Morton H. Blatt and Dr. John P. Kesselring, Electric Power Research Institute, Palo Alto, California, USA.

CONCLUSIONS

The DFHP offers benefits to both the commercial building owner/operator and the electric utility industry. Consumers benefit by having a heat pump with

Figure 4: Relative Seasonal Heating Loads by Stages.



News and Views

Institute for Energetics of Budapest, Hungary searches for business partners for commercialization of hybrid heat pump.

The hybrid heat pump, being developed by the Institute for Energetics, is a compression heat pump with the non-azeotropic mixture NH₃/H₂O as the working fluid.

A pilot plant with a nominal heating capacity of 1000 kW has been built and is in operation. The heat source and heat sink are water temperatures at 25/5°C and 15/85°C respectively. The internal COP is 4.2. The institute wants to introduce the system into the market and is looking for partners. Suitable partners might be a compressor manufacturer or a contractor who is ready to invest capital in energy conservation and, environmental techniques and in marketing the product.

An oil-free screw compressor is applied in the pilot plant, as wet compression is, theoretically, the best solution. This is not a fixed condition. If too costly other compressor solutions are also possible. Some of the rated conditions for the compressor are: Working fluid 85% NH₃ + 15% H₂O (mass ratio), intake flow rate 1000 m³/h, absolute (in/out) pressures 3.6/15.6 bar, temperatures 42.6/104.5°C, density 3.07/11.1 kg/m³.

For more information contact: György Bergmann, Institute for Energetics, H-1251 Budapest, P.O. Box 15, Hungary, Tel: +36 320-720 686-880, Telex 224461.

Heat Transformer

Hoogovens in the Netherlands, a major steel and aluminium works, has decided to install a heat transformer between two of its mills. The heat transformer will use 90°C process

water rejected from a hot strip mill as the heat source for driving the unit. It will produce heat (4.5 MW) for a cold reducing mill. The rated low pressure (2.7 bar) steam production is 6.5 ton per hour at 130°C. Special attention will be paid to the control of the system since the two mills are located some distance apart.

Users group

The idea to establish a users group on large capacity absorption heat pumps and heat transformers has been suggested. The objective is to create a forum for exchange of information between users of these installations. For further information, suggestions and reactions contact the HPC.

Japanese Delegation Visits the Netherlands

Representatives of the High Pressure Gas Safety Institute of Japan (KHK) and Japanese industry visited the Netherlands on 22 January, 1990 to discuss gas engine driven heat pumps and related existing national standards on installation, maintenance and safety regulations.

KHK prepares and gives advice on standards to MITI in Japan with regard to gas engine-driven equipment, including LPG. Other activities of KHK are inspection, certification, training, education and R & D. The meeting was organised by the HPC and in addition, a visit was paid to a gas engine-driven heat pump in an office building, using sewage water as a heat source.

IEA Implementing Agreement on Advanced Heat Pumps

Annexes in preparation and proposals:

- The USA has proposed a new Annex on 'Thermophysical properties of environmentally acceptable refrigerants'. Accurate knowledge of thermophysical properties is essential for identifying suitable replacements for CFCs and designing equipment using these new refrigerants. One of the objectives of the proposal is to determine the properties, resulting in

a publication which will be an internationally accepted bulletin useful to the engineering community and will provide a forum for the exchange of information and data and for the coordination of activities on the subject. A broad industrial involvement in the Annex is essential.

- Chalmers University of Technology, Sweden, is the Operating Agent for a new Annex on 'Experiences with new refrigerants in evaporators'. This Annex is about to commence and any other interested countries can still participate.
- W. Germany has established a national database on new fluids. A proposal has now been submitted for a task on 'New fluids database'. The overall objective is to accelerate the use of non-ozone depleting working fluids in heat pumps and refrigeration systems.
- A new task on 'Second Law Analysis for Heat Pumps' has been proposed by W. Germany. Activities are still in the preparatory stages.

The IEA HPC can provide additional information on new Annexes.

Promotion of Heat Pumps

A significant outcome of the IEA Heat Pump Conferences in Graz, 1984 and Orlando, 1987, was the strong need for a broader awareness of the benefits of heat pumps. This need should be fulfilled through promotional activities. As a result a group of experts from the private sector took the initiative for promotional activities directed towards end users, utilities and governments. The HPC is presently preparing a basis for structural cooperation with the recently established International Heat Pump Promotion Centre (IPC) in Graz.

The IPC create a framework for promotion work. A highlight in the IPC's 1990 programme will be a workshop about promotion, to be held in Graz (see Conference agenda) and organised by the HPC in collaboration with the IPC. Experts from industrial organisations, public interest groups and market researchers will attend the workshop.

Contact: IPC, Lineckerweg 54, A 8044 Graz, Austria.
Tel: +43 316 - 822045
Fax: +43 316 - 392266.

Conferences

**Call for papers*

ASHRAE Annual Meeting and Technical Conference

June 9 - 13, 1990 / St. Louis, Missouri (USA)

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

International Compressor Engineering Conference; USNC/IIR-Purdue Refrigeration Conference; ASHRAE-Purdue CFC Conference

July 17 - 20, 1990 / West Lafayette, Indiana (USA)

Sponsored by the Ray W. Herrick Laboratories.
Contact: Conference Secretary, Ray W. Herrick Laboratories,
School of Mechanical Engineering, Purdue University,
West Lafayette, IN 47907, USA., Tel: +1 317 494-0117.

International Technical Conference on Heat Pumps in Cold Climates

August 13 - 14, 1990 / Moncton, New Brunswick (Canada)

Contact: Dr. S.M. Sami - Associate Professor,
School of Engineering, l'Université de Moncton,
Moncton N.B. E1A 3E9, Canada.
Tel: +1 506 858-4194 / 4002, Fax: +1 506 858-4541 or
Mr. R.L.D. Cane - Caneta Research Inc., 6931 Millcreek
Drive, Unit 28, Mississauga, Ontario L5N 6B8, Canada,
Tel: +1 416 542-2890, Fax: +1 416 542-3160.

Workshop on Concepts for Energy Savings in Heat Pumps and Refrigeration Systems

August 29 - 30, 1990 / Stockholm (Sweden)

Organized by IIR Commission E2, sponsor: The Swedish Council for Building Research. Contact: The Royal Institute of Technology, Dept. of Applied Thermodynamics and Refrigeration, S-10044 Stockholm, Sweden,
Tel: +46 879-074-50, Fax: +46 820-30-07.

*** 3rd International Workshop on Research Activities on Advanced Heat Pumps**

September 24 - 26, 1990 / Graz (Austria)

Organized by the Technical University of Graz.
Contact: Doz. Dr. H. Schnitzer, Organization Committee,
Workshop on Research Activities on Advanced Heat Pumps,
Institut für Verfahrens-technik, Infeldgasse 25, A-8010 Graz,
Austria. Deadline for paper summaries: May 25, 1990.
Tel: +43 316 7061, Telex 311221, Fax: +43 316 77685.

*** Workshop on Market Potential and Programmes to Overcome Impediments for Acceptance of Space Conditioning Heat Pumps**

September 26 - 27, 1990 / Graz (Austria)

Organized by HPC and IPC
(International Promotion Centre, Graz). Contact: IEA-HPC.
Tel: +31 4490-95224, Fax: +31 4490-28260.

4th International Conference Applications and Efficiency of Heat Pumps Systems in Environmentally Sensitive Times. Exhibition

October 1 - 3, 1990 / Munich (W. Germany)

Contact: L. Grove, BHRA, The Fluid Engineering Centre,
Cramfield, Bedford MK43 0AJ, England,
Tel: +44 234-750422, Fax: +44 234-750074.

*** International Trade Fair for Refrigerating and Air Conditioning and Annual Meeting of VDKF (Verband Deutscher Kälte-Klima-Fachleute E.V.)**

October 4 - 6, 1990 / Nürnberg (W. Germany)

(Internationale Fachmesse Kälte-Klimatechnik (IKK) und Jahrestagung des Verbandes Deutscher Kälte-Klima Fachleute e.V.). Contact: Verband Deutscher Kälte Klima-fachleute e.V., Esslinger Str. 80, 7014 Fellbach, F.R.G.

*** Symposium Innovative Applications of Absorption Machinery**

January 19 - 23, 1991 / New York (USA)

Technical Committee 8.3 is sponsoring the above symposium at the ASHRAE Winter Meeting.
Contact: Reinhard Radermacher, Associate Professor,
Department of Mechanical Engineering, The University of Maryland, College Park, MD 20742-3035, USA,
Tel: +1 301454-8876., Fax: +1 301 454-8957.
Deadline for complete manuscripts by May 18, 1990.
Papers should refer to new applications of absorption machines or novel concepts of the integration of absorption units in larger energy conversion systems.

*** New Challenges in Refrigeration**

August 10 - 17, 1991 / Montreal (Canada)

Contact: Coordinator Steve Bettner. XVIIIth International Congress of Refrigeration, 3600 Casavant Boulevard West, St. Hyacinthe, Quebec, Canada, J2S 8E3,
Tel: +1 514 773-1105, Fax: +1 514 773-8461.
Application due by: 1 Oct., 1990; Final date: 1 Dec., 1990.

Bibliography

Installations

Favourable results with the application of electrically driven heat pumps.

J. de Jong, Energiebureau, NV PNEM. Elektrotechnik 67 (1989) 11 (November), pp. 1005 - 1010 (Dutch).

In the Netherlands, in contrast to many other Western countries, the electrically-driven heat pump has only been implemented in very small numbers (except for cooling purposes). Nevertheless, this equipment is an important instrument in achieving energy savings and environmental protection. An electric utility, PNEM, has therefore initiated heat pump projects. This article describes the experiences with a standard 35 kW air-to-water heating-only heat pump. After almost two years it has proved to be a technically and energetically successful project: COP = 3.4; PER = 1.3; load over 90% of available time: no fault. Due to the actual low price of alternative fuels, i.e., natural gas, the economic results to date are lower than originally expected, but are still promising.

Sports and Recreation Centre Glanerbrook, Geleen

1. Preliminary study for the technical installations A.H.W. Vinken, H.J.M. Knipscheer, *Klimaatbeheersing* 18, (1989), nr. 11 (Nov.), pp. 373 - 383 (Dutch).
2. Final technical design and technical operation and maintenance, H.J.M. Knipscheer, *Klimaatbeheersing* 18 (1989), nr. 11 (Nov.), pp. 392 - 399 (Dutch).

The sports and recreation centre encompasses a 400m outdoor skating

track, an indoor ice hockey rink, outdoor and indoor swimming facilities, including a tropical swimming pool, sports halls, sauna, and other recreational facilities.

The first article discusses the results of a feasibility study for determining the technical installation. Seven alternatives were considered including heat recovery, solar energy, co-generation and wind energy. The solution with the shortest pay-back period consisted of using the heat obtained by cooling the skating track and the skating rink to preheat the ventilation air. For that reason, two of the four cooling compressors are used in the heat pump mode. Additional heat is supplied by a boiler. In the summertime the concrete floor of the outside skating track is used as a large solar collector functioning as a heat source for the heat pumps.

The second article discusses the technical design such as the choice of refrigerant (R22 versus NH₃), the design parameters of the cooling and heat pump installation, control aspects, energy balance, investment costs, risks and preliminary evaluation of the start-up period. Calculated energy savings are about 345,000m³ natural gas.

Heat pump cascade with tandem function to generate electricity from natural gas.

H. Loest, Gas Wärme International, October 1989 (German).

The main objective of the initial installation design described in this article was to achieve rational use of energy with emphasis on technical, economic and ecological aspects. This concept is characterized by the option for using gas motors for driving either electric generators or heat pump compressors. Water treatment effluent serves as a heat source and the produced heat is used mainly for space heating purposes. The ideas and

considerations underlying the new supply concept are presented with reference to an analysis of the load structure. Implementation of the project, operating modes and results of the new facility are described and evaluated in this article.

EPRI issues Applications Handbook on Commercial Heat Pump Water Heaters

Electric Power Research Institute (EPRI) (English).

This applications handbook offers a single source of useful information for understanding and successfully applying commercial air-source heat pump water heater technology. As a competitive water heating alternative, these heat pumps generate cooling output without additional energy cost. The handbook, written for utility and technical personnel and their customers, covers hardware, function and performance. It provides guidelines and checklists for site selection, design and operations and maintenance. Request for copies should be directed to RRC, P.O. Box 50490, Palo Alto, CA 94303, USA, Tel: +1415-965 4081.

Refrigerants

ASHRAE publishes CFC resource book (English).

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has published "CFCs: Time of Transition", a compilation of ASHRAE and other world-wide technical literature. The book covers all phases of the CFC issue, including current and future alternatives. Contact ASHRAE Publication Sales, Atlanta GA, USA, Tel: +1404-636-8400, Fax: +1404-321-5478, Order code 90315.

Absorption fluids data survey, 1989 update.

R.A. Macriss and T.S. Zawacki, *Institute of Gas Technology, Chicago, USA. ORNL/Sub/84-47989/4, pp. 20-21 pp. Appendices (English).*

An update is given of a series of prior reports on absorption fluids and data, ORNL/Sub/84-47989/1,2,3. It covers additional data developed and published mainly between 1985 - 1988, and cites 44 additional references (in English, German, Japanese, Russian, or French).

Seventy-four different worldwide publications containing data relating to properties of binary, ternary, and multicomponent absorption fluids were identified. Of these, 30 manuscripts include applications of absorption fluid properties data toward evaluation, assessment, or design of chillers or heat pumps but do not include actual fluid properties data.

The absorption fluids discussed in the 44 documents are combinations of 9 different 'refrigerant' compounds and 30 single, 7 binary, and 1 ternary 'absorbent' compounds.

First industrial application of non-azeotropic mixture.

J.C. Blaise, T. Dutto and J.L. Ambrosino, *Electricité de France, Direction des Etudes et Recherches, Institut Français du Pétrole. International Journal of Refrigeration, Vol. 12, No. 5, September 1989, pp. 255 - 258 (English).*

Experiments were carried out on a heat pump which recovers energy from a refrigerating installation and warms water from 58 - 68°C. The aim of the experiment is to compare the COP and the thermal power of the heat pump using a non-azeotropic mixture instead of R12. Therefore, performance of the heat pump have been determined with R12 to obtain a reference, then R12 was replaced by a ternary mixture. The installation includes 31 sensors connected to a computer. The influence of non-azeotropic mixture on the volumetric and isentropic compression efficiencies and on the overall coefficient of heat transfer of

the condenser can be evaluated. Tests with the mixture give the following results compared with R12: +20% for the thermal power at the condenser; +1.5% for the COP; -2% for the volumetric efficiency; -10% for the overall coefficient of heat transfer at the same heat flux. The influence of refrigerant leakages on the mixture composition was studied. The leakages were simulated during running of the plant. It was noticed that the leakages at the input of the dry expansion evaporator and at the top of the receiver do not modify the concentration of the different components enough to change the working conditions of the heat pump.

Physical and thermal properties of the water-lithium bromide-zinc chloride-calcium bromide system.

S. Iyoki and T. Uemura, *Faculty of Engineering, Kansai University. International Journal of Refrigeration, Vol. 12, No. 5, September 1989, pp. 272 - 277 (English).*

This investigation was undertaken to examine whether the water-lithium bromide-zinc chloride-calcium bromide system is suited for absorption refrigerating machines, absorption heat pumps and absorption heat transformers. The physical properties (density, viscosity, solubility and vapour pressure) and the thermal properties (specific heat capacity and heat of mixing) of lithium bromide-zinc chloride-calcium bromide aqueous solutions were measured.

Measurements of density, viscosity, vapour pressure and specific heat capacity were carried out at various temperatures and absorbent concentrations. Solubilities were obtained in the temperature range 280.25 - 455.25 K. The heats of mixing at 298.15 K were obtained for solutions whose absorbent concentrations ranged from 0 - 78.0 wt%. The empirical formulae for solubility, vapour pressure, specific heat capacity and heat of mixing were obtained from experimental data. On the basis of these observed data, the enthalpy versus concentration chart of this system was constructed.

Vapour pressure of the water-lithium bromide system and the water-lithium bromide-zinc bromide-lithium chloride system at high temperatures.

S. Iyoki and T. Uemura, *Faculty of Engineering, Kansai University. International Journal of Refrigeration, Vol. 12, No. 5, September 1989, pp. 278 - 282 (English).*

The vapour pressures (10.74 - 281.36 kPa) of the water-lithium bromide system were measured in the range of temperatures from 367.05 to 454.85 K and absorbent concentrations from 38.9 to 70.3 wt%. Furthermore, the vapour pressures (62.16 - 259.15 kPa) of the water-lithium bromide-zinc bromide-lithium chloride system were also measured in the range of temperatures from 373.05 to 423.45 K and absorbent concentrations from 50.8 to 63.6 wt%. The vapour pressure measurements of these systems were made using the boiling point method. To examine the accuracy of the experimental apparatus, the vapour pressures of pure water were measured at high temperatures and agreed with literature values. The vapour pressure data obtained for these systems at high temperatures were compared with the extrapolated values from the empirical formulae which were obtained at low temperatures.

Recent papers on Refrigerant R134a thermodynamic properties.

1. J. Petrak, *Refrigerant R134a, the h, lg p. graph and the evaluation of the single stage refrigerant cycle. Klima-Kälte-Heizung, 12/1989, pp. 566 - 570 (German).*
2. H. Lippold, *Thermodynamic properties of R134a. Luft- und Kältetechnik, Vol. 25, No. 4 (1989), pp. 182 - 185 (German).*
3. M.O. McLinden et Al. *Measurement and Formulation of the Thermodynamic properties of Refrigerants 134a (1, 1, 1, 2 - Tetra-fluoroethane) and 123 (1, 1 - Dichloro - 2, 2, 2 - Trifluoroethane). ASHRAE Transactions, Vol. 95, Part 2 (1989) (English).*

In the international literature, many papers are appearing on the new, environmentally safe refrigerants. Recently several papers appeared on the thermodynamic properties of R134a. Petrak presents a h, lg p. graph of R134a, based on work carried out at the Refrigeration Research Institute in Prague.

Lippold presents data in tabular form, derived by VEB Kombinat ILKA in the DDR. Both Petrak and Lippold use their R134a data to compare the performance of R134a with R12. An extensive project on R134a, together with R123 is being carried out at the National Institute of Standards and Technology in the USA.

The paper of McLinden and co-workers formulates the thermodynamic properties of both fluids using a modified Benedict-Webb-Rubin equation of State, fitted to experimental data. The data sources are summarized and compared to other literature sources. Tables and diagrams of the thermodynamic properties of R134a and R123 are presented.

Vapour absorption into liquid films on rotating discs.

F.E. Swallow and I.E. Smith, School of Mechanical Engineering, Cranfield Institute of Technology, Bedford, UK. International Journal of Refrigeration, Vol. 12, No. 5, September 1989, pp. 291 - 294 (English).

The paper describes a novel absorption device for inclusion in a compact sized absorption heat pump. Current research is concentrated on the isothermal falling film absorber for which calculations are presented to show the necessary laminar nature of such films. The importance of film surface lifetime to the absorption process is highlighted and an expression derived for the lifetime within an adiabatic absorber is explained. An absorbent film is picked up by a disc spinning on a horizontal axis and semi-submerged in a pool of concentrated absorbent. Surface renewal occurs on each revolution, from which it is shown how the absorption coefficient is related to the disc speed. Initial experimental results are discussed and reasons for deviation

from the theory suggested. Absorption coefficients about seven times those of films falling under gravity are shown to be achievable, and an equation relating the required absorber size to the rotational speed is proposed.

Thermodynamic modelling of refrigerants

M. Barret, Y. Candeau, C. Marioton, J.P. Balaesque. Rev. Gen. Froid, December 1989, pp. 690 - 695 (French).

For many years mathematical models have been available which enable accurate computation of thermodynamic properties of a large number of refrigerants. On the other hand, modern informatics systems permit an increasing number of specialists to have an efficient calculating tool at their disposal. After a presentation of the numerical models and methods that have been used by the authors, the calculation model "Thermofluid" is detailed, a tool for dimensioning cooling installations.

The programme is written in Pascal and can be run on IBM and IBM PC compatibles.

IEA Publications

Learning from experiences with heat transformers in industrial processes, CADDET Analyses Series No. 2.

K. Munch Berntsson et al; CASU/ CADDET, Sweden and Sittard. December 1989, pp. 117 (English).

This analysis report summarises the results of recent work undertaken by the CADDET Analysis Support Unit (CASU). The work involved: the collection and evaluation of data from demonstration plants; an analysis of the impact of the more important technical and economic parameters on the economics of such systems; a comparison with the more obvious competing technologies; a process integration analysis assessing the impact of heat transformers on the process in various types of industry.

The analysis report contains the following chapters: General technical aspects of the heat transformer; experiences from demonstration plants; technical-economic comparisons with computing technologies; process integration of heat transformers; discussion and general conclusions.

IEA District Heating (Annex II); District heating and cooling, RD&D project review.

Published by NOVEM 1989:R1, pp. 274 (English).

In October 1989 IEA District Heating published an RD&D project review on district heating and cooling. The report deals with various end-use technologies, including heat pumps. Eight Danish projects on heat pumps are described. Topics are decentralized heat pumps in a central low temperature heat source system, heat pumps for heat recovery in industry, in combined heat and power systems, experiences with large scale systems, combined systems with solar heat source (demonstration project Vester Nebel), monitoring of a 650 kW heat pump using 30°C rejected heat of a salt production plant, a gas engine-driven ice-water heat pump and an engine-driven ground water heat source/storage heat pump.

- German projects deal with (direct evaporation) vertical ground coupled heat pumps, lean-burn gas engine drives and advanced absorption systems.
- Finland reports on a 0.5 MW groundwater heat pump.
- A district heating and cooling application in the Sandvika area and a large system with intermediate temperature are reported upon by Norway.
- The USA reports on a two-stage advanced absorption system study and an open cycle system study using water as a refrigerant.

IEA District Heating; Advanced District Heating Production Technologies.

Published by NOVEM, 1989: R2, pp. 717 (English).

IEA District Heating has issued a report on advanced district heating production technologies. Amongst other things 6 Scandinavian heat pump installations are presented. Main emphasis is on the achievement of improved COP values through optimal design, application and use of the heat pumps.

In a Norwegian article it is shown that an effective computerized control system is able to improve COP values by as much as 10 - 20%. Two Norwegian articles deal with the possibility of using heat pumps for district heating as well as district cooling. From a central station water at 25°C is pumped to individual heat pumps which provide heat at 50-80°C.

The heat source for the main heat pump is either sea water or waste water. When cooling is needed in summer the same distribution system can be used. Another article deals with improvement of the evaporator of a Norwegian heat pump using sewage water as a heat source. The conventional shell-and-tube evaporator is replaced by a plate-type evaporator. This is essential for the extraction of heat from cold or unclarified water.

In a Finnish article the use of heat pumps in a back pressure power plant is described. Heat is extracted from several sources within the plant. Utilized heat losses are in the range of 1 - 1.2% of the boiler capacity, representing a cooling capacity of 5.3 MW.

Finally, a Swedish article presents an overview of the use of large heat pumps in district heating systems in Sweden.

Codes & Guidelines

Cost calculations for heat pump heating systems.

The German VDI has issued guideline 2067, Volume 6 "Calculation of the costs of heating installations: heat pumps". This guideline does not contain calculation rules which can be used independently, but deals with the special aspects of the heat pump technique. It must be used in conjunc-

tion with volumes 1, 2 and 4 in which the operational and economical principles, space heating and hot water supply are dealt with respectively.

Volume 6 applies to electrical and combustion engine-driven heat pumps for space heating and for the heating of tap water. Simple relations, tables and graphs represent the means by which the usual heat pump related-costs should be determined. A shortened calculation method is also provided together with an example calculation for explanatory purposes. The price of the volume is DM 72,10. It is published by Beuth Verlag GmbH, Burggrafenstrasse 6, 1000 Berlin 30.

CECOMAF issues new code of practice for reduction of CFC emissions from refrigerating systems.

Source: E.A. Cosijn, *Koude en Klimaat*, Vol. 82 (1989), No. 10 (Oct.), pp. 9 - 10 (Dutch).

CECOMAF is a business organization of European manufacturers of refrigeration equipment; the manufacturers being represented in CECOMAF by their national business organizations. CECOMAF has been involved in discussions on the CFC issue on a European level since the beginning of the eighties.

In 1983, the 'Code of Good Practice for the Reduction of Emissions of Chloro-fluorocarbons R11 and R12 in Refrigeration and Air Conditioning Applications' appeared as a joint publication of CECOMAF and the European Community. This code, translated into many European languages, was widely distributed.

After the '1987 Montreal Protocol on Substances that Deplete the Ozone Layer' it became clear that a new (simplified and improved) code could be of use in many European countries. A CECOMAF working group therefore started the revision of the 1983 Code of Good Practice. Early in 1989 the group was able to finish the work with the publication of the CECOMAF document 'Reduction of Chloro-fluorocarbon Emissions from Refrigerating Systems'. The document lists measures to reduce CFC emissions

during: the production of components and systems; the installation and commissioning of systems; maintenance and repair. The code has been submitted to the European Commission as a proposal for an European Code of Good Practice.

Design and integration guidelines for gas engine driven heat pumps.

H.H. Hamberg et. al. *NOVEM Report October 1989*, pp. 170 (Dutch).

Having a great deal of experience in design, realisation and monitoring of gas engine-driven heat pumps in the Netherlands, the authors present practical guidelines for design and hydraulic integration of bivalent centralized systems for the residential market. With the earlier installations, technical and economic problems occurred as a result of faulty design, over-estimated knowledge and insight into the technology and a wrong approach (refrigeration technology). Primary target groups are consultants and installers in the field of heating and refrigeration.

A model for assessment of the profitability of new energy technologies in buildings.

B. Diczfalussy and B., Rapp, *Swedish Council for Building Research, Stockholm, Sweden*. pp. 32 (English).

The purpose of the paper is to present a simple and standardized model to calculate the profitability of investments in renewable energy technology in buildings. The aim of the model will be two fold. Firstly, it will provide a standardized method for international comparisons of different renewable energy technologies with regard to their profitability. This can be useful, for example, within the International Energy Agency. Secondly, the model will provide a standard input sheet which can be used for application in most types of buildings.



Meetings

Annual meeting DKV 22 - 24 November, 1989.

Abstracts of German papers on the following topics are available:

Comparison and investigation into physical and transport data of refrigerants and their mixtures (R152a/R134a; R134a; R142b/R152a; R134a/R123; R22/R114; R123).

Vuilleumier heat pump (10 kW prototype).

2-Stage absorption heat pump (H₂O-LiBr₂).

Capacity control with non-azeotropic mixtures.

Physical and transport data of sorption fluid mixtures.

Electronic expansion devices.

The proceedings of this meeting will be issued shortly by DKV.

ASHRAE winter meeting Atlanta, 11-14 February, 1990

The various meetings and exhibition offered an excellent opportunity to overview the US heat pump community and the many heat pump activities ASHRAE is dealing with.

During technical sessions various papers on heat pumps were presented, some of which are shown below:

Status on the double-effect absorption heat pump with Columbia Gas.

The effort has led to the design, fabrication and planned testing and demonstration of a prototype residential unit, ready for field testing by 1991. Currently a manufacturer/licensee for this technology is sought to commercialise the system. The heat pump output is 21 kW at 8°C outdoor temperature (10.5 kW cooling at 35°C) and the target heating COP is 1.5 (cooling 0.8). Actual measured heating COP is 1.43 and cooling COP 0.81.

Diffusion absorption heat pump (Creatherm AG, Schlieren, Switzerland)

Results of measurements on 3kW NH₃/H₂O prototype modules show a heating COP of 1.5, obtained with a newly developed boiler. Since a mechanical pump is not required, the units are considerable in height (1.9 m). The standing area is only 0.14 m². The quantity of ammonia in the unit is below 1 kg. Helium is used as inert gas. Modules allow for easy connection, thus producing varying kW performance. Production cost of a total package is claimed to be on the order of the actual price of a mechanical solution pump of a traditional absorption heat pump (no expensive control devices needed). A payback period of less than 10 years is claimed at today's gas prices, and the units operate very reliably.

Heat pump life and compressor longevity in diverse climates

A study of service life and compressor longevity based on a total of 2184 US heat pumps has been concluded. A major finding was that the average heat pump owner can expect to replace the compressor no more than once during the unit's normal service life. The median service life of original factory-installed compressors was found to be approximately 14.5 years. Based upon this and on other life studies and historical heat pump production data, EPRI has made projections on future heat pump replacements, as well as predictions of total future heat pump production needs for the US market.

Canadian ground-source heat pump installation standard (CAN/CSA-C445-M)

An installation standard for ground-source heat pumps was identified by industry, utilities and government. The standard provides customer assurance by the inclusion of a ground-loop warranty. The standard also enhances utility confidence in the long term system performance and reliability of ground-source heat pumps. The standard concentrates on methods, materials, testing and documentation of system design and installation and it includes ice-lensing concerns and ways to prevent them.

Water-source heat pumps

Water-source heat pumps in the USA are achieving ever greater market acceptance, including commercial applications. One paper dealt with the characteristics of closed water-loop systems and includes an analysis of the existing and potential market for this approach for medium and large commercial structures, (Pietsch J.A.).

A survey of system configurations currently utilized in the USA in commercial applications has been performed and results have been presented in another paper. The survey found only one generally accepted open-loop source/sink for commercial applications, i.e., groundwater. The three generally accepted closed-loop source/sinks identified were the heater/rejecter, ground-coupling and environmental water sources (surface water or groundwater). The results may assist designers in selecting the most beneficial system configuration to a given application (Hughes P.J.).

The application of lakewater as a heat source and sink has been investigated by the University of Alabama. Several open-loop systems were monitored and thermal surveys of lakes were performed. Computer codes were developed to determine coil length and lake thermal response. Recommendations are made concerning heat pump selection, pumping systems, piping arrangements and lake size/depth characteristics, (Kavanaugh S.P.).

HPC Newsletter Errata

In Volume 7, number 4, page 6 / article by N. Nagamatsu and H. Moriyama, left column. The 35th line from the top should read: 'The value of the storage capacity is almost the same as the criteria for the interim evaluation for this unit (34 kcal/kg), however the heat recovery rate was below the criteria (75%) of the interim evaluation' (errata underlined).

Future Issues 1990

<i>Vol./No.</i>	<i>Topic</i>	<i>Deadlines</i>
8/2	Third IEA Heat Pump Conference Tokyo.	
8/3	Combustion engine-driven heat pumps (practical experiences, developments, field monitoring).	July
8/4	Sorption heat pumps (residential, commercial, industrial applications, practical experiences, developments).	October 1

New HPC Products

HPC-R6: Engine-driven heat pumps. Analysis of existing systems.

HPC-WR5: Proceedings of the workshop on "High Temperature Heat Pumps".



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