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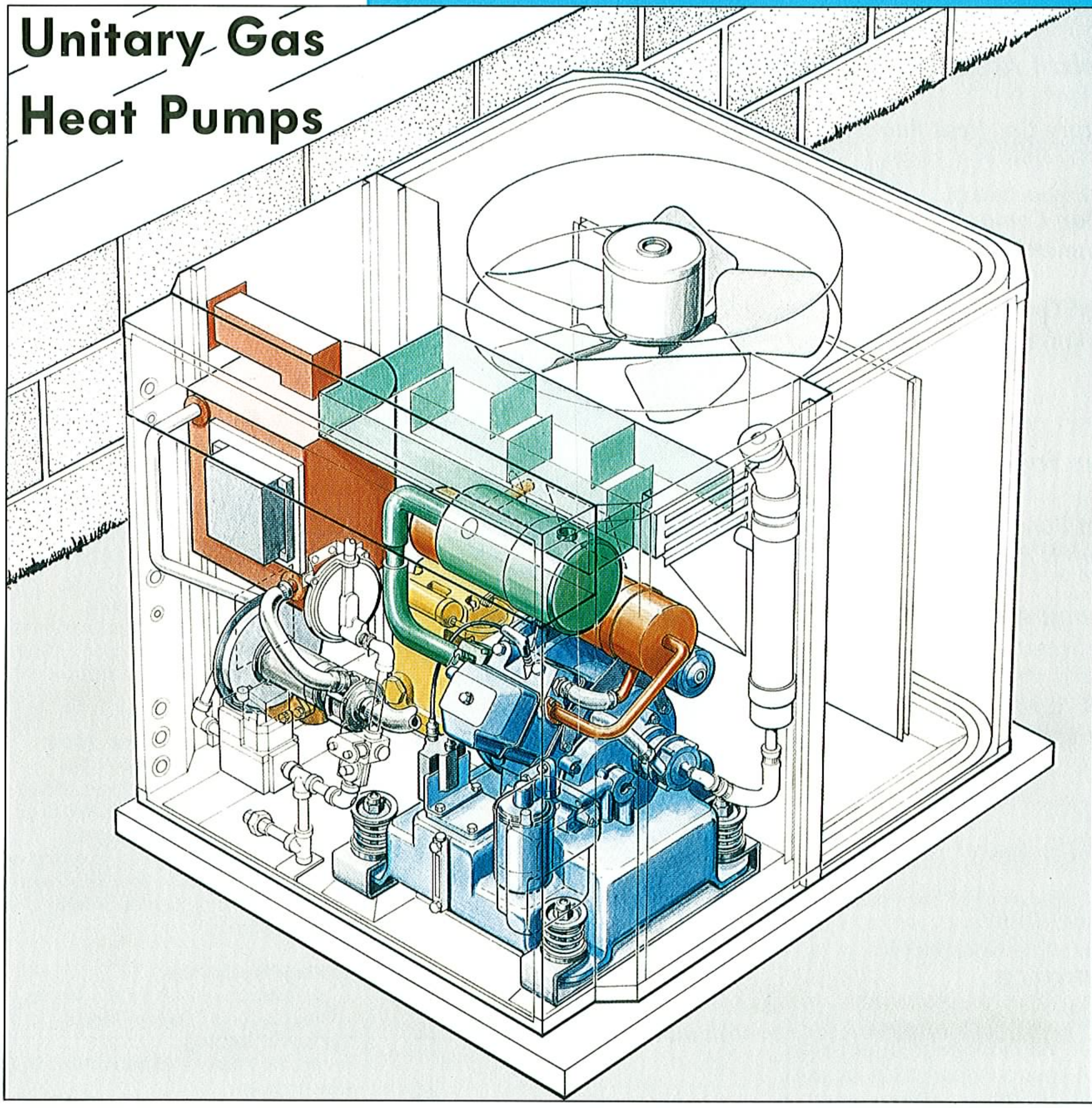
IEA Heat Pump Centre

NEWSLETTER

Unitary Gas Heat Pumps



10 Years HPC

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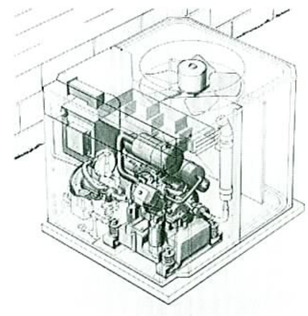
Contents



***Front Cover:** This 10.6 kW gas-engine driven heat pump has recently completed trials in the USA. Further details are given in the article on page 4.*

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

Editing/Production:
Lucinda Maclagan / Roswitha Muyres / Maria de Jong / Heleen Smeets.
Technical Editing:
Jos Bouma / Mike Steadman / Bert Stuij.
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Editorial

This month the IEA Heat Pump Centre commemorates its 10th year of operation. On the 8th of December 1982 the HPC was established in Germany, as Annex 4 of the IEA Heat Pump Programme. Since 1990, it has continued as Annex 16 in the Netherlands.

In those ten years the heat pump market has seen dramatic changes. On one hand, a sharp fall in oil prices has significantly reduced the economic benefits of heat pumps. On the other hand, environmental considerations, in particular concern about global warming, have emerged as a new and powerful driving force for heat pumps in many application areas.

The IEA Heat Pump Programme has responded to these challenging developments with a new long-term strategy plan for the 1990's and into the 21st century. The strategy is based on management by objectives, with an emphasis on the environment, markets and technology. I am confident that the strategy plan will be a sound basis on which to continue our efforts to stimulate the use of heat pumps as an energy efficient and environmentally beneficial technology.

The theme of this Newsletter is unitary gas heat pumps. They have the potential to answer a specific challenge, i.e. the economic realization of heat pumps in areas with a good gas infrastructure, where they have to compete against cost-effective and very efficient gas boilers. Small gas engine vapour compression systems can play an important role here. They show excellent energy efficiency, and major improvements in engine endurance are taking place. At the same time CFC-free gas fired sorption equipment, often with ammonia as working fluid, attains growing attention.

More in general, in the context of the ongoing debate on the acceptability and regulation of refrigerants, the interest in ammonia as a working fluid is growing. Small compression type heat pumps with ammonia as working fluid are now entering the market in Europe.

Significant developments such as these will be dealt with at the 4th IEA Heat Pump Conference, advertised elsewhere in this newsletter. May I encourage you to consider attending this event, and catch up with the latest information about heat pump systems, with a focus on application and experience.

Jos W.J. Bouma
General Manager.

Unitary Gas Heat Pump Development Status in the USA

S.I. Freedman, C.E. French, G. Nowakowski and G.H. Myers, USA

Summary

The Gas Research Institute (GRI) is conducting a multi-faceted development programme to make natural gas fuelled unitary heat pumps commercially available to heat and cool buildings in the residential and light commercial sectors. Natural gas fuelled heat pumps offer the benefit of lower annual space conditioning operating costs for ratepayers, gas load-levelling and market retention benefits for gas utilities, and a reduction in the growth of peak demand requirements for electric utilities.

Gas-engine driven vapour compression heat pumps were successfully field tested in the United States in 1991. Several gas companies in the USA are testing gas-engine driven heat pumps made in Japan. Gas heat pumps based on absorption technology are being developed by both the Department of Energy (DOE) and GRI. Adsorption and chemisorption heat pumps under development by GRI are in component and systems development phases. This paper provides the international heat pump community with an update on recent progress in developing unitary heat pumps for use in the United States.

Introduction

GRI is a private, not-for-profit organization whose membership includes 39 natural gas pipeline companies, 156 natural gas distribution companies, 54 municipal utilities, 51 natural gas producers and 21 associate members from gas companies outside of the United States. GRI plans, manages and develops financing for a cooperative research and development programme on the supply, transportation, storage and end use of natural gas. One of GRI's important programmes is the development of gas-fuelled residential and commercial heat pumps and chillers. Heat pumps are of interest globally as a class of technologies which can enable our industrialized society to provide comfort space conditioning (heating and cooling) at high efficiency of primary energy use and with reduced net energy industry emissions. As energy resource conservation and environmental cleanliness become more important, so does the need for heat pumps. In addition, gas heat pumps are expected to be economically attractive to users; the projected life-cycle cost of heating and cooling are most often lower with gas heat pump systems than with separate gas furnaces and electric air conditioners or with electric heat pumps.

To date, only electric powered heat pumps have been commercially available for residential and light commercial space conditioning service, even though the principles of many of the gas fuelled technologies have been known for decades and used in various industrial processes. Thermodynamically, air conditioners and chillers are heat pumps; however, in this article the term heat pump is used to describe systems which in addition to providing summer cooling, provide winter heating,

Table 1: Gas fuelled unitary heat pump systems under development, engineering and test in the USA.

Type	Main funding source	Developer	Status
Engine driven			
Reciprocating engine	GRI	York/Briggs & Stratton	Market entry
Reciprocating engine	Japanese (GRI Field Test)	Aisin Seiki	Completed field test
Reciprocating engine	Japanese (So Cal Gas Field Test)	Yamaha	Ongoing field test
Absorption			
GAX (H_2O-NH_3)	DOE	Phillips Engineering	System engineering
GAX (H_2O-NH_3)	GRI	Several	Component Development
Adsorption			
Carbon-NH_3	GRI	Wave Air	Development
Chemisorption			
Salt-NH_3	GRI So Cal Gas	Rocky Research	Development

Manufacturer	Size (kW)	Size (RT)
Yamaha	4.6 - 18.5	1.3 - 5.3
Yanmar	10.5 - 27.7	3.0 - 7.9
Aisin	11.6 - 27.7	3.3 - 7.0
Sanyo	3.5 - 82.6	9.9 - 23.5

Table 2: Japanese engine driven heat pumps.

obtained in part by removing heat from a heat source (outdoor ambient air, ground, water).

Background

There are two general categories of heat pumps: mechanically driven and heat actuated. Mechanically driven heat pumps may be powered by electric motors, engines, or by any other source of mechanical power. The mechanical power turns a compressor, which pumps a condensible vapour from a lower pressure to a higher one with heat delivered by the condenser and received by the evaporator. Heat actuated heat pumps involve either solids or liquids which pick up and release a vapour resulting in an appreciable heat interaction. By managing the phase change of the vapour to occur at high and low temperatures and pressures, heat can be delivered to and removed from evaporators and condensers at high and low temperatures.

Heat actuated heat pump processes have several forms of sorption: absorption, whereby a vapour goes into a liquid solution; adsorption, whereby a vapour forms a film which adheres with strong intermolecular forces to a high surface area (solid) material; and chemisorption, whereby the vapour forms chemical bonds in the crystal lattice of a solid. All thermally activated heat pump systems involve evaporators and condensers whose heat interactions involve outdoor ambient and interior air, either directly or through a heat transfer fluid loop. The absorption systems operate in a continuous manner while the adsorption and chemisorption systems act in a batchwise manner, in which beds of sorbent are periodically discharged and charged.

Programme Description

The types, developer and status of the gas fuelled unitary heat pumps under development or test in the USA are shown in Table 1. Currently, reciprocating engine driven heat pumps are commercially available only in Japan. The Japanese units are designed specifically for Japanese buildings and use room convectors to heat and cool interior air directly from the refrigerant. Market acceptance of these units is presently limited to regions where energy costs are similar to those in Japan. As is shown in Table 1, several have been or are being tested in the USA, suitably modified for application in the United States. Table 2 outlines the currently available Japanese units.

Engine Driven Heat Pumps

The most advanced heat pump developed for the market in the United States is the York/Briggs & Stratton 3 RT (10.6 kW) engine driven heat pump (see Figure 1 and front cover). Current plans of the commercialization consortium is to perform a field demonstration in which 50 units will be built and sold in 1992. A ten unit field test programme started in 1990 was completed in 1992. Early results suggest that the heat pump is a major success with excellent performance and reliability. Table 3 shows the performance and average outdoor temperature of the units for the first year of the field test. For reference purposes, the 3 RT gas engine-driven heat pump has steady state COPs of 0.90 and 1.50 at ARI rating conditions of 35°C and 8.3°C outdoor ambient temperature. The availability of entire heat pump systems during the year-long field test was 99%, with five units operable 100% of the time

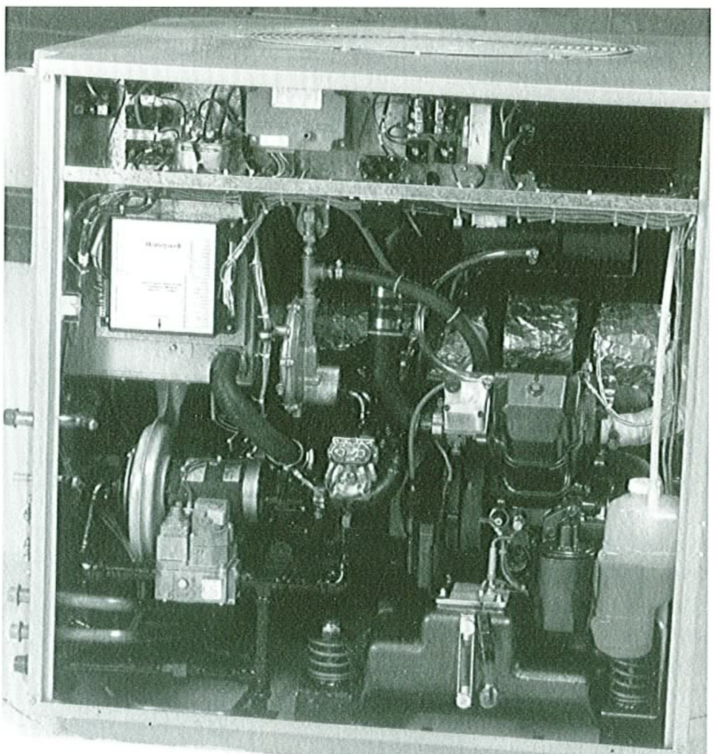

Figure 1: The York/Briggs & Stratton 3 RT (10.6 kW) engine driven heat pump.

Location	Seasonal cooling gas COP @ Average outdoor temperature (°C)	Seasonal heating gas COP @ Average outdoor temperature (°C)	Cooling operating hours	Heating operating hours	Start-up dates
York	1.00 @ 24	1.34 @ 3	2354	5138	12/23/89
Chicago	1.00 @ 24	1.27 @ 1	1902	4189	1/17/90
Wheaton	1.03 @ 26	1.25 @ -2	822	2560	1/26/90
Girard	1.16 @ 23	1.16 @ 2	861	3432	2/09/90
Baltimore	1.07 @ 23	1.20 @ 2	1361	1835	3/23/90
Maplewood	1.05 @ 25	1.27 @ 4	1289	2427	5/04/90
Brooklyn	0.93 @ 27	1.27 @ 4	1165	2865	8/25/90
Atlanta	1.21 @ 24	1.54 @ 7	2041	2561	10/1/90
Phoenix	1.02 @ 32	1.04 @ 7	2093	790	9/17/90
Salt Lake City	0.93 @ 28	1.27 @ 2	346	4305	10/1/90

Note: Phoenix heating performance is low due to substantial operation as a 2-pipe system.

Note: Operating hours include engine hours, fan over-run hours, and auxiliary heater hours.

Table 3: Results of field test of 3 RT (10.6 kW) gas engine-driven gas heat pumps.

excluding breakdowns caused by software programming errors in the control system logic.

In a similar field test, ten 5 RT (17.6 kW) engine driven heat pumps developed by Aisin Seiki were tested in light commercial service at similar representative sites around the United States. As most of these sites were different from the sites where the 3 RT residential heat pump was tested, direct comparison cannot be made of the seasonal performance of the two systems. Table 4 shows the seasonal performance and average outdoor temperatures of the Aisin Seiki heat pump field tested in 1990-1991. The York 3 RT gas heat pump uses a unique, specially developed long life, high efficiency, one cylinder, low emissions engine, built by Briggs & Stratton, while the Aisin Seiki gas heat pump uses a small, three cylinder, automobile engine adapted for long life and low emissions. Both engines have water-cooled engine blocks which recover supplementary heat for winter use. The use of such heat materially improved the heating season COP and assured that delivered air temperature was in the 38°C to 43°C range. This warm delivered air temperature provided superior comfort to the occupants than that provided by electric heat pumps whose return air temperature is in the 27°C to 32°C range.

Table 4: Results of field test of 5 RT (17.6 kW) gas engine-driven gas heat pump.

Location	Seasonal cooling gas COP @ Average outdoor temperature (°C)	Seasonal heating gas COP @ Average outdoor temperature (°C)	Cooling operating hours	Heating operating hours	Start-up date (month/day)
Pittsburgh	1.04 @ 23	1.46 @ 6	2101	1163	1/30
Tulsa	0.80 @ 27	1.09 @ 1	2871	1135	2/07
Salt Lake City	1.01 @ 79	1.15 @ 0	1201	2555	2/28
Atlanta	1.06 @ 27	1.45 @ 5	2120	321	3/08
City of Mesa	0.76 @ 29	1.11 @ 8	3690	201	3/15
Los Angeles	0.86 @ 25	1.41 @ 11	2479	1987	5/11
Toronto	1.10 @ 23	1.39 @ 2	1671	2916	7/06
Detroit	0.93 @ 28	1.48 @ -1	464	2315	7/31
Kansas City	1.36 @ 28	1.70 @ -1	2357	1174	8/30
Brooklyn	0.83 @ 28	1.31 @ 6	1815	2039	9/06

In addition to the GRI field tests of the York 3 RT and Aisin 5 RT gas engine heat pumps, the Southern California Gas Company is conducting a 20 unit field test of the 2 RT (8.8 kW) Yamaha gas engine driven heat pump. The units consist of an outdoor module (engine driven compressor, condensing unit, and controls) and an indoor module (evaporator and fan coil). The outdoor modules, modified slightly to meet safety standards in the United States, were made in Japan while the indoor fan coil modules were purchased domestically.

The units are being field tested in residential and light commercial service principally in the Los Angeles basin with a few units being located in the Palm Springs and Big Bear areas. The Southern California Gas Company is obtaining a data base on the operation, performance, economics and emission characteristics of these units. Other gas companies with similar projects to evaluate Japanese made gas engine heat pumps include Minneapolis Gas Company, the Brooklyn Union Gas company, City Gas of Florida and Consumers Gas (Canada).

Heat Actuated Sorption Heat Pumps

The favoured refrigerant in the various sorption systems is ammonia. Water and ammonia are the cycle vapours which show the potential for highest COP. Water, however, has an extremely low vapour pressure at low temperature which drastically reduces system capacity under conditions where it is needed most, and freezes at low temperature even though the use of additives can somewhat mitigate the consequences of freezing. Consequently, liquid-vapour absorption, solid-vapour adsorption, and chemisorption heat pumps use ammonia as the working fluid.

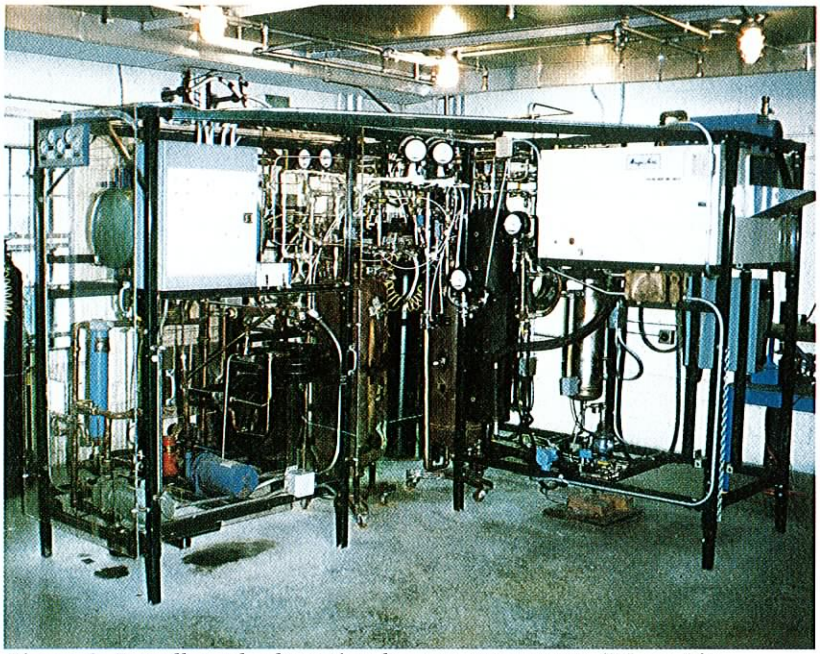

Figure 2: Breadboard adsorption heat pump system (Wave Air Corporation).

Adsorption Heat Pumps

The adsorption heat pump under development by Wave Air Corporation, with GRI support, employs beds of high surface area carbon which are alternately heated and cooled to desorb and adsorb ammonia. A heat transfer oil, selected for thermal stability and acceptable variation in viscosity over a wide temperature range, is used in a serpentine heat exchanger to couple the beds to both the natural gas burner heat source and the external heat rejection heat exchanger. Since the system uses ammonia as the cycle working fluid, a separate fluid loop couples the outdoor unit with the indoor fan coil. A photograph of the breadboard systems development unit is shown in Figure 2. The system's development unit maintains evaporator and condenser at set temperature and pressure levels via temperature-controlled water heat exchangers. When the beds are switched from sorbing to desorbing, the direction of flow of heat transfer fluid in the serpentine bed heat exchanger, the primary (fired) heater, and the heat rejection heat exchanger is reversed. This enables the heat in the fluid to be conserved, with only the minimum addition of heat.

There are numerous structural heat losses and an inherent heat loss in the bed. In order to minimize the heat losses from the bed to the ammonia pressure vessel and the heat exchanger steel itself, a sophisticated two-dimensional transient heat transfer computer model of the process was developed. This computer model is used for the purpose of optimizing system COP. The bed heat losses also depend on bed reversal switching time and heat transfer fluid flow rate as well as fluid passage dimensions and carbon filled passage spacing. For a specified carbon type and serpentine heat exchanger design, the computer program determines the fluid flow rate and bed reversal time which offer the highest COP for a specified heat pump capacity. As the fluid flow rate and bed reversal time is at the discretion of the control system (within limits prescribed by the pump and motor drive), the system can operate over a range of bed "speeds" and system capacities in a manner not dissimilar to that of a variable speed (electric) heat pump. During "low speed" operation, the heat exchangers (especially the fluid-to-air final indoor and outdoor heat exchangers) operate at lower heat flux and consequently, lower temperature drops. This increases COP and decreases capacity over the values obtainable at full speed/full capacity operation.

Absorption Heat Pumps

In the field of absorption heat pump development, the US Department of Energy has been working on the GAX (generator-absorber-heat exchanger) cycle for about seven years with Phillips Engineering. In this system, a portion of the heat rejection of the absorber is used to supply heat to the generator (hence the name). A new heat exchanger is being developed to accomplish this task. As unique components are involved which may be patentable, details of the equipment are not publicly available. To date, the developers have not released performance (COP) information as improvements are still being made. Engineering prototypes are being built and tested as the internal heat exchanger design is evolving. Because of the highly cost-competitive HVAC (heating, ventilation and air-conditioning) equipment business, low manufacturing cost is essential for market success; and cost-performance (COP) tradeoffs are constantly being made to achieve a product which will be attractive in the space conditioning market in the United States.

Presently GRI will begin parallel component development work with several distinct groups for the purpose of bringing the GAX system to the point where a commercial product with an attractive combination of cost and performance can be offered on the market. These GRI sponsored activities include the development of a burner and generator for the GAX system, testing of twisted tube heat exchangers, development of an improved solution pump, and evaluation of improved designs of a rectifier. This work will be coordinated via analytical system performance modelling and the construction of a breadboard system in conjunction with design for manufacturability.

More details on GAX cycles are given in the article on page 22.

Chemisorption Heat Pumps

Several salts react with ammonia vapour to form crystalline ammoniated compounds. These complex compounds sorb and desorb large amounts of ammonia vapour at constant temperature and pressure, akin to a boiling-condensing phase change phenomenon. Many of these salts have several different crystal structures with multiple p-T (pressure/temperature) plateaus where the ammonia contained in the crystal lattice changes from one integer to another. At these p-T plateaus large heat interactions occur where the ammonia is absorbed or desorbed. In chemisorption heat pumps, salt ammonia complexes are selected for the desired phase change temperature level plateaus and then solid-vapour reactor beds are built to provide the heat interactions with the outside environment. Various salt-ammonia cycles are possible involving one, two, three or more beds operating at appropriate temperature levels.

In a GRI sponsored programme with the Rocky Research Corporation, a number of attractive salt complexes have been identified with p-T plateaus at useful values. These salts have been thermally cycled hundreds of times, and show no noticeable change in appearance, density or other property which relates to their use in heat and mass transfer reactor beds. As ammonia is the vapour, it has been found that conventional low cost, low carbon steel is an adequate material for the beds, heat exchangers, pressure vessels and connecting piping.

Conclusion

Ongoing development work continues to show progress in the technically challenging task of creating a commercially viable, gas heat pump. Engine-driven vapour compression gas heat pumps are being sold in Japan, and the York gas heat pump is about to enter the US market. At the same time, work continues on several promising sorption gas heat pump concepts that hold the potential for attractive, future products.

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Authors:
S.I. Freedman, C.E. French, G. Nowakowski and G.H. Myers, Gas Research Institute, USA.
Tel.: +1-312-399-8100;
Fax: +1-312-399-8170.

Italian Compact Absorption Heat Pump Shows Commercial Potential

P. Coda, P. Giacometti, Italy

Summary

With the aim of promoting energy saving and environment pollution reduction, a 3 kW refrigeration power absorption heat pump prototype has been built at ENEA Laboratories in Rome. By using commercially available components, the designers have built a low-cost compact machine that demonstrates the potential for the commercial realization of a 15 kW machine for residential heating and cooling. The design meets the relevant safety regulations and has reversible operation for summer and winter use. Tests revealed favourable PER (Primary Energy Ratio) values of 1.23 for heating and 0.38 for cooling.

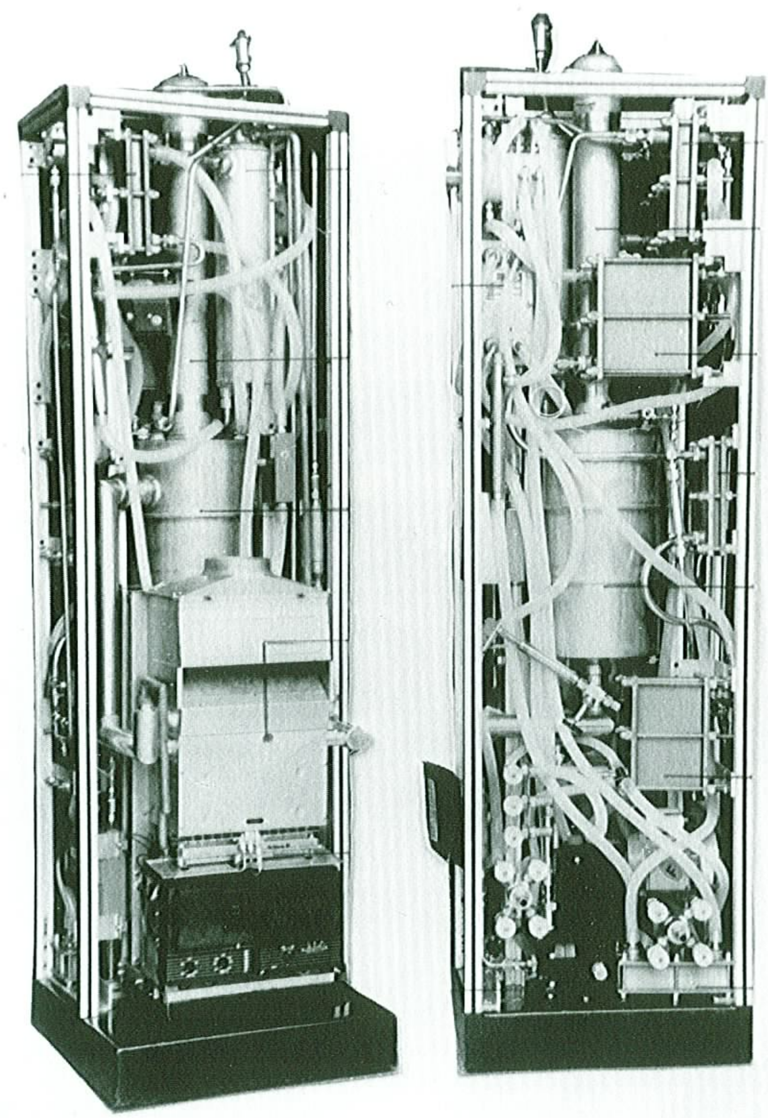
Early Experiences

Activities on absorption heat pumps started at ENEA at the beginning of the eighties with the development of a heating-only ammonia/water machine. While the energy problem was reducing, the interest in summer air conditioning increased. Coupled with the enhanced diffusion of gas supply in Italy, this led to the development of climatization gas systems including sorption technologies. ENEA's experiences in previous activities showed the validity of the absorption heat pump as a means of energy saving, but to success-fully diffuse this technology it was clear that a number of problems needed to be solved:

- long payback period;
- high dimensions and weight;
- limited knowledge of designers and installers of this technology;
- difficulties in achieving reversibility, i.e. operation as chiller and heat pump;
- design and construction problems arising from safety standards.

All these aspects were evaluated and it was decided to start a project to build a heat pump to overcome the problems.

Figure 1: The ISPCA II RSC 3kW absorption heat pump.



Heating power	10 kW
Cooling power	3 kW
Working fluid	water/ammonia
Boiler-generator exchange fluid	propylene glycol
Source temperature range	-5°C to 15°C (design 8°C)
Sink temperature range	max. out 60°C, in 46°C (design 40°C)
Power control	gas partialization
Partialization system	step control to 25% of max. power, under on-off
Dimensions	0,55 x 0,65 x 1,9 m
Weight	180 kg

Table 1: Characteristics of the prototype heat pump.

Project Goals

The project was built up with the aim of testing the feasibility of various technologies that could overcome the described problems, and to acquire adequate knowledge to construct an advanced absorption heat pump, giving winter/summer service with low investment cost. Positive results would lead to the design of advanced cycles and to the development of a commercially viable reversible heat pump.

Features of the New Unit

The developed unit (known as ISPCA II RSC) is shown in Figure 1. It is a single-stage water/ammonia heat pump featuring internal partial heat recovery, and designed to supply hot or cold water to a water/air heat exchanger.

Its main characteristics are given in Table 1. A detailed scheme of the system, with design thermo-dynamic data is available at ENEA.

The following techniques are used in the design:

- the rectification column for the ammonia vapour generator includes perforated plates to increase the hydrostatic pressure (realized by liquid surface tension) to obtain high enthalpic liquid/vapour exchange;
- the ammonia vapour generator uses indirect heating by means of propylene glycol vapour generated by a modified gas boiler. This avoids the safety problems associated with high pressure vessels;
- the absorber includes special plate heat exchangers featuring grids interposed between the plates. This gives a spiral flow between rich and poor solution and hence high heat and mass transfer;
- plate-grid heat exchangers are used for all other heat exchangers;
- a multiway valve selects winter or summer use;
- the solution pump is capable of pumping saturated liquid in the absence of hydrostatic pressure on the suction side.

Commercial Components

Care was taken to build a heat pump which makes use of commercial components as much as possible. The major parts of a commercial boiler, including its pump and electronic control system, are used. All the heat exchangers are of a commercial type, although the seal is made of synthetic rubber. Future models will use a welded seal. The use of commercial components resulted in some lessening of performance due to components dimensions not being adequate for the design. However, tests show a larger machine would overcome this problem.

Tests and Results

For test purposes, the prototype unit used simulators for both the source and sink exchangers. A water/glycol mixture was used to transfer heat from the absorber and condenser to the sink exchanger simulator and from evaporator to

Table 2: Performance.

	Heating	Cooling
Qu, total heating power (kW)	10.00	10.20
Qa, absorber power (kW)	5.75	5.90
Qe, evaporator power (kW)	3.00	3.03
Qr, flue gas heat recovery (kW)	2.25	-
Qi, gas input power (kW)	8.14	7.92
PER	1.23	0.38
COP	1.39	0.44

The following standard conditions apply:

Heating - service fluid: in 40°C, out 53°C; source service fluid: in 8°C, out 2°C.
Cooling - service fluid: in 12°C, out 6°C; sink service fluid: in 40°C, out 54°C

the source simulator. The temperature data shown in Table 1 refers to the sink and source side of exchangers.

Flowmeters, pressure meters and thermocouples, sent signals to a data acquisition system. A full set of tests were performed on the prototype. Performance evaluation gave PER values of 1.23 for heating and 0.38 for cooling. A summary of results is shown in Table 2.

The data show a reduction to about 88% of system performance (PER) on the cycle performance (COP): this is due to flue gas heat recovery which is not considered in COP evaluation and to the indirect gas heating system efficiency. Experimental data indicate that the indirect heating has an efficiency to transfer heat to the cycle of 76% which is about 5% less than direct heating. This difference is due to heat dispersion to ambient air. However this value is higher than that obtained in current commercial absorption heat pumps. Figure 2 shows PER and power output in the heating mode. As shown, variations with external temperatures are smooth. Also cooling power and PER variations, shown in Figure 3, are quite moderate.

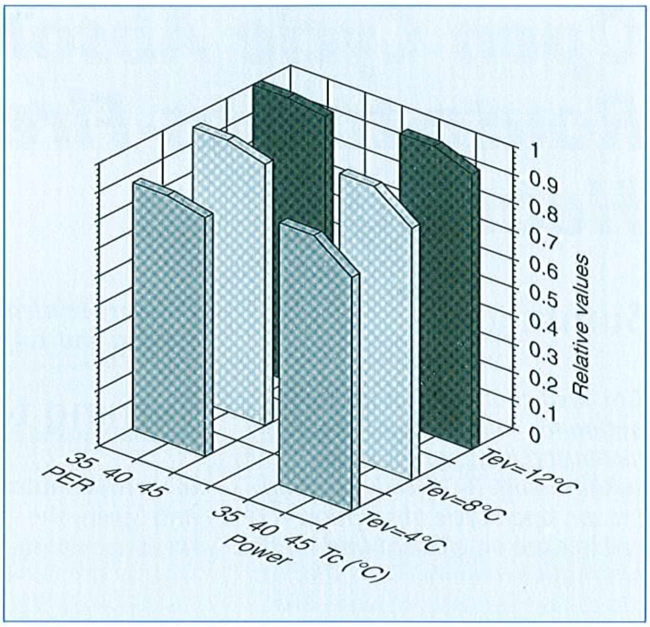
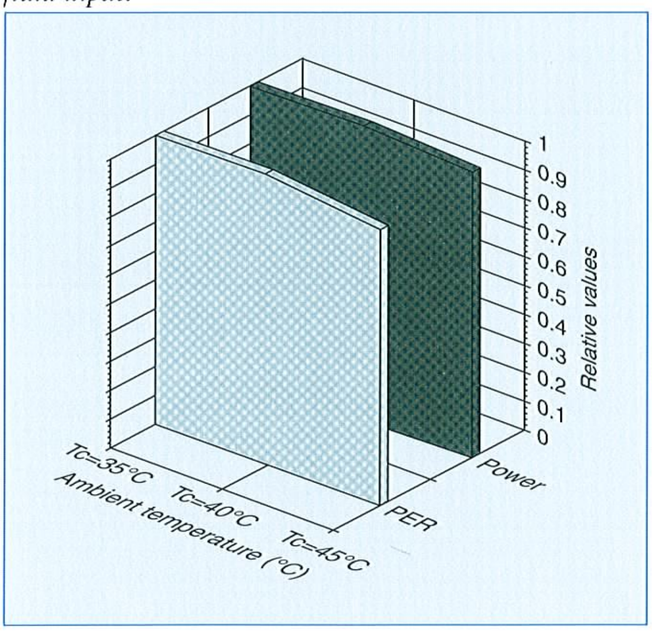


Figure 2: Heating PER and power variations, relative to source fluid input temperature (Tev) for sink temperatures (Tc) of 35, 40 and 45°C.

Figure 3: Cooling PER and power variations, relative to ambient temperature (sink fluid input), for 12°C cooling fluid input.



Looking to the Future

ENEA's success in overcoming the major difficulties in making a low-cost compact absorption heat pump is an important step towards the development of a larger commercial machine. In a new project, involving help from industry, ENEA is developing a 15 kW power prototype which should pave the way to the design of a high performance absorption heat pump.

Authors:
P. Coda and P. Giacometti,
ENEA - Area Energetica, Rome, Italy.
Tel.: +39-6-3048-4128;
Fax: +39-6-3048-6306.

Open Cycle Absorption - A Simple Route to Gas-Fired Cooling and Heating

R.M. Lazzarin, G.A. Longo, Italy

Summary

Gas-fired cooling is an attractive option for countries with a rapidly increasing demand for space conditioning. By directly treating the air, open cycle absorption systems are an efficient and simple alternative to more conventional direct-fired cooling systems. The experimental system described in this article shows how open cycle absorption can be adapted to provide heating as well. Results so far indicate a potential PER (Primary Efficiency Ratio) of 0.5 for cooling and 1.4 for heating.

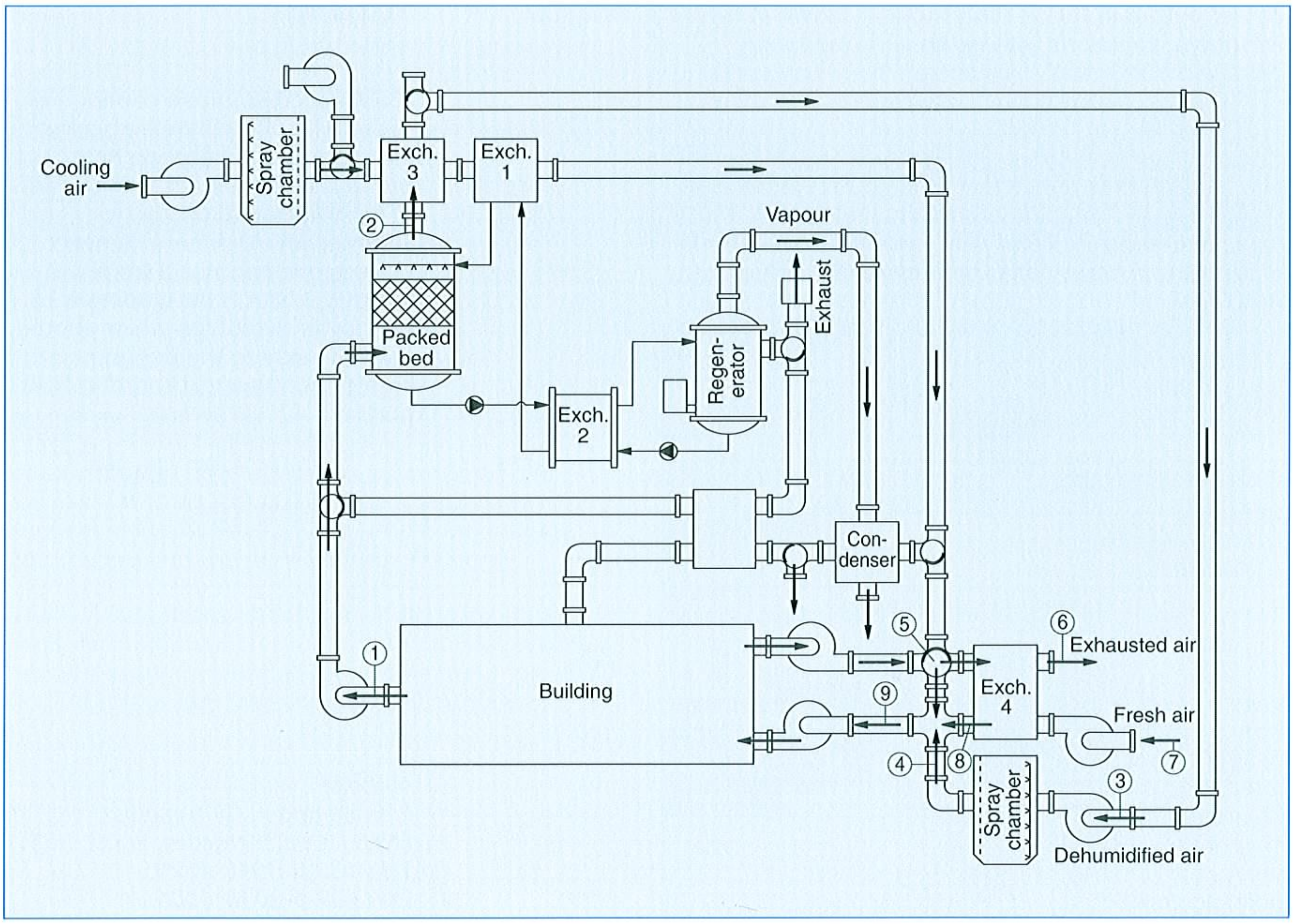
Turning to Gas

In warm countries, such as Italy and Spain, the increasing demand for space conditioning cannot be met by the current capacity of installed electric power. This has led to a growing interest in cooling with natural gas. Also, where the use of natural gas for winter heating is increasing, an alternative use in summer is welcome to level out the consumption throughout the year. This is important because supply contracts are for a constant rate so that during the summer the excess gas must be stored (usually in exhausted wells).

Open Cycle Absorption

A very interesting thermal cooling system is the open cycle absorption one. In an open cycle system the working fluid, which is normally air

Figure 1: Schematic view of the open cycle absorption system in summer-mode operation.



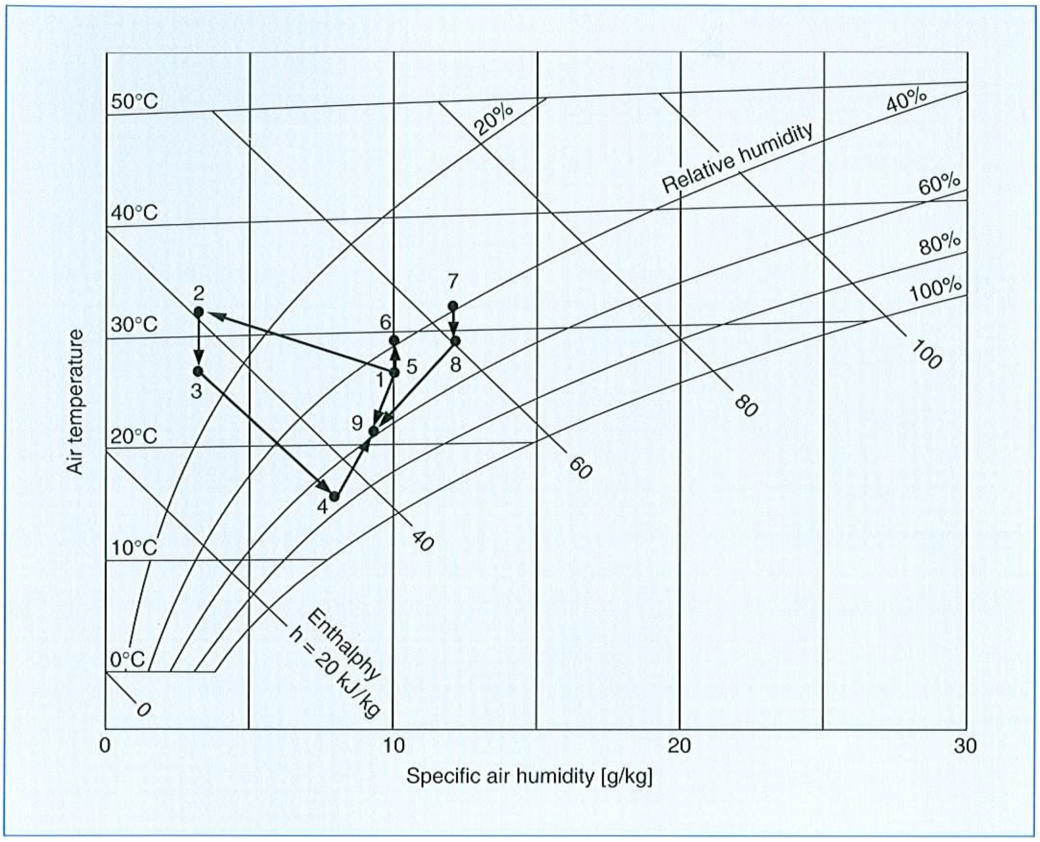


Figure 2: Psychometric chart of the air conditioning processes in summer.

or water, is continuously changed. For space conditioning, an open cycle treats the air directly without heat exchangers and with very low temperature drops. With absorption dehumidification it is possible not only to obtain a cooling system similar in performance to conventional thermal systems, but also, with few modifications, a heating system fed by a natural gas burner. This combines simplicity with very good thermodynamic performance.

System Description

Summer Mode

A schematic view of the proposed system operating in summer mode is shown in Figure 1, where the different devices are widely separated for clarity. The psychometric diagram of Figure 2 plots out the changes in air humidity and temperature as air is cycled from the building ventilation outlet (1) to inlet (9). The heart of the system is the packed-bed tower where air from the building is treated by a sorption solution such as lithium bromide/water. The recirculated air is thus dehumidified and its temperature raised by contact with the warmer sorption solution and due to the heat of absorption. The air is then cooled by adiabatically saturated outside air in heat exchanger EXCH.3. The low humidity air is passed through a spray chamber where it undergoes humidification cooling before being mixed with fresh air. This fresh air is precooled by exhaust air from a second building outlet in heat exchanger EXCH.4. The diluted sorption solution leaving the packed-bed must be regenerated. The solution is preheated in a liquid-liquid heat exchanger (EXCH.2), before entering the natural gas fired regenerator. The hot regenerated solution must be cooled so it can absorb effectively. The cooling is done in an air-liquid heat exchanger (EXCH.1) by outside saturated air.

Winter Mode

The winter operation of the system is illustrated in Figure 3. The air extracted from the heated room is mixed with the exhaust of the regenerative burner. This exhaust is at an appreciable temperature (about 150°C) and with a high water content (more than 0.1 kg/kg). The air/exhaust mixture is then passed through the packed-bed tower where it is dehumidified so that much of its latent energy content is taken up by the sorption solution. The sensible heat increases slightly. Before emission the exhaust air mixture preheats the outside fresh air in heat exchanger EXCH.3. A further preheating is given by the sorption solution in air-liquid heat exchanger EXCH.1 before it enters the packed-bed. The sorption solution cycle is as before. Now the heat of condensation of the vapour separated in the regenerator is used to heat the air entering the building. The air heating is

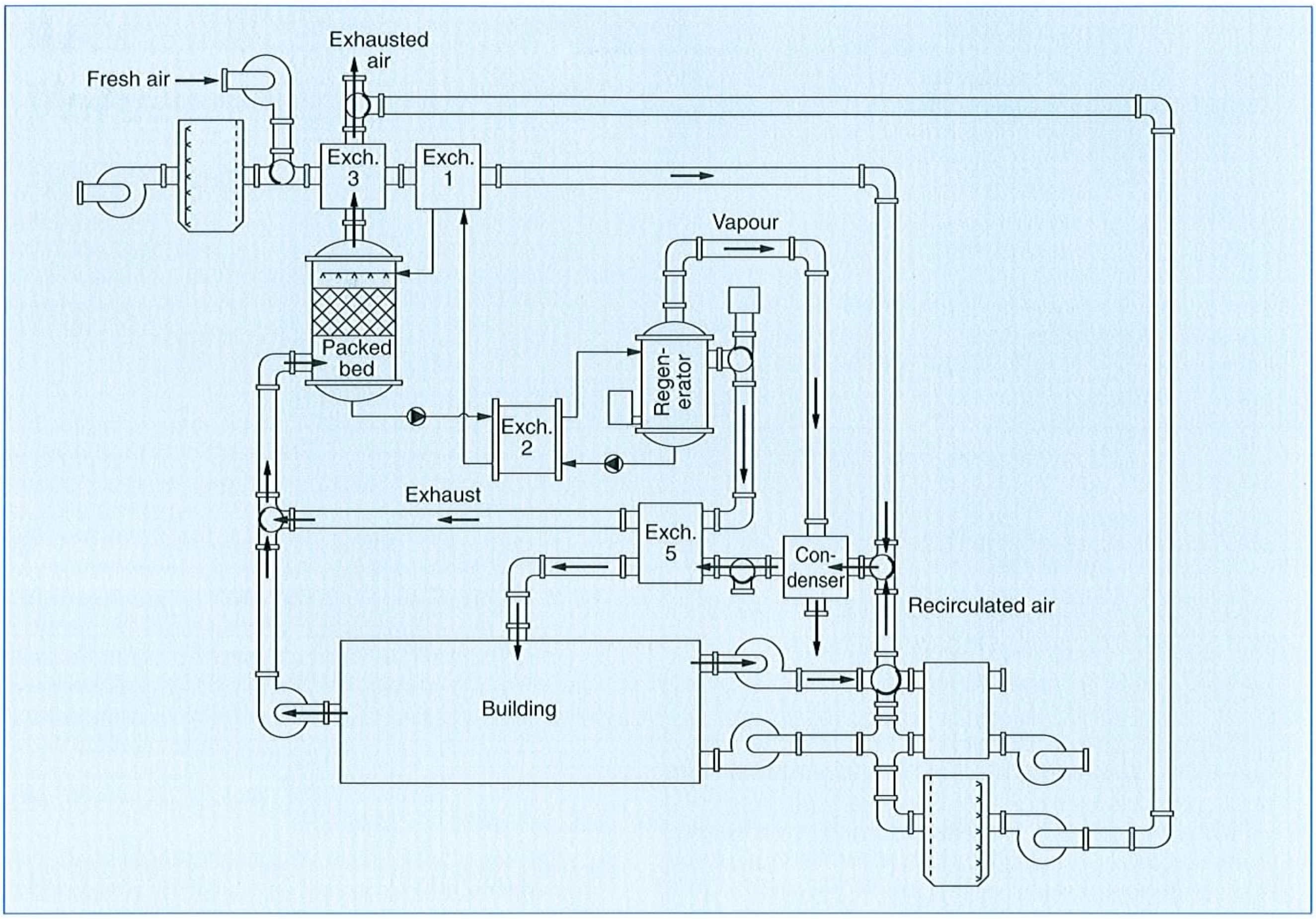


Figure 3: Schematic view of the open cycle absorption system in winter-mode operation.

completed by using the hot exhaust of the regenerator in heat exchanger EXCH.5.

Performance

Air conditioning and heating of a building was simulated to predict the performance of the system and to evaluate the significance of heat exchanger efficiency.

Three types of heat exchanger are used and each has a different 'reasonable' efficiency:

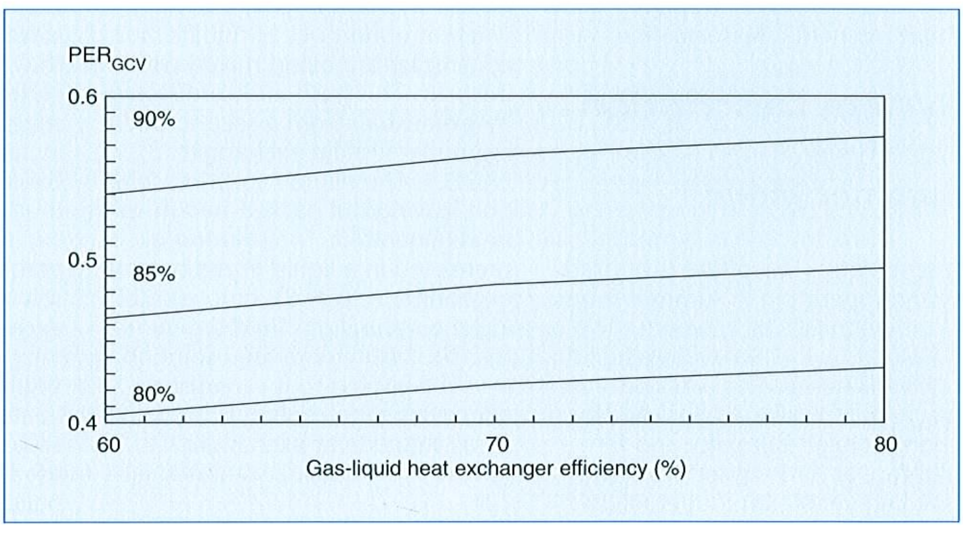


Figure 4: Summer operation as a function of the gas-liquid heat exchanger efficiency for different liquid-liquid exchanger efficiencies (the gas-gas heat exchanger is at 60%).

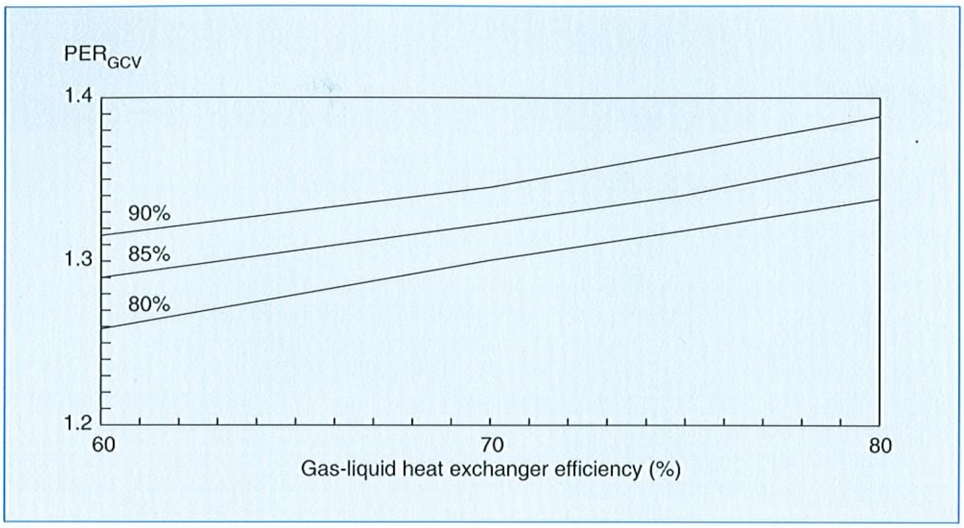


Figure 5: Winter-mode PER as a function of the gas-liquid heat exchanger efficiency for different liquid-liquid exchanger efficiencies (the gas-gas heat exchanger is at 60%).

- gas liquid heat exchanger 1 has 60 to 80% efficiency;
- liquid-liquid heat exchanger 2 has 80 to 90% efficiency;
- gas-gas heat exchangers 3,4 & 5 have 50 to 70% efficiency.

Summer operation

The set parameters were the following:

- building air: temperature 26°C, specific humidity 10 g/kg;
- outside air: 32°C, specific humidity 12 g/kg;
- adiabatic saturator efficiency: 80%;
- ratio between latent and total load: 20% (the higher this ratio the better the performance);
- ventilation air load is 20% of the total sensible load.

Figure 4 shows the Primary Energy Ratio - PER (ratio between the cooling demand and the Gross Calorific Value - GCV of the gas) as a function of the gas-liquid exchanger efficiency for different liquid-liquid exchanger efficiencies (the gas-gas is at 60%). This indicates that a PER in excess of 0.5 is achievable. Although this is not particularly high, it is of the same order as some ammonia-water absorption chillers and it must be appreciated that in this system the air is treated directly without further losses due to heat exchangers or post-heating etc.

Winter operation

The system was simulated to satisfy a load made up of 2/3 heating due to losses and 1/3 fresh air heating. The internal latent load was assumed to satisfy the need of humidification although an adiabatic saturator can be inserted before or after the condenser without altering the results.

Figure 5 gives the PER as a function of the gas-liquid heat exchanger efficiency for different liquid-liquid exchanger efficiencies. For the gas-gas heat exchangers a 60% efficiency was assumed. The PER varies from a minimum of 1.25 to 1.40 with respect to GCV of natural gas. PER values as high as these are difficult to obtain with more complex closed cycle absorption or vapour compression cycle motor driven heat pumps.

Authors:

R.M. Lazzarin, Istituto di Ingegneria Gestionale dell'Università di Padova, Italy (Tel.: +39-444-326-090; Fax: +39-444-326-292)

G.A. Longo, Istituto di Fisica Tecnica dell'Università di Padova, Italy (Tel.: +39-49-831-424 ; Fax: +39-49-831-405)

Heat Pumps in Switzerland - HPC's Newest National Team is Ready to Play a Major Role

Luisa Prista, Switzerland

Summary

After the results of a referendum in 1990, Switzerland introduced an action programme known as Energy 2000 to tackle the country's energy problems. Included in this programme are measures to replace fossil fuel-fired boilers with electric heat pumps. One consequence of this new policy, has been that Switzerland joined the IEA Heat Pump Centre (HPC) early this year.

In line with the operation of the eight other member countries, Switzerland has formed a National Team to act as the focal point for heat pump related activities. By pooling its membership from all bodies that have an influence on the implementation of heat pumping technology in Switzerland, the Swiss National Team is set to play a major role in promoting heat pumps in Switzerland and to become a key player in the international network of the HPC.

Energy in Switzerland

The energy situation in Switzerland is determined by two major concerns:

- Reliance on foreign supply - approximately 84% of final energy consumption is of imported fuels
- Environmental damage - primarily a consequence of energy use. Of particular concern is air pollution, and increasingly, global climate problems.

Despite these concerns, energy use increases every year with a consequent increase in consumption of both electricity and fossil fuels (see Figure 1). Almost two thirds of Switzerland's final energy demand is for heat production, with much of this being met by burning heating oil and other petroleum products. Electricity in Switzerland is generated almost entirely without burning fossil fuels, with a 60 - 40 split between hydro and nuclear power.

Referendum

In 1990 measures to tackle concerns over these issues and about nuclear energy were put before the Swiss public in the form of a referendum. The outcome (see Box 1) brought about a drastic change in Swiss energy policy.

Generally speaking the result of the referendum means that :

- For the first time the Federal Government has the legal basis and the duty to pursue an effective and farsighted energy policy, with the task of introducing legal and supporting measures for an efficient use of energy and for the use of renewable energy.
- The existing nuclear power plants will continue to operate but it will not be possible to obtain licenses for new ones before the year 2000.

Action Programme Energy 2000

As a consequence of referendum results, the Federal Government approved the action programme "Energy 2000" aiming at:

- the stabilization of total fossil energy consumption and of CO_2 emissions by the year 2000 at their 1990 level, and a reduction thereafter;
- a slow-down in the increase in electricity consumption in the 1990s, and a stabilization of demand by the year 2000;
- a significant increase of the contribution of renewable energy towards electricity and heat production by the turn of the century.

A more detailed breakdown of these objectives is given in Box 2. These objectives are based on the concept of "qualitative growth" that is: "the improvement of the quality and duration of life due to everyone's contribution through a lower use of the resources and non-renewable energy, as well as by a reduction of environmental damage through a higher use of know-how and intelligence."

Therefore Energy 2000 does not aim at a reduction of the energy consumption by means of emergency measures but aims at a reduced energy demand obtained by the introduction of a steady and long-term energy efficiency policy, based on a new more rational approach to both energy use and the environment.

Of course this requires new technologies and innovative processes which can provide economic impulses, relieve environmental problems and lead to

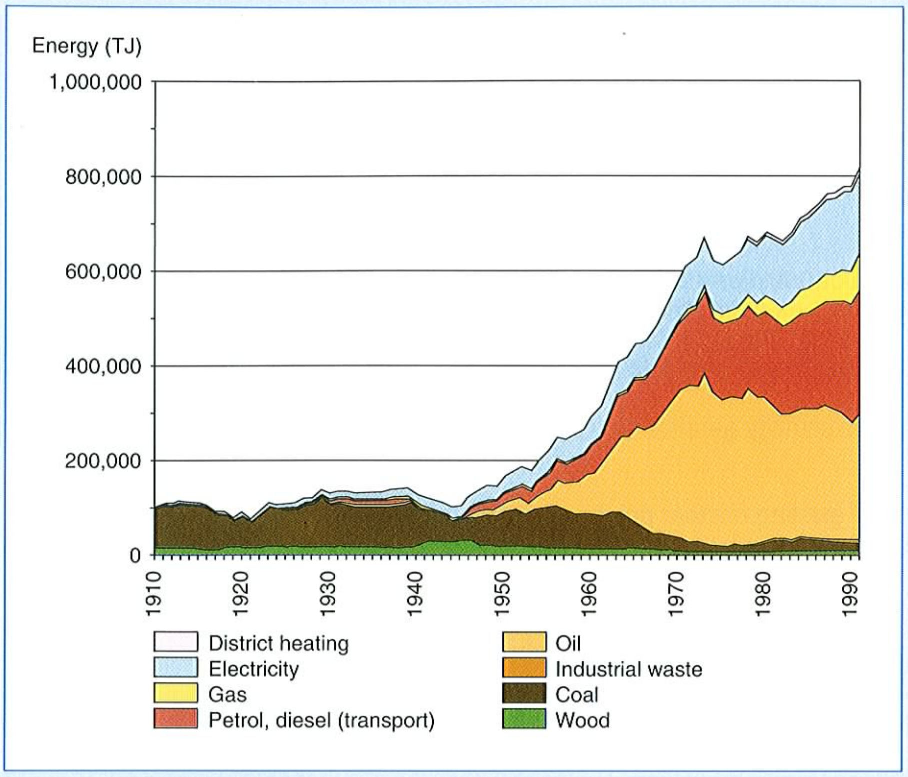


Figure 1: Final Energy Consumption in Switzerland. (Source: Swiss Federal Office of Energy.)

a harmonization of the demands of economy and ecology.

The Action Programme has been developed on three levels:

- The implementation of a decree on efficient use of energy
- The implementation of an information and advice system, R&D actions, P&D (pilot and demonstration) plants, education and professional training
- Voluntary actions and investment programmes in the energy sector by environmental and consumer organizations, professional associations, industry , trade and individuals.

While all the actions carried out are the responsibility of each participant, they are to be coordinated within the framework of "Energy 2000".

The action programme "Energy 2000" is demanding, but not unrealistic. Its ambitious objectives are a challenge for efficient cooperation between all parties (Federal Government, Cantons, municipalities, industry, trade and individuals) throughout its ten year period of operation.

Energy 2000 and Renewable Energy

Within the Energy 2000 framework an Action Group for Renewable Energy (AGR) was formed. Its main task is to support existing installations, and to stimulate new projects by organizing favourable boundary conditions (such as economic incentives).

The group operates in three fields:
- biomass
- solar
- heat from the environment.

This last field aims at the replacement of fossil energy for heat production by electrically driven heat pumps.

Box 1: Results of the national referendum held on the 23rd September 1990.

Acceptance of:

- an amendment of the federal Constitution (Energy Article) containing governmental principles and regulations regarding energy efficiency and incentives for renewable energy
- a popular initiative demanding a 10-year stop to license new nuclear reactors (moratorium initiative)

Rejection of :

- a popular initiative calling for a gradual phase-out of nuclear energy (phase-out initiative)

Box 2: Objectives of the action programme Energy 2000.

1. Fossil energy consumption and CO_2 emissions
   - at least the stabilization between 1990 and 2000 and subsequently reduction.

2. Electricity consumption
   - progressive slow-down of growth and stabilization by year 2000.

3. Renewable energy
   - 0.5 % contribution of photovoltaics, wind and biomass to total electricity production by the year 2000
   - 3% contribution (relative to fossil fuel consumption) of solar collectors, biomass, geothermal resources and **heat pumps** to heat production by the year 2000
   - 10% increase in average hydroelectricity generation from 1990 to 2000

4. Nuclear energy...
   - 10% increase of the capacity of existing nuclear power plants by the year 2000

Note:
Such quantitative objectives were based on energy outlooks. They depend on a number of parameters (e.g. population, economic growth, energy prices), and can therefore not be legally binding. They are however politically committing. They indicate the general direction to be taken and provide a challenge for concrete actions and investments.

However, the electricity consumed by these heat pumps must be derived first from the replacement of existing electrical heating systems or secondly from cogeneration power plants running on a portion of the fossil fuel saved with the replacement of traditional (oil and gas-fired) heating systems by heat pumps (see Figure 2).

Energy 2000 and Knowledge Transfer

The transfer of knowledge is an effective instrument for encouraging the rational use of energy and for stimulating qualitative growth. Effective communication of information is essential to accelerate the transfer from research to technology and from this to practical application.

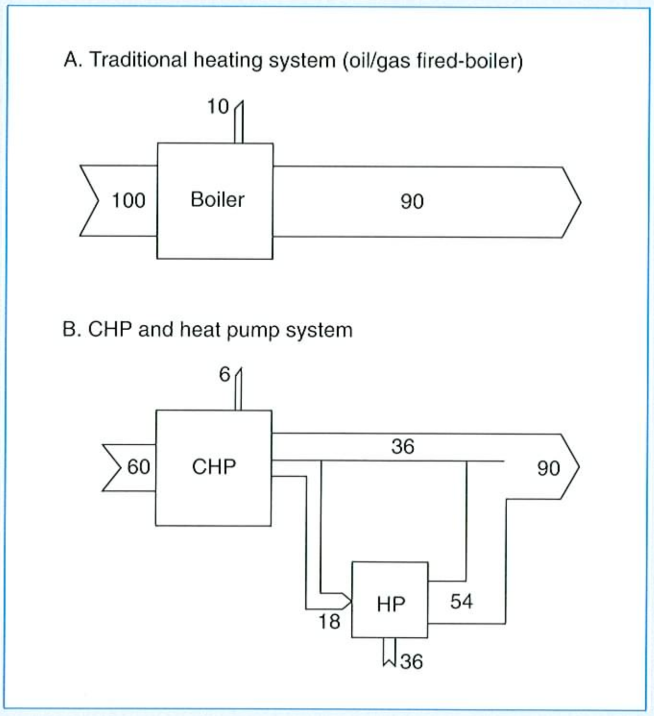
P&D projects are used to make the step from research to a usable technology product. They are the most effective way of proving the success of a new technology and guaranteeing its replication.

Information, training and education play a fundamental role to accomplish the second step of this transfer - from technology to application.

In order to accelerate these transfers and make the whole information system work, the Confederation created information centres, such as Infoenergy. The main task is to make "the link", and to broaden and improve the exchange of information in Switzerland and around the world.

In this context the Heat Pump Centre represents an important additional instrument to the exchange of information in the field of heat pumps.

Figure 2: Heat pumps, in combination with CHP plants, can reduce primary energy consumption and emissions by 40%.



OBJECTIVES

Main

- Further installation of 100,000 electrical heat pumps of an average thermal power of 25 kW by the year 2000. (or the equivalent units for the same annual heat production)

Secondary

- SPF (Seasonal Performance Factor) improvement (50% by 2000)
- Reduction of investment costs subsequent to standardization and industrial production of heat pumps.
- Creation of favourable boundary conditions that will make heat pump installation more economical
- Ensurance of high quality products and systems

MEASURES

- R&D (carried out by universities, technical schools, and private individuals under the management and budget of the Federal Energy Research Programme)
- Improvement of market opportunities by:
  - P&D plants (systems, equipment, technology,components,heat source)
  - Information
  - Education and professional training (courses, Impuls, handbooks, software, etc)
  - Complementary measures (quality assurance, advice, recommendations, special electricity tariffs, legal conditions, promotion schemes)

All participants (Confederation, Cantons, research institutions, utilities, manufacturers industry , professional associations, end-users) are oriented towards the programme objectives.

Box 3: The Heat Pump Promotion Programme.

Heat Pumping in Switzerland

At the end of 1991 about 35,000 heat pumps, mainly electrically driven, of an average thermal power of 25 kW were in operation in Switzerland. About 2/3 use ambient air as heat source.

Since the oil crisis of 1979, 3000-3500 heat pumps have been sold every year and installed mainly for space and water heating purposes in both new and retrofitted residential and commercial buildings. This is a rather small figure when compared with the 40,000 new boilers that are fitted each year in the building sector.

The lack of market success of heat pumps is due mainly to economic factors like high investment costs, high electricity prices (when compared with fuel and gas prices) and to lack of information - most people have the idea that heat pumping is a complex, non-demonstrated technology - an opinion born of bad experiences in the past . Furthermore, rules and recommendations governing ground source heat pump utilization vary from canton to canton and are barriers to heat pump implementation.

From the environmental point of view, heat pumps are strongly dependent on the type of electricity generation system. In Switzerland, since electricity is mainly generated by hydro and nuclear power plants, heat pumps are an effective solution for the reduction of the CO_2 emissions.

It is estimated that the replacement of oil fired boilers by new heat pump installations contributes to an annual additional reduction of the emission of CO_2 of about 42,000 tonnes of CO_2 emissions in Switzerland. Heat pump systems are therefore a promising technology for the achievement of the objectives of Energy 2000.

Swiss Heat Pump Promotion Programme

Considering the potential of heat pumps for emissions reduction, especially since heat production represents 75% of net energy use in Switzerland, the "Heat Pump Promotion Programme" was established. Within the framework of Energy 2000 , this programme has been set up to work as a catalyst for heat pumping related activities in Switzerland.

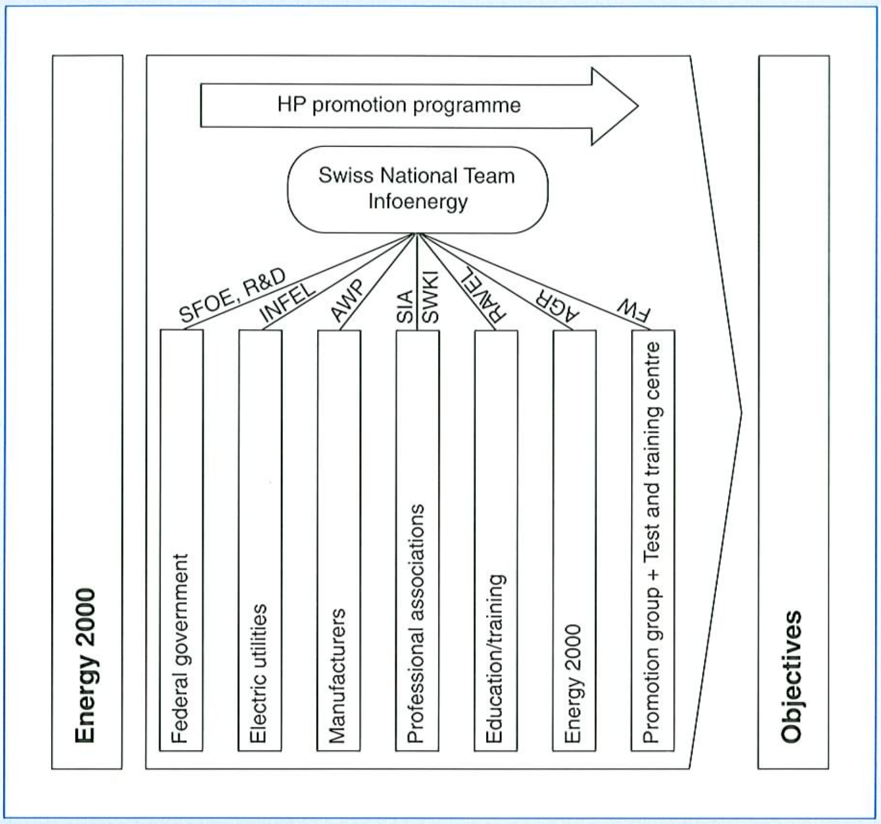


Figure 3: Configuration of the Swiss National Team.

List of abbreviations:
SFOE = Swiss Federal Office of Energy
AWP = Swiss Association of HP manufacturers
RAVEL = Rational Use of Electricity
AGR = Action Group for Renewable Energy
FW = Heat Pump Promotion Group
INFEL = Electricity Information Centre.

The programme aims at increasing the installed number of heat pumps at an annual rate of 30% 1995, followed by a constant rate of 15,000 units per year until the year 2000. It is estimated that a global electrical power of 500 MW will have to be installed to drive the additional heat pumps, representing, for instance, about 2000 small-scale CHP units. Box 3 highlights the objectives and activities of the programme.

Heat Pump Promotion Group

In 1990, under the initiative of the Zürich Canton, FW (Fördergemeinschaft Wärmepumpen or Heat Pump Promotion Group) was created. Its aims are to stimulate market niches for heat pumps and to ensure the high quality and reliability of heat pumps. To increase the confidence of customers in this "new" technology, FW has set up a competition between manufacturers to produce a heat pump that meets stringent conditions of performance and quality. A test centre for such products is now under construction.

The members of this promotion group are the Federal Government, the Cantonal Government of Zürich, the North-eastern Electricity Company NOK, the electric utilities of the Canton and of the City of Zürich, the Swiss Electric Utilities Association, and the Swiss Association of Heat Pump Manufacturers.

Configuration of the Swiss National Team

In order to implement and participate in an active way in the Heat Pump Promotion Programme, the Swiss National Team (SNT) will be made up of members coming from those bodies involved in heat pumping that can play a decisive role in the execution of this programme (see Figure 3). As, shown, the SNT will be coordinated by the energy information centre Infoenergy.

All members of the SNT will contribute individually, collecting and transferring information to Infoenergy and disseminating information received from the centre to the public in their field. The SNT has all the starting conditions to contribute to the achievement of the objectives set by the Heat Pump Promotion Programme in Switzerland. Furthermore, the configuration of the SNT will allow Switzerland to play an active role in the activities of the HPC and will enable fruitful cooperation with the other member countries.

Author:
Luisa Prista, Swiss National Team leader, Infoenergia, Dipartimento del Ambiente, CH-6500 Bellinzona, Switzerland. Tel.:+41-92-243-755; Fax: +41-92-244-429.

Exhaust Air Heat Pumps Cut Heating Demand by 60%

Tom Svenningsen, Norway

Abstract

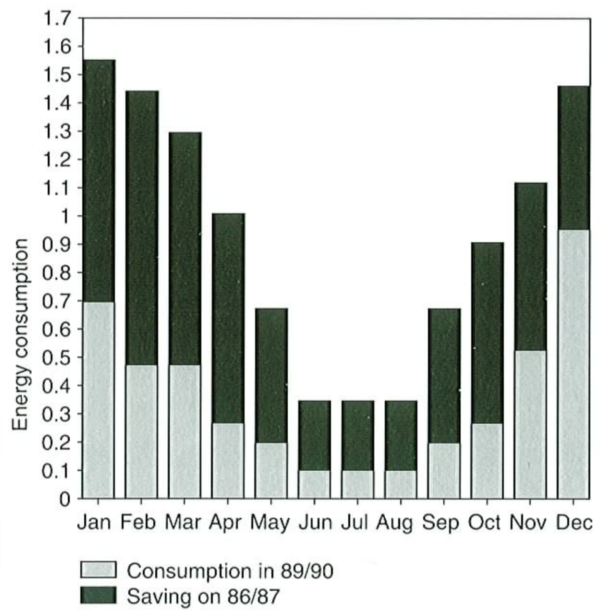
When an apartment complex in Norway underwent a major overhaul of its energy system, the existing heating system, based on oil burners and electric resistance heating was replaced by electric heat pumps. Using exhaust air as heat source, the heat pumps supply heat and hot water to the 984 apartments with an annual electric demand of just 5.6 million kWh. This reduced the annual energy bill by NOK 1.3 million (USD 230,000) in the first year of operation. The investment costs are expected to be paid back within six years.

Background

The Ammerudlia Apartment Complex, just outside Oslo, Norway, comprises four tower blocks containing 984 apartments with a floor area of 72,856 m². In 1989, nearly 25 years after the complex was built, an overhaul of the energy system was undertaken.

In the original design, each of the four blocks had a hot water heater connected to a local area heating system. This system used oil burners and electric hot water heaters with a combined capacity of 4.2 MW. The apartment complex used roughly 50 % of the energy from the local heating system, whereas the rest was sold to neighbouring apartments.

Figure 1: Energy consumption before and after installing heat pumps.



The blocks were equipped with 24 exhaust air fans. After 30 years of operation, the system capacity was running low due to wear and tear. The system was operated on full speed during the day and half speed during the night. The result was poor air circulation and damage to bathrooms caused by high humidity. It was therefore decided to use full fan capacity also during the night.

Energy Savings

With the original heating system, the demand for space heating and hot water heating was 14.3 million kWh annually. After installing the heat pumps and implementing other simple energy saving measures, the energy consumption has decreased to approximately 5.6 million kWh annually, and oil consumption is down one million litre a year. Figure 1 shows the monthly energy consumption both before and after the reconstruction and installation of the heat pumps.

Environmental Benefits

The replacement of oil burners by electric heat pumps has reduced the local emissions by:

- 3 million kg of CO_2
- 9,000 kg of SO_2
- 3,000 kg of NO_2
- 1,500 kg of CO
- 1,000 kg of other particles

Economics

The total investment cost was NOK 11 million (USD 1.87 million) of which 40 % was for necessary maintenance and 60 % was for heat pump installation. In the first year of operation, an annual saving of NOK 1.3 million (USD 230,000) was made. The investment cost is expected to be paid back within five to six years.

Author: Tom Svenningsen, Norman Energiteknikk AS, P.O. box 2059, Grünerløkka, 0505 Oslo 5, Norway. Tel.: +47-2-37-79-55; Fax: +47-2-35-58-05.

GAX Absorption Cycles - Recent Developments Have Sparked Renewed Interest

D.C. Erickson, M.V. Rane, USA

Abstract

By transferring heat from absorber to generator, a "GAX" (Generator-Absorber heat eXchange) cycle heat pump is more efficient than a conventional absorption heat pump so long as the temperature lift is low. The recent emergence of advanced GAX cycles which promise a thermodynamic performance not previously achieved by absorption cycles has intensified interest in this technology. This article describes the essential characteristics of the GAX family of absorption cycles and highlights some examples of both heating and cooling applications where GAX heat pumps can achieve very high COPs (coefficients of performance).

GAX Cycle Generalities

Although it was first disclosed eighty years ago (Altenkirch, 1913), the GAX cycle has remained essentially unknown until the past decade. Whereas the thermodynamic performance of the basic GAX cycle is modest, its mechanical simplicity has attracted substantial attention.

The distinguishing characteristics of a GAX cycle are:

- generation (desorption) and absorption each occur over a large temperature glide;
- the respective glides are large enough that there is temperature overlap between the hot end of the absorber and the cold end of the generator; and
- in the temperature overlap zone, heat is transferred from the absorber to the generator.

The GAX heat transfer (from absorber to generator) can be indirect via a circulating heat transfer fluid, or preferably direct. The greater the temperature overlap, the higher the possible COP.

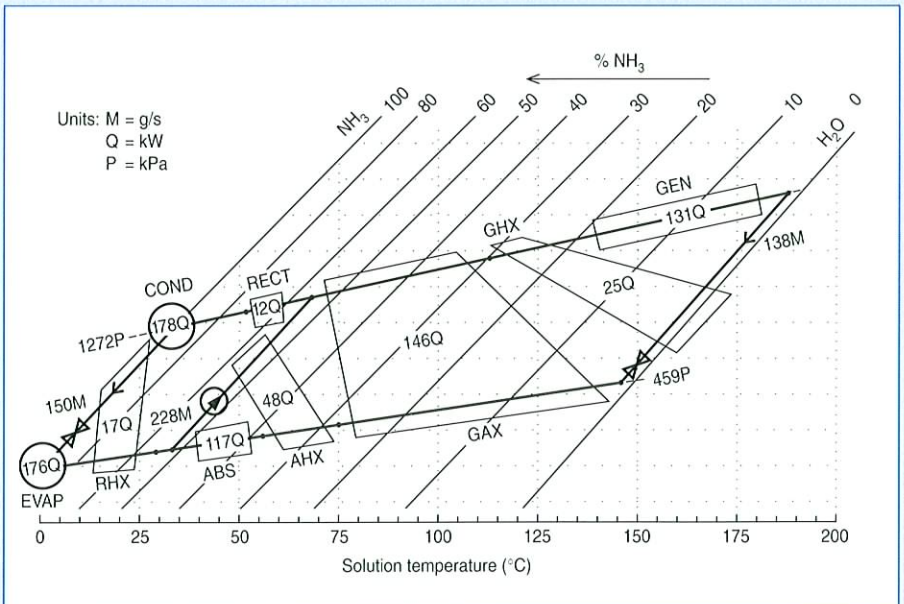
Basic GAX Cycle

The basic GAX cycle has two pressure levels and a single sorbent circulation path with no branches or joins. In the basic GAX cycle, no temperature overlap is achieved until the generator temperature increases so that the "drop" (T_{gen} minus T_{cond}) is about 2.6 times the "lift" (T_{cond} minus T_{evap}). Thus one general characteristic of GAX cycles is that they only apply when the available driving heat is much hotter than for a conventional single-effect absorption heat pump.

For a fixed lift and drop, it is frequently possible to design an "integer"-effect absorption cycle (e.g. single, double, or triple-effect) (Alefeld, 1985) or possibly a "rational"-effect (e.g., 1 1/2 effect) (Erickson, 1991) cycle which has a higher COP than

Figure 1: Basic GAX cycle chiller.

List of abbreviations:
COND = condenser
RECT = rectifier
GHX = generator heat exchanger
GEN = generator
GAX = generator-absorber heat exchanger
AHX = absorber heat exchanger
ABS = absorber
RHX = refrigerant heat exchanger



the GAX cycle. However, those cycles must be designed for the most extreme drop-lift conditions expected, and their COP remains relatively constant at all milder conditions.

In contrast, the GAX cycle COP automatically improves as conditions become milder. Even though the basic GAX cycle may have a lower design point COP than an optimized integer-effect cycle, its seasonal COP will usually be higher.

The most exacting requirement with regard to achieving the full potential of GAX is obtaining the full temperature glide in absorber and generator in the presence of heat and mass transfer. This requires techniques which run counter to much current practice in the absorption heat pump field (although the techniques are widely used in other disciplines). In order to achieve these glides, it is necessary to minimize both temperature mixing and concentration mixing, where the latter is frequently more detrimental than the former. That is to say, all heat and mass transfers should be conducted at near-equilibrium conditions. This is a particularly exacting requirement when using a volatile mixture such as ammonia/water.

Working Pairs

The absorption working pairs (sorbent and working fluid) which are suitable for GAX cycles are those which are capable of achieving large temperature glides. Solid adsorbents have been applied in pseudo-continuous GAX cycles using an intermediary heat transfer fluid (Shelton, 1987; Tchernev, 1987). This article is limited to liquid working pairs.

At space conditioning temperatures, ammonia/water exhibits commanding thermodynamic advantages, which are tempered in some scenarios by safety and toxicity questions. Water as working fluid is applicable primarily in higher temperature GAX cycles for industrial uses, where the pressures are high enough (deep vacuum operation does not give the required temperature glide). Alkitrate™-water has advantageous properties for high-temperature operation (Howe, Erickson, 1991). Other possible working pairs such as HFC-organic or MMA-H_2O (monomethyl amine/water) are not precluded, but critical case-specific non-thermodynamic concerns must be solved.

Cooling Applications

Traditionally, one of the major rationales for adopting the single-effect ammonia/water absorption cycle in space conditioning applications has been that it can be air cooled. Higher COPs are possible by using a lithium bromide cycle with a water cooled condenser. But this requires a separate cooling tower.

However, with the GAX cycle, the higher pressures of the ammonia condenser allow an evaporatively cooled condenser to be directly integrated into the cycle at minimal added cost. And the increased temperature overlap resulting from the lower cycle lift yields a substantial COP increase.

Cooling COP of 1.34

For example, Figure 1 illustrates a basic GAX cycle with a 3°C evaporator and 33°C evaporatively cooled condenser (typical for commercial chilling). The cycle cooling COP is 1.34 for the 30°C lift. With a comparable air-cooled basic GAX cycle at the same ambient conditions, the condenser would be as high as 48°C resulting in a 45°C lift and a COP of only 0.95.

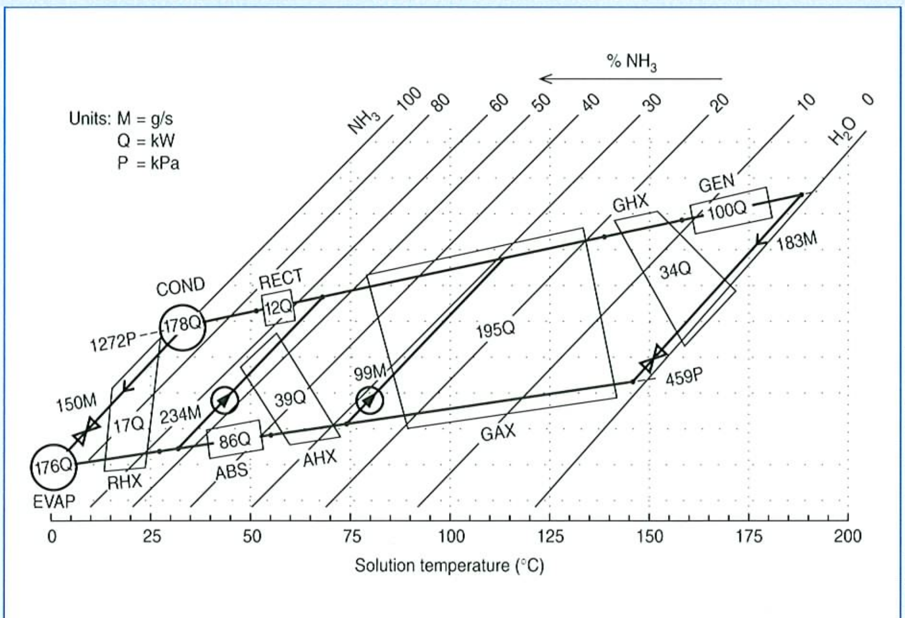


Figure 2: Branched GAX cycle chiller.

List of abbreviations:
COND = condenser
RECT = rectifier
GHX = generator heat exchanger
GEN = generator
GAX = generator-absorber heat exchanger
AHX = absorber heat exchanger
ABS = absorber
RHX = refrigerant heat exchanger

Branched GAX Cycle

As the various thermodynamic limitations of the basic GAX cycle have become evident, modified cycles have been advanced to overcome them. The Branched GAX cycle has been developed to overcome the heat mismatch between the overlap portions of the absorber and generator (Ziegler et al., 1986). Heat mismatch occurs because, in the temperature overlap zone, the absorber cannot produce all the sorption heat that the generator can accept. The heat mismatch must be added to the external heat requirement.

With the Branched GAX cycle (Erickson, 1991 b), the solution flow rate through the temperature overlap portion of the absorber is increased in order to increase the heat release. A larger fraction of the vapour from the evaporator is absorbed in the high flow zone. After absorption, the increased sorbent flow is pumped (via a "branch") to an appropriate midpoint of the generator. This causes a relative decrease in the sorbent flow through the cold end of the generator and a corresponding decrease in its heat requirement. In practice, the branch flow is adjusted until the heat mismatch disappears.

30% COP improvement

The above explanation is quantified for a specific case by comparing Figure 1 to Figure 2, which shows the Branched GAX cycle at the same 3°C to 33°C conditions. By eliminating the mismatch, the Branched GAX cycle increases COP from 1.34 to 1.76, a 30% improvement.

Design criteria

In designing a Branched GAX cycle it is essential to avoid temperature pinch or crossing in the GAX exchanger. The quantities in Figures 1 and 2 are based on a minimum 6°C approach in all heat exchangers, plus the assumption of mass equilibrium. In reality, concentration difference driving forces will decrease the cycle COPs to about 95% of the values shown (Phillips, 1991). Flue losses will mean that the gas COP will be a further 10-15% less. Thus a gas cooling COP of the order of 1.5 can be expected from the Branched GAX cycle. This is a design point COP - the seasonal COP will be modestly higher.

Comparison of Figures 1 and 2 shows that the total heat duty is almost identical for both cycles. The Branched GAX cycle merely shifts external duty to internal duty. The necessary increase in the surface area of the heat exchangers is determined by the relative magnitude of the internal and external transfer coefficients, while allowing for the reduced LMTD (Logarithmic Mean Temperature Difference) of the Branched GAX internal exchanges. Overall, the cost of the 30% improvement in COP is a second pump, a 16% increase in pump duty, and about 10% increase in transfer surface.

Variable COP

As with all GAX cycles, COP varies with temperature lift. As the temperature lift decreases, the amount of temperature overlap increases, and the COP of the basic GAX cycle increases correspondingly. Furthermore, the heat mismatch also increases with decreasing cycle lift. Therefore the advantage of Branched GAX over basic GAX increases rapidly at lower lifts.

Conversely, as the cycle lift increases, and the point is approached where the overlap disappears, the advantage of Branched GAX over basic GAX also disappears. The higher lift scenarios are typical of heating as opposed to cooling conditions. Figure 3 compares the basic GAX and Branched GAX COP as a function of lift.

Other Advanced GAX Cycles

A limitation of both the basic and the Branched GAX cycle is the loss of temperature overlap at high temperature lifts (i.e. above the ideal double-effect lift). In practical terms, the result is that the externally cooled absorber operates over a wide temperature glide and the cooling medium is heated substantially above ambient resulting in wasted availability. In some scenarios this can be a tangible benefit, e.g., co-production of hot water at temperatures up to about 65°C. However, in the general case it would be preferable to convert that wasted availability into more cooling effect. Several advanced GAX cycles have been developed to overcome this problem. All entail a third (intermediate) pressure level, plus an auxiliary generator and auxiliary absorber at the third pressure. Four advanced cycles are outlined below:

- Variable Effect Cycle
  This cycle, disclosed by Kauffman in 1981, places both the auxiliary generator and the auxiliary absorber in separate GAX (internal) heat exchanges.

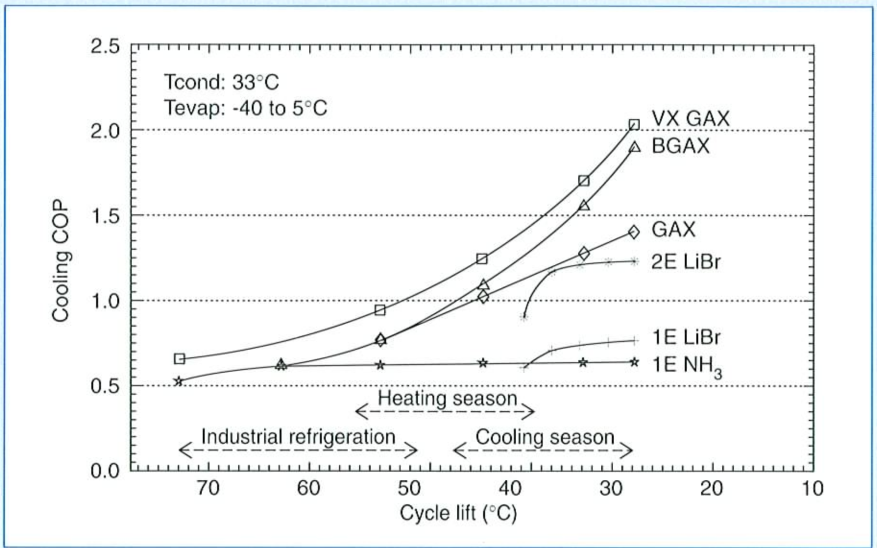
- Regenerative Cycle
  This cycle, disclosed by Rasson in 1988, applies external heat to the auxiliary generator and external cooling to the auxiliary absorber. Only a single GAX exchanger is present.

- Variable Regenerative Cycle
  This cycle, disclosed by Modahl and Hayes in 1992, incorporates features of each preceding cycle. It locates the auxiliary generator at the cold end of the cycle and the auxiliary absorber at the hot end.

- Vapour Exchange GAX Cycle
  This cycle, disclosed by Erickson in 1992, applies external cooling to the auxiliary absorber and uses a second GAX exchanger to apply otherwise wasted low pressure absorber heat to the auxiliary generator.

Figure 3: Comparison of absorption cycle COPs.

List of abbreviations:
VX GAX = vapour exchange GAX
B GAX = Branched GAX
2E = double effect
1E = single effect.



Each of these advanced GAX cycles enjoys a very high hypothetical COP, but each entails some very practical difficulties in achieving it. Analysis to date has indicated that the mechanically simplest (and hence lowest cost) route to high COP is via the VX (Vapour Exchange) GAX cycle. Figure 3 shows the level of COP performance which can be expected from VX GAX using realistic and cost-effective hardware. Note that the largest proportional improvement in COP occurs for high lift scenarios, e.g., industrial refrigeration or space heat pumping.

GAX Applications

Applications are dependent on the inherent thermodynamic capacity of the cycle, the capital cost, and the operating economics (thermodynamic performance).

Figure 3 compares the thermodynamic performance of the three highlighted members of the GAX family (basic GAX, Branched GAX, and VX GAX) to the thermodynamic performance of the two commonly available Lithium Bromide chillers (1E and 2E). The GAX cycle COPs are calculated values based on the use of ammonia/water working fluid and 6°C minimum approach temperatures across the heat exchangers.

As suggested by Figure 3, there are a wide variety of prospective applications for the GAX cycles, ranging from space conditioning, (chilling and heat pumping) to industrial refrigeration - even down to very low temperatures. In all of these applications, a GAX cycle can achieve a markedly better COP than the best conventional technology.

Driving Heat

The source of driving heat can be direct-fired fuel, waste heat, or solar heat. The latter choice becomes very attractive in sunbelt locations having high electricity costs, because the high GAX cycle COPs substantially reduce the size and cost of the required solar collector.

Some Examples

Specific applications which show great promise with the various GAX cycles include:

Basic GAX
Small-scale (<50 kW) air-cooled heat pump for residential or light commercial use. $COP_C = 0.85$; $COP_H = 1.6$

Branched GAX

- Moderate-scale (50 - 400 kW) heat pump or chiller (evaporatively cooled) for commercial or industrial use; $COP_C = 1.5$; $COP_H = 1.8$
- Small to moderate industrial refrigerator down to - 15°C; $COP_C = 0.9$
- Moderate to large industrial evaporator (Erickson, 1989); $COP_H = 4$ or higher

VX GAX

- Large-scale space conditioning system; $COP_C = 1.8$; $COP_H = 2.1$
- Low temperature (- 40°C) industrial refrigerator; $COP_C = 0.75$
- Large-scale moderate temperature industrial refrigerator; $COP_C = 1.1$

Economics

The economics of absorption machines are dominated by the cost of transfer surface in the heat exchangers. Taking the examples of Figures 1 and 2, where the total heat transfer duty is 837 kW to produce 176 kW cooling, and further assuming a conservative 6°C LMTD throughout and an overall transfer coefficient of

0.5 kW/m²K, yields a total surface requirement of 279 m². At a cost of USD 100/m², the machine cost is USD 27,900 (or USD 156/kW). A straightforward energy cost-capital cost tradeoff is possible dependent on the local cost of power, e.g., doubling the LMTD nearly halves the capital cost but decreases COP by 19%. Thus a range of possibilities is available:

- thermodynamic performance the same as conventional technology, capital cost lower;
- capital cost the same as conventional technology, thermodynamic performance better;
- capital cost higher, thermodynamic performance much higher.

GAX Projects Around the World

The following GAX cycle projects have been undertaken:

- In the U.S., Phillips Engineering (Phillips, 1991 a) are now field testing 10 kW basic residential heat pumps in a project which began in 1984.
- Also in the U.S., Trane (Modahl, 1988) completed laboratory prototype testing of an 80 kW basic GAX commercial chiller in 1989.
- In the Netherlands, Rendamax has developed a 250 kW basic GAX heat pump (Bassols, 1990), and has now completed 2,600 hours of testing. This system will be installed in a space conditioning application early in 1993.
- In Japan, several basic GAX projects are reportedly in the planning stages.
- The U.S. Department of Energy and Lawrence Berkely Laboratory has supported work on the regenerative cycle for 15 years (Zimmerman, 1987), and that work continues at a reduced funding level.
- Energy Concepts Company in the U.S. is constructing a laboratory prototype of an industrial 50 kW icemaker using the Branched GAX Cycle (Erickson, 1991). This work will culminate in a field demonstration of a waste-heat powered 65 kW icemaker with a COP of 1.2, and is financially supported by the Alaska Science and Technology Foundation and the Alaska Energy Authority.
- The U.S. Gas Research Institute (GRI) is initiating a multi-faceted research programme on GAX cycles, encompassing both small rooftop heat pumps, and larger (100 to 300 kW) chillers. (GRI, 1992).

An Opportunity to Meet Environmental Problems

It is indeed fortuitous that precisely at the time in history when the traditional method of heating and cooling our homes and buildings is becoming implicated in major global environmental problems, this new technology has emerged which promises substantial amelioration of those problems. "Fast-track" exploration and development of this GAX technology is called for.

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Authors:
D.C. Erickson and M.V. Rane, Energy Concepts Co., USA.
Tel.: +1-410-266-6521; Fax: +1-410-266-6539.

News and Views

The Heat Pump Centre welcomes information and comments from all its readers!

IEA Heat Pump Programme

Heat Pump Centre Celebrates its 10th Anniversary

This issue of the Newsletter marks the IEA Heat Pump Centre's (HPC's) first steps into the second decade of its existence. It was on December 8th, back in 1982, when the greenhouse effect was virtually unheard of, and a ban on CFCs an environmentalist's dream, that the HPC was born. Then, as now, the HPC set out to increase the implementation of heat pumps by improving the flow of information between relevant groups of people.

After seven years valuable work in Karlsruhe, Germany, the HPC moved to Sittard, the Netherlands where the member countries' aims continue to be served through activities such as Analysis Studies, Workshops, Inquiry Service, Promotion Activities and the production of this Newsletter. HPC staff members in Sittard are shown below. The focus for the following year's activities is set at the annual meeting of the National Teams of the HPC.

National Teams Working Meeting

This year's meeting was held in September in Maastricht, the Netherlands and was extended to three days to celebrate the HPC's 10th Anniversary. The celebrations culminated in an "Anniversary Dinner" (see photo on page 28) during which members of the HPC network joined Mr. Jerry Groff, (Chairman of the Advisory Board IEA Heat Pump Programme) and Mrs. Gudrun Maass (Principal Administator of the IEA's Division for Energy R&D Collaboration), in a toast to the continued success of the HPC. Also included in the programme was a visit to Rendemax bv's Absorption (GAX cycle) Heat Pump Project in the Netherlands.

At the meeting, agreement was reached on a proposal to hold a workshop in North America on "Domestic Hot Water Heat Pumps in Residential and Commercial Buildings" in the Summer of 1993. Also, National Teams agreed to supply data for an analysis entitled "International Heat Pump Status and Policy Review."

HPC Staff Members (from left to right):
Left photo - 1st row: Minie Wilpshaar (Secretary), Susan Ross (Technical Services Coordinator) - 2nd row: Jos Bouma (General Manager), Mike Steadman (Technologist), Bert Stuij (Senior Technologist). Right photo - 1st row: Lucinda Maclagan (Head of Publications), Heleen Smeets-Helgers (Sales and Stock Control) - 2nd row: Roswitha Muyres (Editor), Maria de Jong-Hurley (Assistant Editor) .

At a castle overlooking Maastricht, members of the National Teams, Advisory Board and Heat Pump Centre look forward to the HPC's 10th Anniversary Dinner.

Annex 18 Measures Up for the "Refrigerant Olympics"

IEA project Annex 18 has the title "Thermophysical Properties of the Environmentally Acceptable Refrigerants." The goal of this Annex is to develop property formulations, in the form of tables, diagrams and computer programs, for certain alternative refrigerants that would become international standards. In order to achieve the best possible formulation, an evaluation, selection and correlation process, referred to as the "Refrigerant Olympics" has been developed, to compare competing equations with experimental data.

The evaluation of data on HCFC-134a and HCFC-123 will be completed in the Spring of 1993 and the "winning" equations will be selected. Member countries have proposed an extension of this Annex beyond its original 1992 end date so that work can begin on HCFC-22 replacements including mixtures.

Annex 17 "Experiences with New Refrigerants in Evaporators"

This Annex aims to increase of knowledge regarding performance of new refrigerants, especially heat transfer and pressure drop behaviour in the evaporator part of heat pump plants. Experimental work has been performed, and results are being evaluated using existing correlations, and possibly developing new ones. The Final Report is expected in early 1993.

Annex 20 "Working Fluid Safety"

The work in Annex 20 is entering its final phase. After a review of regulations and accident statistics related to refrigeration machines and heat pumps, the Operating Agent in Belgium is now developing quantitative techniques to evaluate the risks involved in the use of alternative working fluids. *(Source: J. Berghmans, Operating Agent, Katholieke Universiteit Leuven, B-3001 Heverlee, Belgium, Tel.: +32-16-286611; Fax: +32-16-222345.)*

Annex 21 "Global Environmental Benefits of Industrial Heat Pumps"

The initial work of surveying current state-of-the-art of industrial heat pumps (IHPs) and existing installations has begun. Developments are also underway to utilize this data to evaluate the technical feasibility of IHPs and determine cost and performance for various process conditions. A meeting of experts participating in this project took place in November 1992 in the USA where discussions focused on developing a methodology for determining the economic and market potential of IHPs.

Norway Signs Up

Reflecting the Norwegian Government's considerable interest in heat pump technology, Norway has recently joined Annexes 18, 20 and 21. In addition, Norway also participates in Annex 17 and the Heat Pump Centre.

Legislation

Norway Reduces Heat Pump Subsidies

On October 6th, the proposal for the Norwegian National Budget was released by the Government. Overall, the budget is relatively tight, and that also affects the public funds allocated to energy conservation measures in general, and heat pumps in particular. The proposal is to cut the funds for energy conservation measures from NOK 516 million to NOK 321 million (USD 56.8 million. The heat pump subsidy programme introduced in January 1992 is also trimmed. The proposal is to reduce the maximal subsidy percentrage from 40 to 30. In addition, the smallest split units for residential heating will no longer be eligible for subsidy. The National Budget will be decided on in December. *(Source: the Norwegian National Team.)*

Korea Imposes Compulsory Peak-Shifting Measures

The rapid rise in installed air-conditioning units in South Korea has lead to government intervention to avert an energy supply crisis. The huge demand for daytime electricity for air-conditioning has severely stretched Korea's power generation capacity. In an effort to improve power plant operating ratio, a new compulsory rule has been introduced by the government recently in order to match the maximum demand in summer to the supply capacity in generation plants. The new rule is as follows:

"When a building with a larger scale than the standard is to install a central cooling system, it must adopt either a gas driven system or a (cool) heat storage tank with a capacity of more than 60% of maximum cooling load."

The peak-shift problem is mainly due to air conditioning demand from large buildings. In Korea the small-sized room air conditioner has not diffused so much as in Japan, but clearly a growth in this market would have a significant impact on Korea's energy situation. *(Source: the Japanese National Team.)*

Products

Japanese Utility Reports Steady Growth in Installed GHPs

Data from Tokyo Gas shows that the installed capacity of gas engine-driven heat pumps (GHPs) within its service area has risen from 4.47 GW in reference year (Oct. to Sep.) '90 to an estimated 4.85 GW in reference year '91. A breakdown of sales by outlet shows that 2.4% were for residential use, 40% for offices, 7% for stores and restaurants, 20.9% for schools, 9.4% for factories and 20.3% for other uses. *(Source: JARN, July 1992.)*

Steep Decline in Stirling Engine Manufacture

Despite considerable support for Stirling engine development by the Japanese government, interest in this promising technology is diminishing rapidly. The results of a recently released government sponsored survey (see Table 1) show that the number of manufacturers involved in Stirling engines has dropped from seven in the mid-eighties to only three in 1991, all of which have reduced output. Today, a total of 68 Stirling Engine Heat Pump systems are in operation in Japan. Government sponsored Stirling engine activities in Japan have included a "National Project on Stirling Engine R&D for General Use" and a "Feasibility Study of Stirling Engine Heat Pump Systems." *(Source: the Japanese National Team.)*

Table 1: Survey of manufactured Stirling engine units in Japan.

Manufacturer	'81	'82-'87	'88-'90	'91	Total
Aisen Seiki	7	21	30	11	69
Mitsubishi Electric	-	28	16	10	54
Sanyo Electric	2	17	21	6	46
Toshiba	-	10	-	-	10
Sanden	1	6	-	-	6
Matsushita Electric	-	5	-	-	5
Kawasaki Heavy Ind.	-	1	-	-	1
Total	9	88	67	27	191

Sanyo to Open Absorption Heat Pump Plant in China

Sanyo Electric Co. will begin producing lithium/bromide absorption heat pumps in The People's Republic of China in June 1993. The new facility will be located at the Dalian Economic and Technical Development Zone in Riaoning and will manufacture about ten units in its first year of operation. The heat pumps are designed for large-scale space conditioning systems for commercial buildings and factories, and for district heating/cooling systems. Annual output is expected to expand to 250 by 1997. *(Source: JARN, August 1992)*

Conferences

Teleconferences Inform U.S. Audience About Geothermal Heat Pumps

Heating, cooling, and water heating with earth energy is one of the more significant developments in today's world of rapidly changing energy technology. On July 21, 1992, a teleconference informed over 3,500 participants across the USA about recent improvements in geothermal (ground source) heat pumps and applications, demonstrated how they have become cost-effective customer options, and confirmed that programmes encouraging their installation are wise policy.

An audience of state energy officials and utility executives saw examples of geothermal heat pump installations in a broad range of building types, from low-income housing to large institutional buildings. Panel discussions highlighted the advantages of geothermal heat pumps. After presentations by each of the panellists, viewers called in questions which were answered by the panel. Two more teleconferences will be offered in 1993 by the same sponsors.

The March 3, 1993 conference, for an audience of dealer/contractors, drilling contractors, builders, loop installers, and other trade allies interested in participating or who are already profiting from this growing market, will feature "success" stories from contractors in the business and will review innovations in actual geothermal heat pump installation. The programme will emphasize sales and equipment design, selection, and installation.

The April 28, 1993 conference will be directed to an audience of architect/engineers, who want to learn more about geothermal heat pumps and how they can reduce heating and cooling costs for their commercial clients. The programme content will include case studies of successful geothermal heat pump installations in a number of different building types and climates, as well as guidelines for equipment and heat exchanger selection and sizing for different applications.

There is no fee for the televised portion of the conferences. The sponsors will arrange for regional downsites where a local programme will be offered using the televised programme as a "centrepiece". Those wishing to sponsor such "organized downsites" or who want more information should contact the conference coordinator, Policy Research Associates, Inc. at tel.: +1-703-742-8402. *(Source: David P. Ross, Policy Research Associates, Inc., USA.)*

First Open Norwegian Heat Pump Conference

The first "Open Norwegian Heat Pump Conference" was arranged by the Norwegian National Team on the 15th and 16th of September. The conference was divided in two parts: on the evening of the 15th there was a National Team meeting with Mr. Jos Bouma of the Heat Pump Centre and Mr. Peter Oostendorp of TNO (The Netherlands) as guest speakers. Mr. Bouma gave a presentation on the IEA Heat Pump Centre, while Mr. Oostendorp talked about the role of the Dutch National Team in The Netherlands. The informative meeting was a great opportunity for members of the Norwegian National Team to get a closer look at international heat pump activities.

The second day was devoted to the conference itself. Three guest speakers were invited: Professor Hans J. Laue of Fachinformationszentrum Karlsruhe, Germany, spoke about "The German Response to the HCFC Question"; Professor Hermann Halozan presented the report on "The Impact of Heat Pumps on the Greenhouse Effect" and Mr. Wilhelm Ritter talked about Heat Pumps in Austria. The conference, attended by more than 70 participants, generated much interest and enhusiasm, and the Norwegian National Team has already decided to repeat it next year. *(Source: the Norwegian National Team.)*

Working Fluids/CFCs

Azeotrope Promises High Efficiency HCFC-22 Replacement

Recent tests suggest that the replacement of HCFC-22 in space conditioning systems by an azeotrope of HFC-32 and HFC-125 would bring energy saving benefits. This, according to U.S. refrigerants manufacturer Allied-Signal Inc., is due to the superior heat transfer and pressure drop characteristics of this azeotrope.

Azeotropes offer several benefits over blends. Unlike blends, the composition of an azeotropic mixture does not change as it is evaporated and condensed in a heat pump cycle. This means that an azeotropic heat pump would be easier to service and maintain than one using a blend, because the working fluid is inherently more stable. Also, the stability of azeotropes means that a non-flammable azeotrope will remain safe throughout its working life. Allied Signal azeotropes for space conditioning and refrigeration applications are currently being tested by major compressor and equipment manufacturers, and also under ARI's (Air-conditioning and Refrigeration Institute's) Alternate Refrigeration Programme. *(Source: The Air Conditioning, Heating and Refrigeration News, September 28, 1992.)*

Building Officials Allow Use of HCFC-123 and HFC-134a

The membership of the International Conference of Building Official (ICBO) has voted to accept a proposal that will grant code-acceptance status for HCFC-123 and HFC-134a. This reverses a decision to reject the proposal in February 1992. The accepted proposal allows use of these low ODP (Ozone Depletion Potential) working fluids if the precautions listed in ASHRAE Standard 15-1989R are taken. These include the use of leak-detection systems, alarms, and mechanical ventilation. *(Source: The Air Conditioning, Heating and Refrigeration News, September 14, 1992.)*

Systems/Installations

HFC-134a Heat Pump Serves Yeast Factory and District Heating

The late summer of 1992 saw the opening of a HFC-134a heat pump installation in a yeast factory in Sollentuna, Sweden. The installation maintains the fermentation process at 30° C and delivers 80 °C heat to the local district heating system at a COP of 2.9.

The 5 MW (heating) turbo system is thought to be the first industrial heat pump using HFC-134a to deliver heat at such a high temperature. The SEK 18 million (USD 3.2 million) investment cost is expected to be paid back within six years due to energy savings. The system also reduces environmental damage by eliminating the exploitation of ground water for cooling. *(Source: Wärmepumpe, IZW, Germany. Tel.:+49-72-47-808-351; Fax: +49-72-47-808-134)*

Research and Development

EPRI Launches Ozone-Friendly Heat Pump Development Programme

The United States Electric Power Research Institute (EPRI) has launched a major initiative to develop, demonstrate and commercialize air- and water-source heat pumps with zero ozone depletion and minimum global warming potential. After evaluating the performance of a range of working fluids and lubricants, EPRI will design prototype heat pumps which will eventually lead to full-scale commercialization. As well as meeting environmental criteria, the designs must match today's standards for efficiency and be no more difficult to install, operate or maintain than existing systems. *(Source: The Air Conditioning, Heating and Refrigeration News, September 14, 1992.)*

The 4th IEA Heat Pump Conference

"Heat Pumps for Energy Efficiency and Environmental Progress"

Maastricht, the Netherlands, April 26-29, 1993

Goal:
The goal of the conference is to promote the worldwide implementation of heat pump technology via exchange of technical, market, policy and regulatory information.

Keynote speakers:
- *Markets: Ms. H. Steeg (IEA director)*
- *Environment: Ms. J. Aloisi de Larderel (UNEP director)*
- *Technology: Mr. Y. Makise (Mitsubishi president)*

Sessions:
- *Environmental overview - CFC and CO_2 regulations, plus studies on the role of heat pumps*
- *New Refrigerant Technology Status - Research on and experiences with new refrigerants*
- *Technology Advances - Includes high temperature, advanced control and process integration*
- *Market Aspects - Trends, forecasts and impediments in different regions*
- *Market Influences - Standards, incentives, promotion and the role of utilities and R&D*

Pre-conference tours:
Tours of small, medium and large-scale installations in buildings and industry will be conducted in the week prior to the conference: one in Germany and the Netherlands, the other in Norway and Sweden.

Other Events:
Plenary Session • Poster Session • Exhibition of heat pump hardware

Registration:
A full registration package is available from the Conference Secretariat or HPC National Teams.

Conference Secretariat:
Van Namen & Westerlaken Congress Organization Services. Tel.:+31-80-234471; Fax:+31-80-601159.

Regional coordinators:
- *North America: Mr G. Groff, Marquard Switches. Tel.: +1-315-655-8050; Fax: +1-315-655-8042.*
- *Asia/Oceania: Mr Y. Igarashi, Heat Pump Technology Center of Japan. Tel.: +81-332-58-1035; Fax: +81-332-58-1037.*
- *Europe: Mr J. Bouma, IEA Heat Pump Centre. Tel.: +31-46-595-236; Fax: +31-46-510-389.*

Sponsors include:
Member countries of the IEA Heat Pump Programme plus the International Institute of Refrigeration (IIR).

In Memoriam: Bengt Lundquist

Just back from the Executive Committee's meeting (for the IEA Heat Pump Programme) in Chicago, I learned with great sorrow and surprise that the former Swedish delegate to the Committee, Bengt Lundquist, had died on 17 May at the age of 71. To this meeting, which was the first after he withdrew as the Swedish delegate, he sent us a letter dated April 26:

Dear Delegates,
In more than ten years I have been a member of the Executive Committee as Delegate for Sweden. It is now time for me to withdraw and give my place to a younger person. These ten years have given me many good individual relations to many of you and it is only to state that I am going to miss you. I wish to say thank you to all of you for your willingness to co-operate in many common Annexes and also in many other questions of importance for the work in the Executive Committee.
I see the new Strategy Plan as necessary for the future and hope the plan will be a success in relationship to industries and new markets.
Good luck to all of you in your work for a better heat pump technology and a better environment.

Bengt Lundquist

This letter speaks for itself about Bengt's commitment towards his work and international cooperation.

Bengt Lundquist joined The Swedish Council for Building Research (BFR) in 1979 after a long career with important positions in Swedish industry. In 1982 he became the Swedish delegate to the IEA Implementing Agreement on Advanced Heat Pumps as well as to the Nordic Expert Group on Heat Pumps and it was there that I first met him. Bengt was always easy to cooperate with and I soon grew to know him as a person with clear and well-founded opinions on energy, heat pumps and international cooperation, and as someone who cared greatly about closer cooperation between the Nordic countries. It was largely due to his influence that Norway joined the IEA activity on heat pumps.

Bengt added weight and influence to the Executive Committee and always stated his opinion clearly. He represented the very best of Swedish tradition in international cooperation; responsibility, commitment, and objectivity, always focused on solving important problems and not creating new ones.

On behalf of his many friends in the International Energy Agency, the International Institute of Refrigeration, the Nordic Expert Group on Heat Pumps and in many other contexts, I thank him for what he did and what he was for us. He will be missed whenever we come together.

Prof. Per-Erling Frivik
Norwegian Delegate and Former Chairman of the Executive Committee

Bibliography

Heat Pumps - An Opportunity for Reducing the Greenhouse Effect

Aimed at decision makers in government, industry and the building sector, this 12-page full colour brochure provides background information on the greenhouse effect and highlights the options available to reduce global warming. The brochure looks at the evidence uncovered by the IEA Heat Pump Centre's analysis "The Impact of Heat pumps on the Greenhouse Effect" and shows that the heat pump option is significant in many situations. The Brochure (HPC-BR1) is available free-of-charge from the IEA HPC.

Norwegian Text Book on Industrial Heat Pumps

A Norwegian text book on industrial heat pumps will be issued in December. Produced under Norway's "Programme for Heat Pump Implementation", this is the third in a series of heat pump text books aimed at higher education levels. The first book deals with theoretical background, while the second is on heat pumps for buildings. The books are in Norwegian. Perhaps it would be an idea to translate them into other languages? Contact the Norwegian National Team (see back cover) for further information.

JARN HVAC & R Directory 1992

Published by the Japan Air Conditioning and Refrigeration News (JARN) Ltd., this buyers' guide lists over 400 manufacturers, traders, contractors and associations in Japan. It gives statistics on the Japanese HVAC & R industry and includes a list of overseas Japanese subsidiaries. More information from the editor of JARN magazine Mr. A. Ishida, Tel. +81-33-584-4704; Fax: +81-33-584-4708.

Protecting the Ozone Layer - Refrigerants

UNEP IE/PAC, ISBN 92-807-1333-7 / US Sales No. 92-111-D6

Published by UNEP in English, French and Spanish (Arabic and Chinese versions are in preparation) this brochure is designed to inform decision makers in government and industry on CFCs and other ozone depleting substances (ODSs) used for refrigerants. It describes the environmental effects of ODSs and reviews the technical and economic implications of current and soon-to-be-available alternatives. Available from: UNEP IE/PAC, Tel.: +33-1-40-58-8850; Fax: +33-1-40-58-8874.

Air Quality, Desiccant and Evaporative Cooling Systems

IEA, ISBN 91-540-5489-3 / D13-1992

Final report on a workshop held in Orlando, USA, in January 1991. For more information contact: Svensk, Byggtjänst, S-171 88, Solma, Sweden.

Conferences

*Call for Papers

International Seminar on New Technology of Alternative Refrigerants - Lubricants and Materials Compatibility
February 8 - 10, 1993 / Tokyo (Japan)
Contact: Ms. Yoshiko Miyazawa, Japanese Assoc. of Refrigeration, San-ei Bldg., 8 San-ei-cho, Shinjuku-ku, Tokyo 160, Japan.
Tel.: +81-3-3359-5231 Fax: +81-3-3359-5233

Building Design, Technology & Occupant Well Being in Cold and Temperate Climates
February 17-19, 1993 / Brussels (Belgium)
Sponsors: ATIC (Association Royale Belge Technique de l'Industrie du Chauffage, de la Ventilation et des Branches Connexes) and ASHRAE. Contact: ATIC-CDH.
Tel.: +32-2-348-0550; Fax: +32-2-343-9842.

ISOTHERM - Trade Fair and Congress for Insulation, Sanitation Heating and Energy Saving Technology
February 25-28, 1993 / Salzburg (Austria)
Contact: Praesenta Fachmessen GmbH, Praterstrasse 12, A-1020 Wien, Austria.
Fax: +43-222-266-52922

CLIMATIZACION 93 - International Air Conditioning, Ventilation, Cooling and Heating Trade Fair.
March 3-7, 1993 / Madrid (Spain)
Held in conjunction with 2nd Ibero-American HVAC Congress.
Contact: R.G. de Calderon, IFEMA, Parque Ferial Juan Carlos I, Apdo. de Correos 67067, 28080 Madrid, Spain.
Tel.: +34-91-772-50-00.

ISH '93 - International Trade Fair Sanitation, Heating, Air-Conditioning
March 23-27, 1993 / Frankfurt (Germany)
Contact: Messe Frankfurt GmbH, Ludwig-Erhard Anlage 1, 6000 Frankfurt 1, Germany.
Tel.: +49-69-75750; Fax: +49-69-757564-33.

AIRAH Exhibition (The Australian Institute of Refrigeration, Air-Conditioning and Heating Inc.)
April 4-7, 1993 / Darling Harbour (Australia)
Contact: AIRAH, 191 Royal Parade, Parkville, Victoria 3052, Australia.
Tel.: +61-3-347-4777; Fax: +61-3-347-8571.

The 4th IEA Heat Pump Conference
April 26-29, 1993 / Maastricht (The Netherlands)
Conference Secretariat: Van Namen & Westerlaken Congress Organization Services, P.O. Box 1558, 6501 BN Nijmegen, the Netherlands.
Tel.: +31-80-234-471; Fax: +31-80-601-159.

SAUDI Aircon 93 - Riyadh's Air-Conditioning, Ventilation, Heating and Refrigeration Show
May 9-13, 1993 / Riyadh (Saudi Arabia)
Contact: Trevor Punt, Overseas Exhibition Services Ltd., 11 Manchester Square, London W1M5AB, Uk.
Tel.: +44-1-486-1951; Fax: +44-1-935-8625

Energy Efficiency in Refrigeration and Global Warming Impact
May 12 - 14, 1993 / Ghent (Belgium)
Organized by the International Institute of Refrigeration
Contact Prof. P. Moerman, Rug, Rozier 44, B 9000 Gent, Belgium.

Sixth International Stirling Engine Conference and Exhibition
May 26 to 28, 1993 / Rotterdam (The Netherlands)
Contact: The Organizing Secretary, P.O. Box 16350, 2500 BJ The Hague, The Netherlands.
Tel.: +31-70-3819394; Fax: +31-70-3824321

INTERKLIMA - International Exhibition of Heating, Cooling, Ventilating, Air-Conditioning and Sanitary Equipment
June 8-12, 1993 / Zagreb (Croatia)
Contact: Zagrebacki Velesajam, Avenija Borisa Kidrica 2, 41020 Zagreb, Croatia.

1993 ASHRAE Annual Meeting
June 26-30 1993, Denver, Colorado (USA)
Contact ASHRAE Meetings Department, 1791 Tullie Circle NE, Atlanta, GA 30329, USA.
Tel.: +1-404-636-8400 Fax: +1-404-321-5478

Indoor Air '93 - International Conference on Indoor Air Quality and Climate
July 4-8, 1993 / Helsinki (Finland)
Sponsors include: the IEA, ASHRAE and the World Health Organisation.
Contact: Prof. Olli Seppänen, Helsinki University of Technology, SF-02150 Espoo, Finland.
Tel.: +358-0-451-3600; Fax: +358-0-451-3611.

Chinese International Compressor Technique Conference and Exhibition
August 15 - 18, 1993 / Xi'an (China)
Contact: Danqing Wu, Associate Professor, Room 227, Chemical Engineering Building, Xi'an Jiatong University, 28 Xian Ning Road, Xi'an, 710049, P.R. China.
Tel.: +86-29-335011 Ext. 3980; Fax: +86-29-337910

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

Article Overview HPC Newsletter Volume 10 / 1992

Future Issues

Vol./No.	*Topic*	*Deadlines*
11/1	Industrial heat pumps	**20 December 1992**
11/2	Special Issue on the 4th IEA Heat Pump Conference	-
11/3	Heat Pumps and the Environment	**1 June 1993**
11/4	Trends in Heat Pump Technology & Applications	**1 September 1993**
12/1	Heat Pump Working Fluids (including Alternative Refrigerants)	**20 December 1993**

New HPC Products

HPC-ASR1 The Impact of Heat Pumps on the Greenhouse Effect. This summary report is available free of charge.

HPC-AR1 The Impact of Heat Pumps on the Greenhouse Effect. This analysis report can be purchased from the IEA Heat Pump Centre for NLG 80. Available to HPC member countries only.

HPC-BR1 Heat Pumps - An Opportunity for Reducing the Greenhouse Effect. This brochure is available free of charge.

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Date __________

Signature __________

Austria
Mr. H. Halozan, TU Graz
Inffeldgasse 25
A-8010 Graz, Austria
Tel.: +43-316-873-7303
Fax: +43-316-873-7305

Canada
Mr. D. Cane, CANETA Research Inc.
6981 Millcreek Dr., Unit 28
Mississauga, Ontario, Canada L5N 6B8
Tel.: +1-416-542-2890
Fax: +1-416-542-3160

Italy
Mrs. L. Manduzio, ENEA - C.R.E. Casaccia
Via Anguillarese, 301
00060 S. Maria di Galeria, Rome, Italy
Tel.: +39-6-3048-6445
Fax: +39-6-3048-6306

Japan
Mr. Y. Igarashi, Heat Pump Technology Center Japan
Azuma Shurui Bldg. 9-11 Kanda Awaji-cho 2-chome,
Chiyoda-ku, Tokyo 101, Japan
Tel.: +81-33-258-1035
Fax: +81-33-258-1037

The Netherlands
Mr. P. Oostendorp, TNO
Department of Heat and Refrigeration Technology
P.O. Box 342, 7300 AH Apeldoorn , The Netherlands
Tel.: +31-55-493-493
Fax: +31-55-419-837

Norway
Mr. R. Aarlien, SINTEF
Norwegian Institute of Technology
Division of Refrigeration Engineering, N-7034 Trondheim, Norway
Tel.: +47-7-593-929
Fax: +47-7-593-926

Sweden
Mr. B. Bäckström
Chalmers Teknikpark
S-41288 Göteborg, Sweden
Tel.: +46-31-7724-226
Fax: +46-31-418-056

Switzerland
Mrs. L. Prista
c/o Dipartimento dell'Ambiente
CH-6500 Bellinzona, Switzerland
Tel.: +41-92-243-755
Fax: +41-92-244-429

USA
Mr. M.A. Broders, Oak Ridge National Laboratory
Building 3147, P.O. Box 2008
Oak Ridge, TN 37831-6070, USA
Tel.: +1-615-576-2731
Fax: +1-615-574-9338

IEA Heat Pump Centre
Swentiboldstraat 21, 6137 AE Sittard
P.O. Box 17, 6130 AA Sittard, The Netherlands
Tel.: +31-46-595-236
Fax: +31-46-510-389

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IEA Heat Pump Centre
P.O. Box 17
6130 AA SITTARD
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