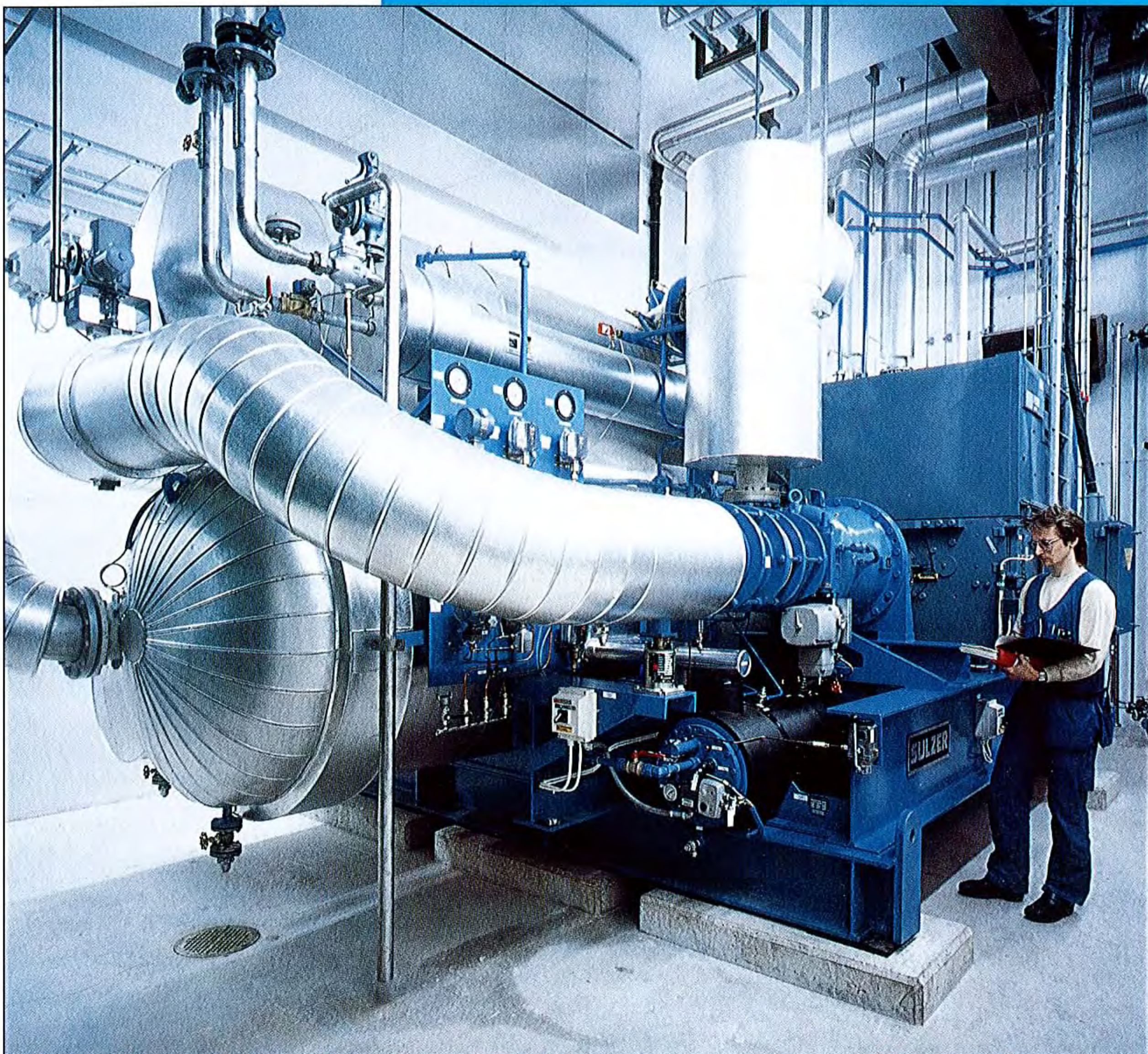
Vol. 12, No. 4, December 1994

IEA Heat Pump Centre

NEWSLETTER



Industrial Heat Pump Applications

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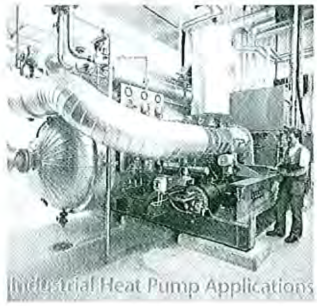

News & Views

Articles on Industrial Heat Pump Applications

Non-topical Articles

Regular Features

Front Cover: *This closed-cycle vapour-compression heat pump supplies hot water or steam up to 130°C for a vegetable oil processing plant in Sweden. During normal operation, 3.5 MW heat at 105°C is supplied with a COP of 4. (Photograph courtesy of Sulzer, Friotherm AG, Switzerland).*

International Energy Agency

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

A basic aim of the IEA is to foster cooperation among the 23 IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology, and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 36 Implementing Agreements, containing a total of more than 75 separate collaboration projects.

IEA Heat Pump Centre

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

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Broadening Horizons

As we get closer to the year 2000, many countries are becoming more sensitive to the environmental consequences of energy utilization. Alongside this, there is a growing awareness of the economic aspect of energy conservation.

Accounting for about one quarter of the total energy consumption of most industrialized countries, industry is a key area for taking energy saving measures. Well-known and reliable energy-saving technologies such as variable-speed motors, monitoring equipment and digital controls, have existed for many years.

However, they are not applied widely on the market place, either for reasons of complexity, or because first costs are too high. Industrial heat pumps also suffer from these difficulties.

But in many ways, industrial applications present good opportunities for heat pumps. Process heat demand shows little seasonal variation and the size of the demand often offers economies of scale. And when first costs and running costs are analyzed together, industrial heat pumps can offer an attractive return on investment.

The articles in this issue of the Newsletter include many examples of successful applications. In many cases the use of heat pump technology not only saves energy but also leads to other benefits such as improved product quality or a reduction in the quantity and temperature of industrial effluent. One article (page 26) shows how the use of analysis techniques such as pinch technology can lead to improved heat flow systems where heat pumps play a central role.

What are the limits to industrial heat pump design?

More than the dimensional, technical, or economic limitations, the limits are mostly set by our own creativity. This issue of the Newsletter is designed to broaden our horizons by drawing inspiration from successful applications. I urge you to spread the information around.

Jean-Pierre Galloin
Managing Director of Danfoss S.A.R.L., France and
member of the Advisory Board of the IEA Heat Pump Programme

News & Views

US Climate Change Action Plan targets heat pumping technologies

USA - President Clinton and Vice President Gore, in conjunction with industry and environmental leaders, last year announced the Climate Change Action Plan (CCAP). CCAP's main goal is to reduce US greenhouse gas emissions to 1990 levels by the year 2000. The significant greenhouse gases are carbon dioxide, methane, nitrous oxides, and hydrofluorocarbons (HFCs). Approximately 45 Actions are characterized in CCAP, which, to achieve the goal, must reduce the projected emission level by the equivalent of about 106 million tonnes of carbon below the year 2000 forecasted level. Heat pumping technologies are featured in a number of CCAP Actions.

Actions 4 and 6 of CCAP, "Market Transformation for High-Efficiency Building Equipment," will help expedite the market introduction and penetration of advanced technologies into residential and commercial buildings. To do so, the Department of Energy will facilitate partnerships with stakeholders including: manufacturers, utilities, building owners, state energy offices, builders, engineering design firms, financial institutions, and professional and research organizations. The mission addresses the removal of market barriers by achieving lower cost, lowering perceived risk, developing needed infrastructures and increasing familiarity with new, more energy-efficient technologies.

Heat pumping technologies under consideration in Actions 4 and 6 are:

- high-efficiency residential and small commercial air conditioners and heat pumps;
- high-efficiency non-CFC chillers;
- heat pump water heaters;
- high-efficiency commercial refrigeration.

Technologies and programmes will be targeted for implementations that have the potential to achieve a major market impact within 5 years. US$ 9 million has been allocated to implement Actions 4 and 6 in 1995. The impact of these two actions could reduce the projected emission level for the year 2000 by 9.1 million tonnes of carbon equivalent.

Action 26 targets renewable sources. Included is a major effort among industry to increase geothermal (ground-coupled) heat pump unit sales from 40,000 to 400,000, while reducing greenhouse gas emissions by 1.5 million tonnes of carbon equivalent annually by the year 2000. Termed the National Earth Comfort Program, this effort has a US$ 6 million investment for 1995, and includes a marketing strategy on a regional as well as national level. For example, by segmenting the market, regional training centres can disseminate information and conduct demonstrations to expedite increasing customer knowledge.

Participation in IEA Heat Pump Programme Annexes and activities promoting emerging heat pumping technologies are means by which the US National Team (for the IEA Implementing Agreement for Heat Pumping Technologies) can assist the US in meeting the CCAP goal. Progress and success stories relating to CCAP's focus on heat pumping technologies will be reported through future issues of the *IEA Heat Pump Centre Newsletter*. In this manner, other countries developing their own initiatives to reduce greenhouse gas emissions will benefit from US experiences.

(Source: US National Team)

Design manual for GSHPs

Canada - An engineering manual for the design, installation and start-up of ground-source heat pump systems for large commercial and institutional buildings is nearing completion. The manual has been developed by Caneta Research Inc. on behalf of the Canadian and United States governments and industry sponsors. The draft final document is now undergoing an expert peer review organized by ASHRAE (American Society for Heating, Refrigeration and Air-Conditioning Engineers) under the sponsorship of the US Department of Energy. ASHRAE plans to publish the manual in the spring of 1995. For more information write to W. Seaton, Manager of Research ASHRAE, Inc., 1791 Tullie Circle, NE, Atlanta, Georgia USA. 30329.

(Source: Canadian National Team)

Unused Energy Project begins field tests

Japan - Field tests will begin in 1995 on technologies developed under the national Unused Energy Project. The Agency for Natural Resources (ANRE) and the Ministry of International Trade and Technology (MITI) have together selected four sites for these tests.

At the Tokyo bay area, heat from an incinerator, sea water and an electric substation will be used as heat sources for a district heating and cooling system using three heat pumps - a screw heat pump, a turbo heat pump and an absorption heat pump.

At the Konan power station of Kansai Electric Power Co. Inc., a compression heat pump will provide space conditioning for offices utilizing heat from sea water.

At the Tarumi sewage treatment works in Kobe City, an absorption heat pump will utilize sewage heat to supply space conditioning to offices.

At Sea Side Momochi in Fukuoka City, sea water will be the heat source and sink for a turbo heat pump for a district heating and cooling system.

Set up in the fiscal year of 1991, the project is promoted by the New Energy and Industrial Technology Development Organization (NEDO) in collaboration with the Heat Pump Technology Center of Japan (HPTCJ). Nineteen companies participate in this project with subsidies from ANRE and MITI.

(Source: Japanese national Team)

Japan and China to work together

China - In October 1994, twelve members of the Japanese National Team visited China in a successful bid to establish closer communication. In meetings held in Beijing and Shanghai, they were met by over eighty people from government, universities, laboratories and manufacturing companies. The Japanese delegation stressed the importance of international cooperation and highlighted the activities of the IEA Heat Pump Programme. There is clearly much awareness in China of the role heat pumping technologies can play in addressing environmental problems. As a result of these meetings, the Chinese plan to establish a "National Team" for exchanging technological information with Japan.

(Source: Japanese National Team)

Ground-coupled heat pumps symposium

Germany - Despite the difficult market for heating-only heat pumps, developments in the field of ground-coupled heat pumps continue apace in the German-speaking countries. Reflecting this interest, over 80 people, mainly from Germany, Austria, and Switzerland, attended a three day symposium held for the second time at the conference castle in Rauischolzhausen.

The presentations illustrated the many ways in which heat from the ground can be utilized by heat pumps. The majority of the papers dealt with vertically-oriented ground-coupled systems. Several new vertical ground probe concepts were discussed, including the use of concrete hollow piles as a casing for the heat exchanger tubes. An interesting application is water in abandoned salt/mineral mines and deep oil/gas wells as heat source.

With the conviction that only monovalent heat pump systems can be economically attractive in new homes, some utilities in Germany have been investigating and demonstrating ground-coupled heat pumps for many years. Shallow vertical earth probes appear to promise the best option in regions with favourable ground and ground-water conditions. Horizontal ground and ground-water coils are often not suitable for economic reasons.

Several manufacturers showed how ground-coupled heat pumps can use air as a heat source. In one example, pre-heated ambient air flows through a concrete duct in the ground, either underneath or adjacent to the building, before it enters the evaporator. Another concept combines the pre-heated ambient air with heat recovery from ventilation air leaving the building.

A French company based in Germany has had much success with a residential heat pump with a horizontal, direct-expansion coil. Space heating is provided directly by the HCFC-22 refrigerant using a condensation coil arranged in zones in the floor. The company has installed 4,500 systems in ten years, of which approximately 2,000 are in French homes and more than 1,000 in Switzerland. Replacement of HCFC-22 for this application is under investigation.

Proceedings of the symposium will be available in 1995.

(Source: IEA Heat Pump Centre)

German speaking heat pump groups link up

Germany, Austria, Switzerland - Heat pump groups from Austria, Switzerland and Germany met for the first time in June 1994, to discuss closer collaboration in the promotion and development of heat pumps as one of the most efficient energy technologies for space heating, hot water heating and industrial process heating.

Switzerland was present with the "Fördergemeinschaft Wärmepumpen (FWS)", the heat pump promotion society supported by all large Swiss utilities, heat pump manufacturers and installers. Austria was represented by the Leistungsgemeinschaft Wärmepumpe (LGW), a collaboration of heat pump manufacturers and utilities. For Germany the Initiativkreis Wärmepumpe (IWP) participated. The IWP has a wide basis including architects, builders, consultants, installers, manufacturers, utilities, banks and universities.

Formal links with the IEA Heat Pump Programme do not as yet exist. Interestingly, however, discussions highlighted a strong and shared interest in low temperature (30°) heating systems with heat pumps. This topic may now be pursued by Switzerland as a potential Annex within the IEA Heat Pump Programme.

Suggested joint activities between the FWS, LGW and IWP include standardization, a collaborative search for ways to reduce heat pump costs, an international heat pump certificate, and the collaborative generation of promotion and information material for end-users.

The group met again in November at the Swiss Heat Pump Testing and Training Centre in Winterthur-Töss, to elaborate further on the suggestions of the June meeting.

(Source: Swiss National Team, Phänomenen, Austria 3/94)

Free heat pumps for universities

China - In a positive step to heighten interest in heat pumps amongst academics, the Tecka organization, a large joint venture in continental China, has offered 50 of its heat pump water heater/chillers to Chinese universities. The 17.6 kW (5 ton) air-cooled units will be used for teaching and demonstrating heat pump technology to HVAC students.

While sales of air-conditioning and refrigeration equipment are growing rapidly, heat pumps are unfamiliar to most people. However, the heat pump is beginning to gain recognition in some circles as an energy-saving technology, with a large market envisaged for the southern regions.

(Source: Mr Li Song Zhe and Mr He Ron Zhi, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, 81 Central Martyrs' Road, Guangzhou, China)

Technology & Applications

Avoiding ground-water use in dairies

The Netherlands - New regulations on ground-water use are leading to a significant interest in heat pump technology here. The dairy industry in particular is looking for ways to reduce the impact of a ground-water tax of NLG 0.17/m^3 (nine US$ cents per m^3) which will be charged from 1 January 1995. Large quantities of ground-water are needed for the water-cooled condensers of chiller equipment.

Engineering bureau BCZ Friesland, with support from the Netherlands Agency for Energy and the Environment, Novem, has proposed a novel solution. Instead of treating the condenser heat at 35°C as waste heat that must be cooled away, heat pump technology is used to upgrade this low-grade energy so as to provide further cooling.

The proposed system, comprising a combination of a vapour compression heat pump and an absorption chiller works in two steps. Firstly, the vapour compression heat pump supplies 90°C heat using the 35°C condenser heat as source. The 90°C heat is then used as the drive energy for the absorption chiller which provides cooling at between 6 and 12°C. A choice can be made between an electric or a gas engine driven vapour compression heat pump. The more expensive gas-engine heat pump would operate at a lower condenser temperature, with heat from the engine used to reach an output temperature of 90°C. Depending on the design, excess heat from the vapour compression heat pump may also serve other heating needs in the dairy such as for cleaning purposes.

It is hoped that a demonstration project can be set up in the near future to try out this novel combination of absorption and vapour compression heat pump technology.

(Source: Dutch National Team)

Cascade heat pump for monovalent heating

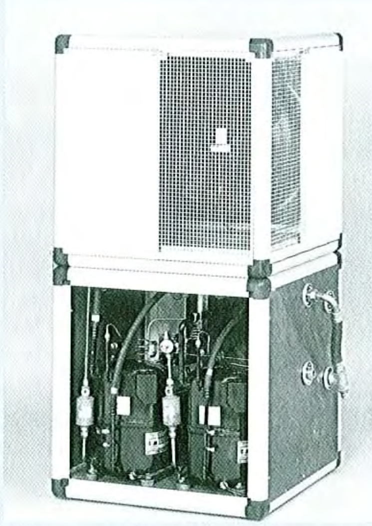
Germany - Designing an efficient heating system for operation in all low-temperature conditions is an age-old problem for heat pump designers. Especially for retrofit applications, residential heat pumps must generally be installed as bivalent systems, in which a conventional heating system is used during very cold periods. However, it is difficult to persuade home owners to make the additional investment needed for the heat pump.

German manufacturer, KVS Klimatechnik, hopes to expand the heat pump market with the introduction of the "Mono-tech" heat pump that can be used in place of a conventional boiler. The heat pump comprises two refrigerant circuits, connected in cascade. At temperatures above 0°C, only one compressor is in operation. Below 0°C, the second compressor switches in and the operation is configured so that the condenser of the second refrigerant circuit supplies heat to the evaporator of the first.

The cascade heat pump has a compact design (see Photo) and will be available in eight heating capacities. These range from 6 to 24 kW at an outside temperature of -15°C and a supply temperature of 35°C. They can operate up to 65°C, allowing home owners to completely replace their conventional heating system for both space and tapwater heating.

All "Mono-tech" heat pumps will be supplied with propane refrigerant.

(Source: Karl von Staudach, KVS Klimatechnik. Fax: +49-711-855773)



"Mono-tech" cascade heat pump for monovalent operation.

Winter of content for GAX heat pump

The Netherlands - An absorption heat pump based on generator-absorber heat exchanger (GAX) technology has reported favourable results after its first winter of operation. This highly advanced heat pump, described in *IEA Heat Pump Centre Newsletter* Vol.11, No.2, p.8, supplies heating and cooling to a government building using the nearby river Maas as a heat source. Table 1 shows the results.

(Source: Energie- en Milieuspectrum, The Netherlands, September 1994)

Table 1: Average operation values from September 1993 to April 1994.

Month	Source temperature (°C)	Heat supply temperature (°C)	PER (Primary Energy Ratio)
September	11.8	44	1.50
October	8.1	46	1.47
November	4.7	47	1.37
December	3.5	48	1.34
January	2.9	47	1.35
February	3.2	44	1.32
March	3.9	40	1.45
April	6.4	42	1.43

Thermal storage system serves insurance office

Winter operation meets summer cooling needs as well

The Netherlands - Insurance company Anova Verzekering has installed an innovative space conditioning system in its newly renovated office in Amersfoort. In winter, an electric heat pump supplies a hydronic heating and cooling distribution system using heat from a warm ground-water aquifer as heat source. During the heating mode, the ground-water is cooled to 8°C and stored in a second water layer (see Figure 1).

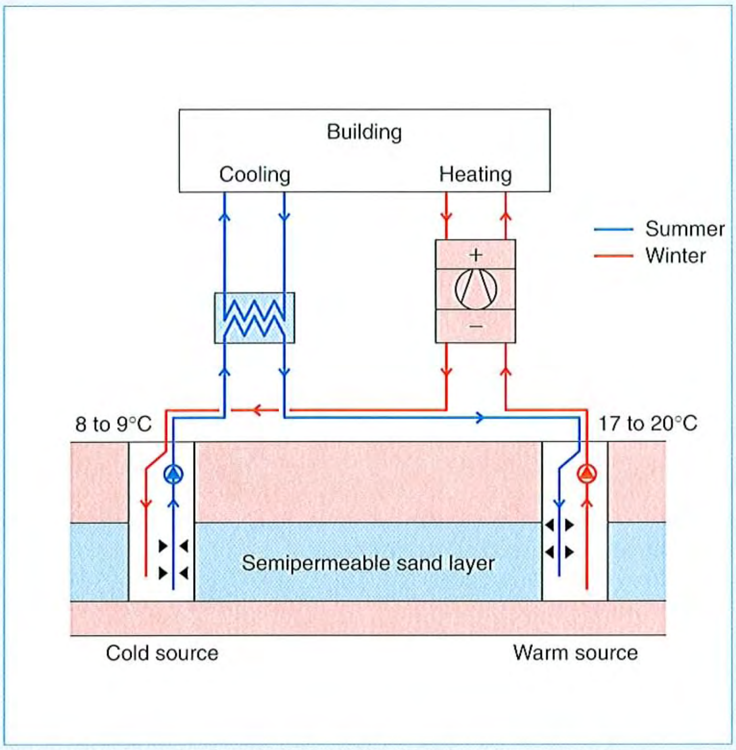


Figure 1: Thermal storage space conditioning system.

At the end of the heating season, sufficient cool water has been stored to meet the offices cooling needs in summer without requiring operation of the heat pump or any other active cooling system. When cooling is needed, the cooled ground-water is pumped up and used to extract heat from the hydronic system. It then returns to the warm well at temperatures of between 17 and 20°C, thus providing a useful source of stored heat.

Very efficient heat pump operation can be expected by utilizing a warm heat source, coupled with the use of a heat distribution temperature of just 35 to 40°C. Key to the success of this design is the use of an advanced ceiling-mounted hydronic heating and cooling distribution system.

As shown in Table 2, the project offers considerable environmental benefits. With a government subsidy of NLG 406,000 (US$ 212,000), representing over 20% of the total installation costs, the savings in energy costs will pay back the additional investment costs within 6.5 years. This is relative to the conventional alternative technology of gas heating and electric air conditioning.

(Source: Dutch National Team)

Table 2: Energy and environmental benefits of the thermal storage system.

Annual consumption/emissions	Conventional system	Thermal storage system	Reduction
Gas (m^3)	215,800	95,500	120,300 (56%)
Electricity (kWh)	395,500	511,500	- 84,000 (-21%)
Primary energy* (m^3)	322,000	179,000	143,000 (44%)
CO_2 (kg)	608,000	346,000	262,000 (43%)
NO_x, SO_2			40%

* Primary energy is calculated as the equivalent amount of natural gas based on the assumption that 0.25 m^3 gas is used in the generation of 1 kWh electricity.

Working Fluids

ICARMA asks that HFCs be left alone

USA - The International Council of Air-Conditioning and Refrigeration Equipment Manufacturer's Associations (ICARMA) has issued a policy statement on global climate change that focuses on the use and regulation of hydrofluorocarbons (HFCs). The statement urges policy makers engaged in the debate on global climate change not to implement control measures for HFCs. While acknowledging that the release of HFCs will contribute to global warming, ICARMA points out that HFCs also have a beneficial effect, by helping to curb CO_2 emissions.

"Thanks to technology advances, current air conditioning and refrigeration systems using HFC refrigerants operate efficiently and actually reduce energy consumption and power plant emissions of CO_2. This has a greater impact on reducing greenhouse gas emissions than would any action to limit direct HFC emissions."

The statement goes on to say that HFCs should not be judged on global warming potential alone. Other factors such as performance, flammability, toxicity, durability and ozone depletion potential should also be considered."Removing a refrigerant option that provides efficiency at a reasonable cost will be counterproductive from a total health and environmental standpoint and will be an economic penalty for consumers". For more information contact: ICARMA Secretariat at the Air-Conditioning and Refrigeration Institute (ARI), USA, Fax: +1-703-528-3816.

(Source: Air Conditioning, Heating and Refrigeration News, October 17, 1994)

Soft-optimized system tests completed

USA - The R-22 Alternative Refrigerants Evaluation Program (AREP) has completed the final phase of its activities with the completion of soft-optimized system tests for several HCFC-22 alternatives. As described in *IEA Heat Pump Centre Newsletter* Vol.12, No.1, p.20, AREP is an international cooperative research programme established by the Air-Conditioning and Refrigeration Institute (ARI) to assist manufacturers in obtaining performance data on a multitude of HCFC-22 and R-502 alternatives.

In the soft-optimization tests, equipment designed for use with HCFC-22 was tested with several alternative refrigerants after making a first level optimization (soft-optimization). This could involve changes to:

- the lubricant - type, amount;
- the compressor - displacement, speed, motor size;
- the expansion device;
- the heat exchangers-circuiting, size;
- the addition of a liquid-line/suction line heat exchanger.

Figure 2: Performance of R-32/125 (60/40).

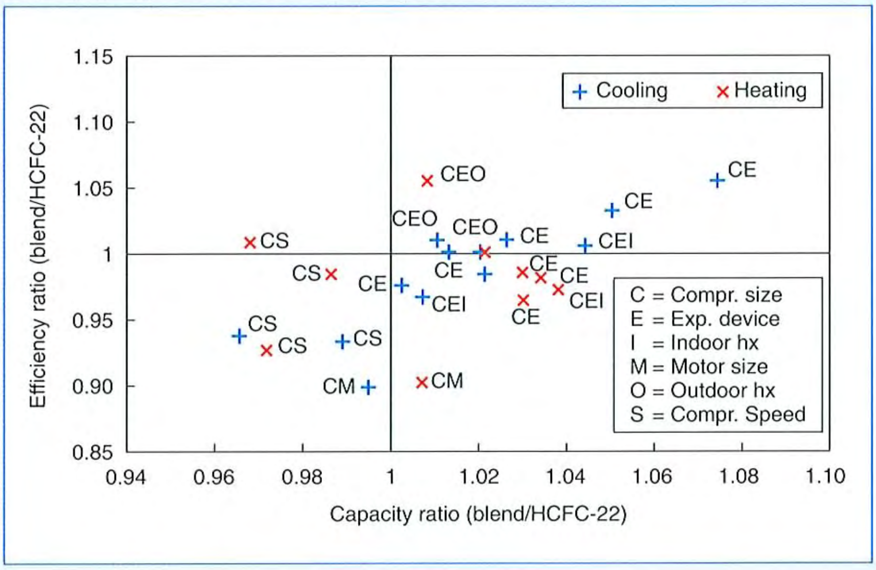


Figure 2 shows the results of one test - on the blend R-32/125 (60/40). The major modifications made to the system are noted next to the data points. Other blends tested were R 32/125 (50/50), R-32/125/134a (30/10/60/) and R-32/125/134a (23/25/52). Results of all tests made under AREP are available from the Air-Conditioning and Refrigeration Institute (ARI), USA, Fax: +1-703-528-3816.

(Source: Tech Update from ARI, September 1994)

Hydrocarbons in India

In March 1994, the first Indian refrigerator was converted to work on a propane/isobutane mixture at IIT Delhi. With assistance from Germany and Switzerland under the "Ecofrig" project, the three main refrigerator manufacturers have now started hydrocarbon conversion trials. Preliminary results have been positive. For more information contact INFRAS, Rieterstrasse 18, CH-8002 Zurich, Switzerland.
Tel: +41-1-202-9341; Fax: +41-1-202-3365.

(Source: Ozon Action, Special Supplement No. 2, September 1994)

World first for HFC-134a

USA - According to Carrier Corp., the world's first residential central air-conditioner using HFC-134a was installed on June 25, 1994 at a home in Clearwater, Florida. The chlorine-free air conditioner, known as the "Weathermaker" was introduced on the market last April. As well as being ozone-friendly, the "Weathermaker" has low energy consumption with an SEER rating of 10.7 (equivalent to an SPF of 3.1).

Meanwhile, DuPont has announced the second of its development products to replace HCFC-22 in residential and commercial air-conditioning equipment. "SUVA" 9100 is a binary near-azeotrope mixture of HFC-32 and HFC-125. According to Dupont, "SUVA" 9100 offers a higher-capacity option to "SUVA" 9000, a mixture of HFC-32, HFC-125 and HFC-134a. Dupont sees pure HFC-134a as a low-capacity alternative.

(Source: The Air Conditioning, Heating and Refrigeration News, October 17 and 31, 1994)

Markets

Air conditioning sales set new records

China, Japan, USA - Hot summers in the three largest air-conditioning markets have led to record market data. In the US, a record 632,215 unitary air-conditioners were shipped in June. This was 100,000 more than the previous highest monthly figure of June 1989, and 38% more than were shipped in June 1993.

Japan's monthly record occurred in July 1994. In that month, domestic demand for room air conditioners (RACs) reached 2.4 million units, far exceeding the previous monthly record of 1.72 million units recorded in June 1991.

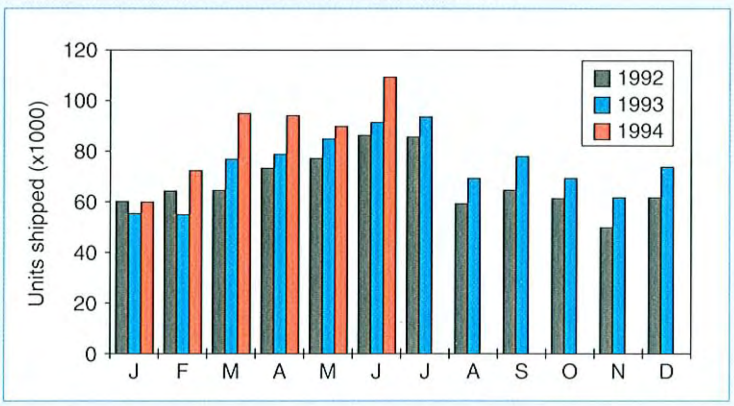
China's air conditioning market continues to set new records. Demand is predicted to exceed three million units for 1994, up 20% on the preceding year. Growth has continued apace since 1990 when only 400,000 units were sold, and is likely to out-strip previous predictions of reaching annual sales of five million units by 1997.

In Japan and the US, heat pump sales are closely linked to the air-conditioning market. Over 80% of RACs sold in Japan in 1993 were heat pumps. Total sales of RACs from October 1993 to July 1994 were up an amazing 33% on the same period the year before. Annual sales (October '93 - September '94) are expected to reach 6,800,000, just under the current record of 6,950,000 set in 1991.

In the US, factory shipments of air-source heat pumps in the first half of 1994 reached 520,649 units, up 18% from January-June 1993. Figure 3 shows the monthly shipments for 1992 - 1994.

(Sources: Koldfax from the Air-Conditioning and Refrigeration Institute, August 1994 and JARN, September 25, 1994)

Figure 3: US air-source heat pump shipments.



IEA Heat Pump Programme

HPC embarks on high profile year

Netherlands - On 3 and 4 October, 1994, representatives of the National Teams of the IEA Heat Pump Centre sat together with HPC staff and Advisory Board members for the annual National Teams Working Meeting. Located close to the point where the borders of Belgium, Germany and the Netherlands meet, the castle of Bloemendal in Vaals provided an inspiring setting for deciding on the coming year's programme of international cooperation.

Central to the 1995 work programme will be activities to raise the profile of the IEA Heat Pump Centre. National Teams agreed unanimously to embark on a new promotion strategy for heat pumps, a key element of which will be a drive to reach a wider audience with HPC information. Marketing campaigns aimed at increasing awareness of the HPC's products and activities should not only lead to a wider distribution of HPC products but, more importantly, to a greater awareness of the benefits of heat pumps.

At the meeting, National Teams were given a demonstration of Internet as an illustration of how modern communications technology can play an important role in promotion activities. It is envisaged that information on the activities and publications of the IEA Heat Pump Programme could be made accessible to a wide audience via Internet.

Other heat pump promotion activities were also discussed, including the production of brochures and the setting up of an award scheme for recommended heat pump systems. National Teams also agreed to set up mechanisms whereby promotional experiences could be exchanged. Alongside promotion activities, the meeting also decided on topics for analysis work, workshops and Newsletter issues (see Table 3) and discussed possible topics for new Annexes of the IEA Heat Pump Programme.

It was also suggested that a seminar be held in conjunction with the 19th IIR Congress in the Netherlands. Since then, the IIR has generously agreed to include this seminar as an integral part of the Congress.

(Source: IEA Heat Pump Centre)

Table 3: 1995 HPC Work Programme.

HPC Newsletter Topics	
March '95	CFC and HCFC Replacements
June '95	Heat Pump Market Forces
September '95	Residential Heat Pumps
December '95	Standards and Regulations
March '96	Systems and Applications
Workshops	
N. America	Workshop on heat pump systems and controls for energy efficiency
Netherlands August 25	International Seminar on"International Heat Pump Status and Policy Review"
Analysis Work	
Building Equipment Energy Efficiency Regulations and Labelling Requirements	

IEA HPC and IPU HPC join forces

Switzerland - In their first collaborative effort, the International Power Utility Heat Pump Committee (IPUHPC) and the IEA Heat Pump Centre jointly organized a workshop on "Heat Pumps for Retrofit and New Applications in Buildings". The workshop was held on September 26 and 27 in the Stadtcasino of Baden, Switzerland. Organizer on behalf of the IPUHPC was Mr Handl of the largest Swiss utility, NOK. Notably his efforts led to an excellent event, which was both thought provoking and highly enjoyable.

Around 60 heat pump experts participated from 12 countries, including non-HPC member countries such as Australia, the UK, Germany and Sweden. Part of the programme was a visit to the Heat Pump Testing and Training Centre, at Winterthur-Töss.

The workshop opened with a plenary session, in which the heat pump market status and perspectives were reviewed in a number of countries by leading representatives from European, Japanese and North American utilities. The workshop then continued in two parallel sessions.

In one parallel session, a total of thirteen papers focused on technology, applications and operational experiences. Practical application issues covered included the use of alternative working fluids and bivalent heat pump systems. On the topic of retrofits, experiences with ductless replacement units in France were presented, along with a Dutch development to retrofit electric water heaters to heat pumps.

In the other parallel session, heat pump market aspects and market factors were reviewed. After a presentation on the target cost level for heat pumps, several cost-effective or potentially cost-effective heat pump systems were highlighted. External market forces discussed included the impact of utility and government heat pump programmes. Programmes to exchange information on heat pumps were also addressed. At national level, information from institutes such as the Swiss Heat Pump Testing and Training Centre can have a profound impact (see *IEA Heat Pump Centre Newsletter* Vol.11, No.3, p.27). On the international stage, the IEA Heat Pump Centre is seeking to accelerate market penetration through information exchange under its promotion strategy.

The workshop highlighted the increasingly active role played by utilities in promoting heat pumps. With considerable synergy between the activities of utilities and those of the IEA Heat Pump Centre, there is considerable scope for more joint ventures.

The proceedings are available from the IEA Heat Pump Centre.

(Source: IEA Heat Pump Centre)

Refrigerant workshop addresses practical issues

Sweden - Over sixty people attended the IEA Heat Pump Centre workshop on "Consequences of (H)CFC Replacement in HVAC Applications", held at Chalmers Teknikpark in Gothenburg, Sweden on 7-8 September. Participants heard nearly twenty excellent papers covering a wide range of replacement topics, all of them with a strong emphasis on practical issues.

The workshop started with an overview of the working fluid replacement situation in various countries. In four papers, the situation in Austria, Germany, France, Sweden and the US was reviewed. The presentations highlighted differences in emphasis, for instance between the US and some European countries. Flammable refrigerants are not yet considered for building applications in the US, but are beginning to penetrate the European market.

In the following five papers, the practical applicability of flammable refrigerants was examined. Due regard was given to safety aspects, with a presentation on the recently issued report "Working Fluid Safety" (Final Report of Annex 20 of the IEA Heat Pump Programme - published by the IEA Heat Pump Centre). Relevant standards and codes were reviewed, and several application examples were presented.

Other replacement aspects were discussed such as the economic consequences and environmental aspects.

The workshop concluded with a discussion session. The need for better information channels was stressed, and suggestions made included the publication of a dedicated working fluid newsletter, and the provision of courses.

The proceedings are available from the IEA Heat Pump Centre.

(Source: IEA Heat Pump Centre)

Industrial Heat Pump Applications

An International Overview

Mike Steadman, IEA Heat Pump Centre

The recently issued IEA Heat Pump Centre Analysis Report "International Heat Pump Status and Policy Review" [1] provides new information on the current status of industrial heat pumps (IHPs) in a number of countries (see pink box). This article draws on the results of this analysis to answer questions on the current and future use of IHPs. The blue boxes provide application examples from various countries.

Countries covered by the IEA Heat Pump Centre Analysis "International Heat Pump Status and Policy Review (Part 1)"

Austria, Belgium, Canada, Denmark, France, Greece, Germany, Italy, Japan, The Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, USA.

* * *

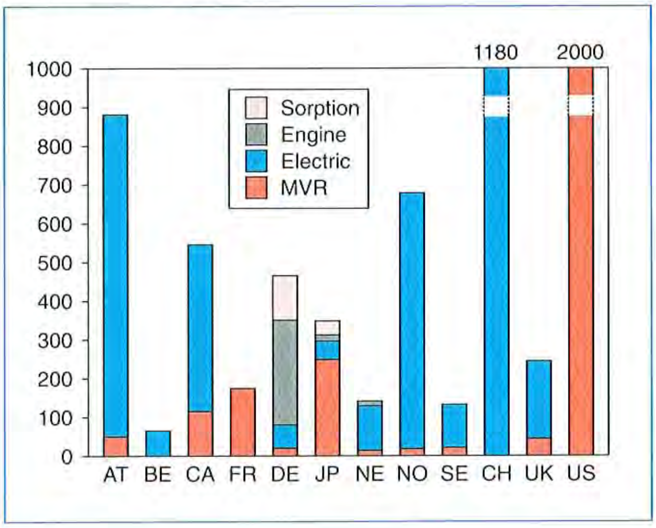
Industrial applications present many opportunities where heat pump technology can offer benefits. In nearly all situations, heat pumps will save energy, and in many cases they can offer other advantages as well. Such advantages can be diverse, ranging from an improved product quality, to compliance with environmental regulations that would otherwise be difficult to achieve. In particular, IHPs can help meet increasingly stringent regulations on the temperature of industrial effluent, the use of (ground)water for cooling, and the handling of sludge and manure.

It seems likely that growing pressure and associated support for environmentally benign technologies will encourage the use of IHPs. Furthermore, the increasing use of optimization methodologies, such as process integration, should also stimulate the market for IHPs, since heat pumps are often a logical element of truly optimized plants and processes.

From an economic stand-point, IHPs have some specific economic advantages in comparison to heat pumps in buildings. Their large size can yield economies of scale and, notably in process heating systems, they have long operating hours with modest seasonal variations. Long operating hours are beneficial for any capital investment which has to save on operating costs such as for energy.

However, despite their many advantages, IHPs are not applied in large numbers today, perhaps with the exception of lumber dryers. This is primarily due to low energy prices.

Figure 1: Number of industrial heat pump installations in operation in 1992.



How Many Are There?

The available statistics on heat pumps for industrial applications are incomplete. However, it has been estimated by the IEA Heat Pump Centre [1] that roughly 7,000 IHPs are currently in operation in the countries mentioned in the pink box.

In Figure 1, a breakdown of the IHP stock in various countries is given. Different types are considered, i.e. mechanical vapour recompression (MVR) systems, closed cycle electric and engine driven heat pumps, and thermally driven systems such as absorption heat pumps and heat transformers.

Where Are They Used?

IHPs serve a variety of heating needs at temperatures below 150°C, including the provision of process heating and cooling, and of space conditioning or tapwater heating in industrial premises. Heat pumps

Austria

Ebensee, Upper Austria, was the site of the worlds's first IHP - an MVR system constructed by Peter Ritter van Rittinger in 1854. This hydropower driven system was used in salt production. Today, two centrifugal heat pumps with an electric power input of 4 MW each are in operation for the same purpose at this site and achieve COPs of 12 to 16.

The majority of IHPs in Austria use industrial waste heat for space conditioning the factory, such as the system described in *IEA Heat Pump Centre Newsletter* Vol.11, No.1, which uses a variable refrigeration volume (VRV) multi-split heat pump system to recover heat from cooling water.

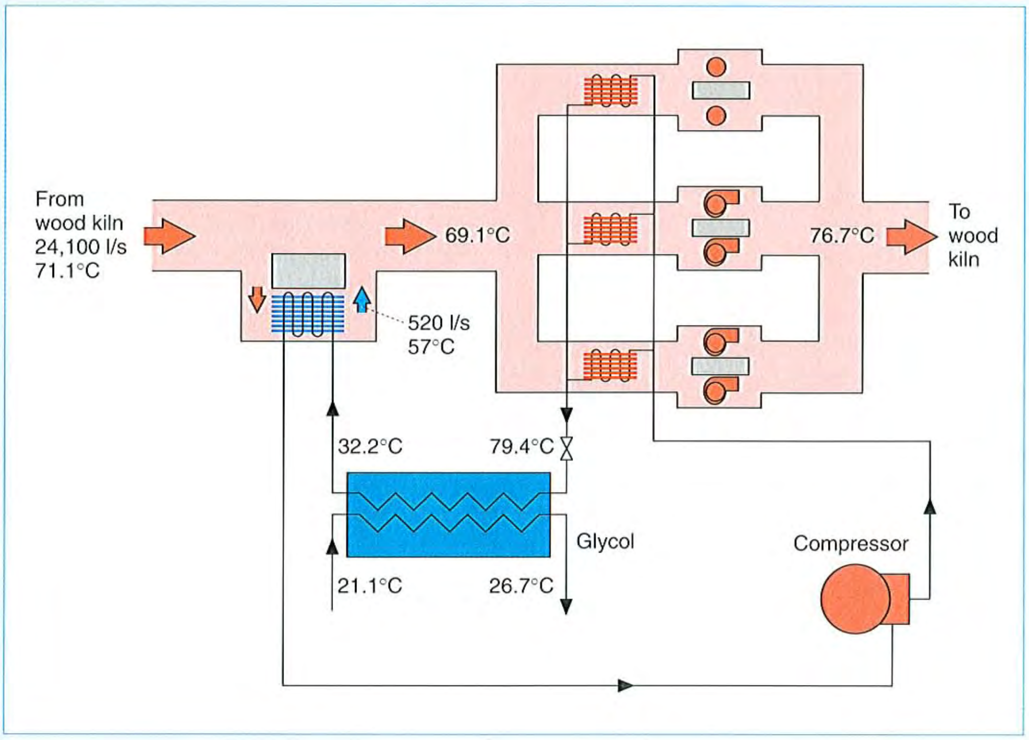
The integration of heat pumps into industrial processes is often inhibited because of the need for a high output temperature. One successful high-temperature heat pump system has been realized for use in cleaning mineral water bottles using a waste water heat source. The system reaches condensing temperatures above 100°C with CFC-114 as working fluid.

(Source: Mr Hermann Halozan, Austrian National Team)

Canada

By far the biggest application area for IHPs is timber drying, with 350 installations reported in the HPC's Analysis [1]. One example is the heat pump dehumidification system installed at Guelph Utility Pole Company (see figure). In this system, air is circulated through a wood kiln where it picks up moisture. A fraction of the moist return air from the wood kiln is diverted to the evaporator of an electric heat pump where it is cooled so as to cause condensation. The dehumidified air is then remixed with the return air before being fed to the condensers. The system thus recovers latent heat from the moisture removed from the timber. In addition, excess heat from the evaporator is removed by a glycol run-around loop which is used to preheat the chemical solutions used in the fixation process. Three such heat pumps were installed in 1992 at a cost of US$ 231,000. They provide a total of 675 kW heating with an average COP of 3.9.

(Source: ASHRAE Report RP-656, "Heat Recovery Heat Pump Operating Experiences" prepared by Caneta Research Inc., Ontario, Canada)



may also be used to upgrade industrial waste heat for use in district heating networks.

IHPs are most successful in applications where they can offer many other benefits to an industrial plant over and above energy cost savings. These may include improved product quality, increased production rate, better reliability, lower effluent temperature and volume, and reduced cooling water demand.

A major application area is in industrial water removal processes such as drying or volume reduction. MVR heat pumps, in which the removed water is often the working fluid, are highly suited for this purpose. Applications include food processing, especially in dairies, distillation processes, and pulp and paper manufacture. An emerging drying application is the drying of industrial, communal and animal sludge. Apart from water removal, MVR heat pumps are also used extensively in the chemical process industries involving distillation.

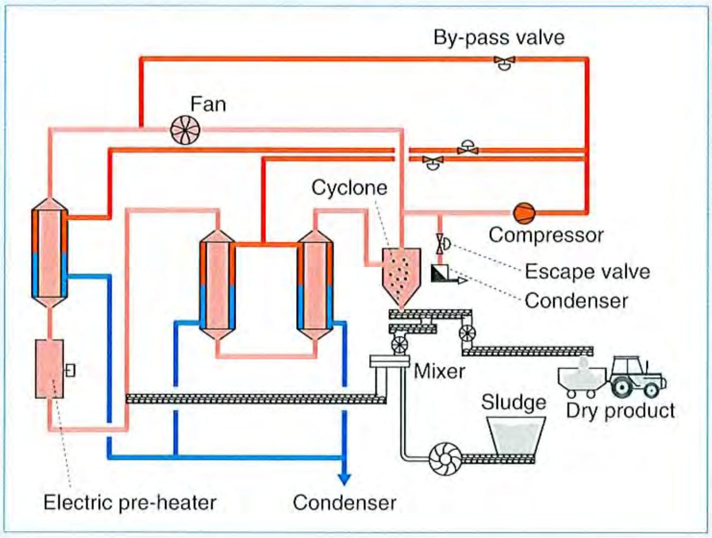
Lumber drying offers many opportunities for IHPs in many countries. These IHPs are generally closed-cycle compression heat pump/dehumidifiers.

Another important opportunity for IHPs occurs in applications with a cooling need. As environmental regulations become increasingly strict, active cooling may be required to reduce the use of ground water for cooling, or to cool down industrial effluent before it is rejected to the environment. In all these circumstances, the condenser heat of the cooling equipment should ideally be utilized for the provision of process heat, space heating or hot tapwater.

While cooling and water removal applications offer extra advantages for IHPs, IHPs are also used as more straightforward heating components. Either using waste heat streams or natural heat as the heat source, IHPs generate hot water or steam for use in process heating or for applications such as cleaning or sanitation.

France

Well over 100 MVR heat pumps are used in the food industry, eighty of them in the dairy industry [1]. Like the Netherlands, a new application for IHPs is in the processing of industrial and communal sludge. The figure shows the operating principle of a system now being demonstrated by EdF (Electricité de France). In this system, damp waste material is dried using super-heated steam. As shown, part of the extracted steam containing moisture from the material is fed to an electric compressor and then to a condenser at 187°C.



This system minimizes the need for steam and provides drying with an energy consumption of 200 to 280 kWh elec./tonne evaporated water, depending on the type of material being dried. The demonstration plant has a capacity of 400 l/hr evaporated water.

(Source: Ms Catherine Gillet, EdF, France; Fax: +33-1-6073-6440)

Italy

Very few IHPs are reported in Italy. The most well-known example is an electric vapour compression IHP installed at a polymer production plant. Using the refrigerant CFC-114, this system produces steam at 2.2 bar and 123°C using cooling water at 59°C as heat source. Unfortunately this system has not been successful. Because the heat source did not meet the design capacity, the COP is only 2.37 and the system is not economical.

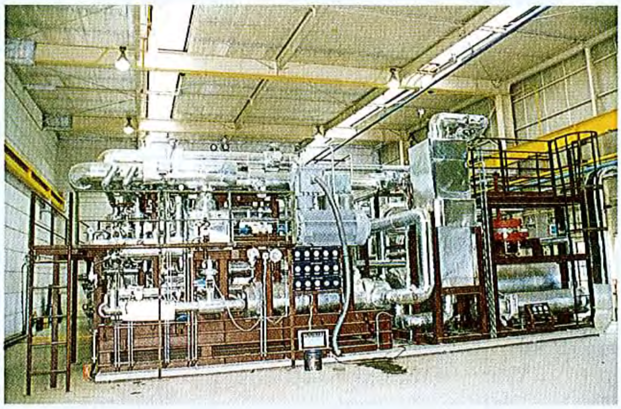
(Source: Laue H.J.; Reichert J., 1994 "Potential for Medium and Large Sized Industrial Heat Pumps in Europe", Thermie Programme Action I 49, Fachinformationszentrum Karlsruhe, Germany)

Japan

Two projects developed under the Super Heat Pump Programme represent the state-of-the-art in IHP technology. A vapour compression system using TFE (trifluoroethanol) is shown in the photograph. This system is designed to recover waste heat at 50°C in applications such as the drying of corn starch or milk powder or organic distillation processes. COPs of 3.0 and 5.0 have been demonstrated for output temperatures of 95°C and 150°C respectively.

Another system using water as refrigerant has demonstrated a COP of 3.0 for a temperature lift from 150°C to 300°C. By changing the supercharger compressor cylinder diameter, the same system achieved a COP of 5.8 for a temperature lift from 200°C to 300°C. Applications are envisaged in petroleum refining, petrochemical processes, paper making and pulp production.

(Source: Mr Yoshio Igarashi, Japanese National Team)

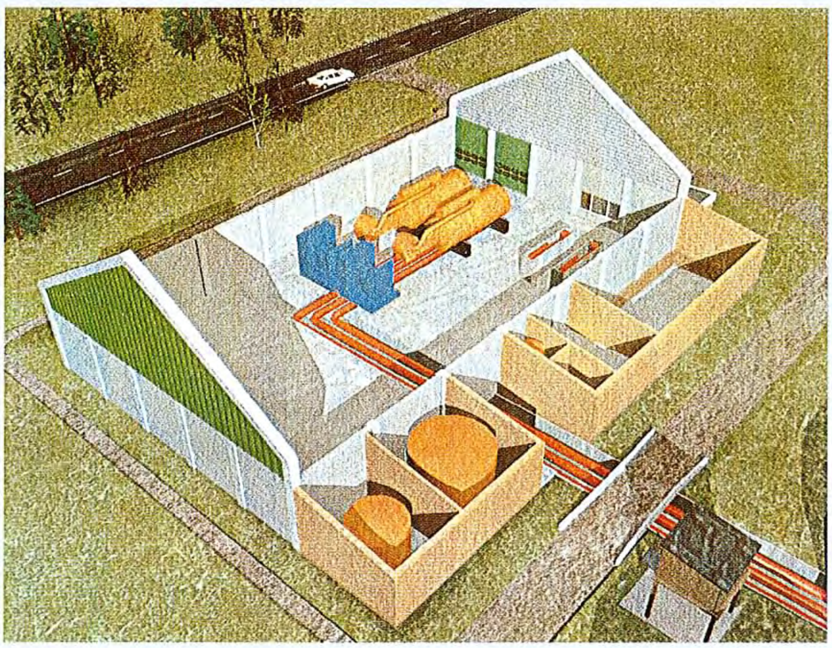


Netherlands

IHP applications have traditionally been centred around the chemical and petrochemical industries and food industries such as dairies and breweries. A new application is the handling of waste such as animal manure - an activity that will expand rapidly with the introduction of new legislation.

A project in Odiliapeel, conducted by van Aspert, is demonstrating an energy-efficient solution. A new type of shed (see picture) has been developed in which urine and faeces are separated and dried by ventilation air. The urine is then fed to an MVR heat pump which reduces the volume by a factor of 7 to 10. This project has a capacity of 25,000 tonnes per year and demonstrates a 70 to 80% reduction in the use of primary energy in comparison to traditional methods for manure handling. This system can also be used for handling industrial sludge.

(Source: Mr Onno Kleefkens, Dutch National Team)

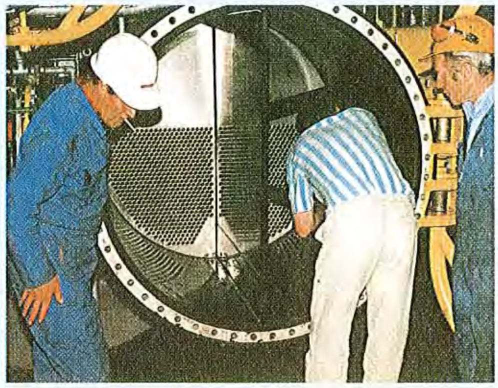


Norway

Around 750 heat pumps are in operation. While most of them are used for drying processes in the timber and fishing industries, one of the largest IHPs is used in the production of alginate from seaweed. Alginate is used in the food, pharmaceutical and textile printing industries. Using sea water as heat source, the 6.4 MW (heating) electric heat pump supplies water at 50°C with an SPF (seasonal performance factor) of four. The HCFC-22 system supplies 45 GWh heat annually. By replacing the original oil-fired boilers, annual emissions of 15,000 tonnes CO_2 and 100 tonnes SO_2 are avoided.

The installation was carried out in 1986 at an investment cost of NOK 10 million (US$ 1.5 million). Since then it has saved more on the alginate manufacturer's energy bill than the Norwegian government has spent on its National Heat Pump Programme. As illustrated in the photograph the heat pump is inspected regularly to ensure good operation.

(Source: Mr Ulf Rivenæs, Norwegian National Team)



Absorption heat pumps can utilize both high (>80°C) and low-temperature waste heat streams. Both Denmark and Sweden have applications in refuse incineration plants, where waste heat is used to drive an absorption heat pump for the provision of hot water.

Some countries cite agriculture as a major application area for IHPs. These systems are often space heating heat pumps for greenhouses or animal housing, sometimes providing cooling for farm produce. Fish farming presents a very attractive agricultural application as the low temperature lift requirements result in high COPs.

What Is The Potential?

While a number of highly interesting development projects are demonstrating the use of IHPs for high-temperature applications, most IHPs will be used in applications where heat is needed at temperatures below 150°C. Of the countries surveyed by the analysis [1], most countries where data is available report that around 5% of total final energy consumption is used to supply process heat at these temperatures.

Only in a portion of these medium and low-temperature applications will it be appropriate to install a heat pump. However, as well as supplying process heat, IHPs can also be used to provide heat for space conditioning or domestic hot water. The potential for these types of IHPs is difficult to estimate as it depends on individual factors such as the proximity of buildings which can use the heat.

More detailed information on the potential of IHPs in several countries will be made available through the work of Annex 21 of the IEA Heat Pump Programme "Global Environmental Benefits of Industrial Heat Pumps" (see page 26 of this Newsletter).

Of the countries surveyed by the IEA Heat Pump Centre's recent analysis [1], only a few countries could provide reliable data on heat production from IHPs. In Norway it is estimated that about 8% of industrial and agricultural heat is delivered by heat pumps. Industrial heat production from IHPs in Canada, Sweden and Denmark ranges from 0.3 to 1.3%, while in the USA, The Netherlands and Greece, it is considered to be negligible.

What Are The Constraints?

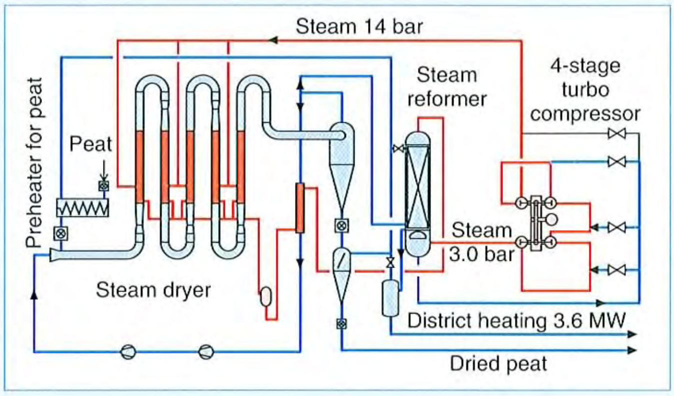
The main reason for the limited use of heat pumps in industrial processes is that energy prices are too low to justify investment. Despite the fact that most IHPs achieve a COP of at least three, and with many MVR systems registering COPs of six or more, the payback time for the additional cost of a heat pump is often more than three years - too long for most commercial companies.

Another constraint to the use of IHPs is the lack of appropriate working fluids for the medium temperature range (90-120°C) now that CFC-114 has been phased out. Water and hydrocarbons are among the alternatives being considered for vapour compression heat pumps. Alkitrate has the potential to allow absorption heat pumps to work at these and even higher temperatures (up to 260°C).

Sweden

IHPs in Sweden are predominantly used to supply space heating or domestic hot water, often via district heating systems. With little opportunity for new district heating systems, the current market for industrial heat pumps is stagnant. Regarding IHPs for process heating, the largest MVR system is used for peat drying. The system (see figure) has a total capacity of 63 tonnes water vapour per hour and a drying rate of 194 kWh elec./tonne. It also supplies 3.6 MW heat to the district heating network of a nearby village. The COP is four.

(Source: Mr Mats Westermark, Vattenfall Utveckling AB, Sweden; Fax: +46-8-739-6802)

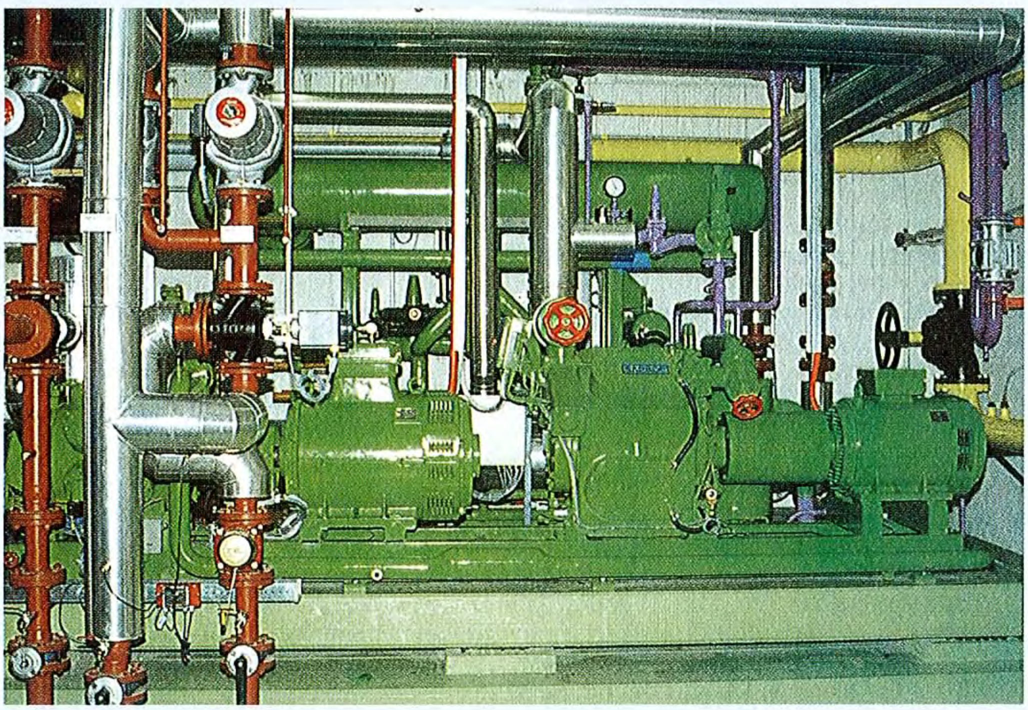


Switzerland

IHPs for heating-only applications are not widespread due to long payback periods. Most IHPs are cooling systems with heat recovery, with ammonia and HFC-134a being the only ecologically acceptable working fluids.

A typical example is shown in the photograph below. This is an ammonia chiller/heat pump installed at a food processing plant owned by Nestlé. Water is cooled from 15 to 8°C to provide cooling for food production. At the same time, hot water at 65°C is provided for space heating in winter and for cleaning purposes in summer. The 292 kW heating capacity system has two compressors (low and high pressure) and is filled with 50 kg ammonia. More information can be obtained from Mr U. Bickel of Frigorex AG (Fax: +41-41-449255).

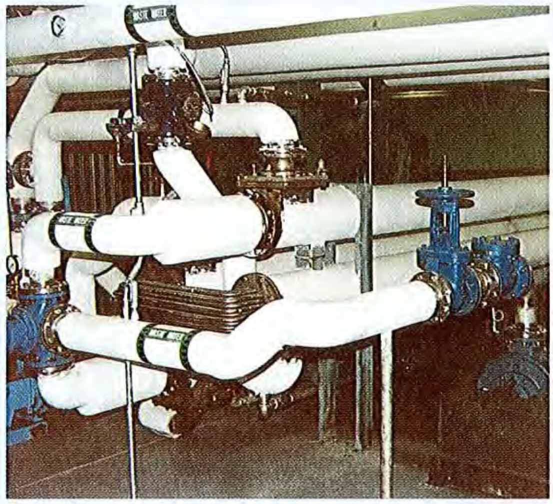
(Source: Mr Thomas Afjei, Swiss National Team)



USA

While data is limited on the number of IHPs, MVR systems are thought to be widespread in refineries, paper plants and pulp and paper mills, and around 2000 dehumidification dryers are used in the timber industry [1].

At a textile plant in North Carolina, an electric heat recovery heat pump is used to fulfil the dual needs of energy-efficient heating and the cooling of effluent (see photograph). Effluent at 51°C is first used to preheat process water to 45°C in a shell-and-tube heat exchanger. The cooled effluent (41°C) then acts as the heat source of the heat pump and is further cooled to 30°C, which is below the minimum temperature required by the local authority. The heat pump condenser heats the process water to about 60°C.



(Source: Mr Frank Pucciano, Georgia Power Company, USA; Fax: +1-404-621-2457)

What Are The Answers?

One way to improve the competitiveness of IHPs would be to increase their efficiency. Further progress in the development of IHP components will result in increased COPs and PERs. However, the biggest improvements in efficiency are likely to result from better system design. The use of design tools such as process integration and pinch technology will lead to better integration of IHPs in industrial processes so that they operate in an optimal way.

Another way to improve the competitiveness of IHPs is through the adoption of policy measures that either raise the price of energy or lower the initial cost of heat pump equipment. While a number of countries have government or utility-backed financial incentive schemes that can support IHP technology, no programmes specifically related to IHPs have been reported.

Investment in IHPs, at least in the short term, is more likely to be encouraged by the impact of environmental regulations than by the incentive of reduced energy bills. Existing industries may look to IHPs to help them meet new requirements for lower temperature effluents, or restrictions in the use of ground water. Other regulations open up new opportunities for IHPs such as the processing of waste material.

Considering All The Benefits

There is no doubt that IHP technology offers much potential for reducing energy consumption in industry. Studies such as the one conducted under Annex 21 of the IEA Heat Pump Programme, are bringing a clearer picture of this potential and should help motivate further support for IHPs from policy makers.

However, for industrial plant managers, saving energy cost is seldom the only incentive for investing in new technology. If IHPs are to attract investment, with current energy prices, IHPs must be considered not only for their energy-saving value, but as reliable and economically viable components with many other benefits.

Reference:

[1] Stuij A.B.; Stene J., 1994 "International Heat Pump Status and Policy Review", IEA Heat Pump Centre, HPC-AR3.

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Retrofit of a Syrup Evaporator

Thermocompression Gives Energy, Capital and Process Benefits

Andrew McMullan, USA

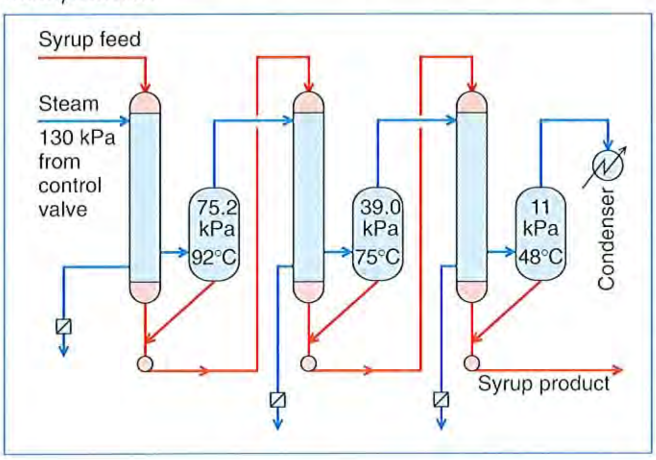
Mechanical vapour recompression (MVR) and thermocompression (thermal vapour recompression) techniques are frequently used to reduce the operating costs of new evaporation systems in industrial processes. Modifying existing multi-effect evaporators to operate with heat pump systems is less common, but can offer many benefits. This article describes the modification of a multi-effect corn syrup evaporator to a thermocompression type evaporator.

* * *

In corn processing facilities, the steam and cooling demands of the syrup evaporators account for a large percentage of the overall process utility demand. At the site in question, there was a need to identify and remove bottlenecks from both the steam and cooling systems to allow an increase in factory production. In addition to the debottlenecking requirements, another problem was that at high production rates, the syrup temperature in the first effect of two multi-effect evaporators was reaching a level where quality problems could be experienced. As a result, methods for improving the performance of the two evaporators were investigated in an analysis completed under the US DOE Advanced Industrial Heat Pump Application and Evaluation Programme.

The use of MVR was not considered to be feasible because of the high boiling point elevation of the syrup. Conversion to four-effect configuration was also not acceptable because it would have caused the first-effect temperature to increase. In syrup manufacture, the colour of the final product is a critical quality concern. Higher processing temperatures increase the likelihood of an off-colour product. The investigation therefore recommended that the multi-effect units be retrofitted to operate as thermocompression units.

Figure 1: Simplified schematic of evaporator prior to modification.



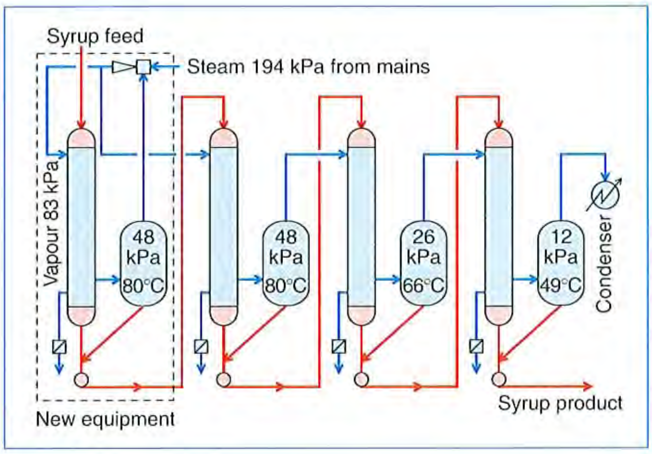


Figure 2: Simplified schematic of evaporator retrofitted with thermocompression heat pump.

The System

Figures 1and 2 show the main liquor and vapour flows for a triple-effect evaporator before and after conversion to thermocompression operation. The conversion requires a new evaporator body with additional surface area for the first effect, a vapour separator, a thermocompressor, and appropriate piping and controls, as indicated. Provided there is space available, the installation is quite straightforward. The thermocompressor is a multi-nozzle type which is controlled by throttling the steam supply pressure.

In the straight multi-effect mode, all the vapour generated in the first effect is used in the second effect (or for liquor preheat), and so on. In the thermo–compression case, about 50% of the first-effect vapour is compressed in a thermocompressor by medium pressure steam, and the combined stream is used to drive the first effect. The temperature lift provided by the thermocompressor is 15°C. At operating rates lower than design, the temperature lift achieved may not meet the design value. However, under these

Based on design operating rates the total savings achieved were as follows:

Steam savings	3750 kg/h (net) US$214,000/yr*
Cooling duty reduction	3460 kW (about 20% of cooling tower capacity)
First-effect temperature reduction:	13 - 19°C depending on production rate
Debottlenecking (Estimate of associated capital costs saving)	US$50,000
Total installed cost	US$650,000
Simple payback time	2.8 years

* based on a 1991 steam cost of US$6.75/tonne (natural gas fuel).

Table 1: Benefits of retrofitting thermocompression systems to two syrup evaporators.

conditions the evaporator effectively has more heat transfer surface than required, therefore it can operate with reduced temperature differences.

Why Thermocompression?

In terms of energy efficiency, converting a triple-effect evaporator to triple-effect with thermocompression, has similar benefits (and costs) as simply adding an additional effect to make the unit a four-effect evaporator. So why recommend thermocompression? In this case, the deciding factor was the process temperature in the first effect. A side effect of thermocompression around the first effect of an evaporator is a reduction in the pressure and temperature in the first effect, in comparison to straight multi-effect operation. This consideration outweighed the disadvantage of losing prime steam condensate and the consequent increase in the need for boiler feed water make-up and its associated steam demand (in many cases it is possible to reduce the impact of this by installing heat recovery to boiler feed water using other heat sources in the plant).

Retrofitting to a thermocompression system can also allow for cost-effective debottlenecking of multi-effect evaporators, because of the change in distribution of evaporation load between effects. In a straight multi-effect unit there is a fairly even distribution of evaporation between effects. However, in a thermocompression unit much more evaporation occurs in the first effect. Therefore, when a multi-effect unit is converted, the second and subsequent effects become relatively over-surfaced. Extra capacity can be gained by correct sizing of the new first effect, and the thermocompressor, with only one new body required. Debottlenecking a straight multi-effect unit would require multiple new bodies.

The Benefits

The project has made considerable steam savings and the cooling load on the cooling tower which serves the evaporators is reduced. Just as important as the dollar value of steam savings is the fact that the coal boiler, which was operating at capacity in the original system, is unloaded. This allows production increases without having to fire standby gas boilers (gas is a more expensive fuel) to provide the process steam needed. Similarly the reduction in cooling duty has freed up cooling capacity for the production increase, saving the need for capital expenditure on debottlenecking the existing tower.

The cost and energy benefits are outlined in Table 1. As shown, the simple payback time for the retrofit was 2.8 years, without any consideration of the value of reduced product temperatures. The systems have operated without problems since their installation.

Scope for Replication

Evaporation processes have always been good candidates for heat pumping applications, as evidenced by the number of industrial applications. However, evaluation of the heat pumping opportunities generally occurs when the equipment is originally purchased.

As energy costs rise, and companies strive to reduce operating costs while maximizing output and minimizing capital expenditure, the usefulness of heat pumps in retrofit situations is likely to increase.

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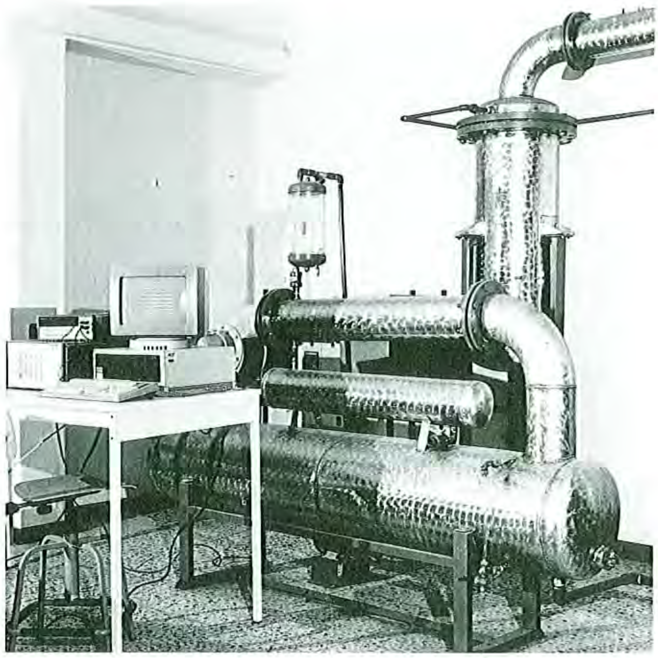
Open-Cycle Absorption Heat Pump for Convection Drying

Renato Lazzarin and Giovanni Longo, Italy

From paper and textiles, to food and pharmaceuticals, drying processes are required in a wide range of industries, and demand a significant amount of energy. For convection processes, air recirculation and heat recovery using heat exchangers is sometimes applied to reduce the loss of sensible heat in the exhaust air. However, much more savings could be made if the latent heat content of the evaporated water vapour was also recovered.

In Italy, an experimental system has been developed that uses an absorption process to extract this latent heat and re-utilize it for heating the drying air. The complete system, which also uses air recirculation and heat recovery, works as an open-cycle absorption heat pump and offers energy savings of 30% on conventional open-loop dryers with air recirculation and heat recovery.



Experimental rig for the study of open-cycle absorption dehumidification drying.

* * *

In convection drying, the material to be dried, which may be supported by for example a grate, conveyor or a trolley, is heated by a hot air flow. This air flow enters the dryer at a temperature higher than ambient in order to heat up the product to be dried so as to pick up the moisture. Technically, the driving force to absorb the moisture is the difference between the saturation moisture content at the wet-bulb temperature of the air around the product, and the moisture content of the supply air. With a higher air temperature, the saturation moisture content is increased, so that the process is faster and requires a lower specific flow rate. However, the inlet air temperature must usually be kept at a moderate level so that the product is not spoilt by burning or by a too rapid moisture migration. Temperatures are generally below 100°C.

Conventional Dryers

During drying, the humidity of the process air increases, so outside air must be taken in and heated, and the moist process air discharged. Once the flow rate and temperature are fixed, the use of 100% outside air gives the best drying conditions and the highest drying speed. However, this method will lead to the highest energy costs. These costs can be reduced by partially recirculating the process air as illustrated in Figure 1, but even then, the energy efficiency of convection drying is not very high.

The main parameters differ from one dryer to another. The amount of circulating air depends on the optimum air velocity required for the product, the drying time and the air temperatures. However, an application with inlet temperatures in the range 60 to 80°C, and a moisture pick-up rate in the range 5-10 g/kg_{air}, could be considered typical, for example in the food industry. Then the ratio between the latent heat of the removed water (which can be considered as the minimum energy requirement) and the energy supplied to the dryer is seldom higher than 0.50. A useful parameter is the Specific Moisture Extraction Rate (SMER) which gives the mass of water evaporated per unit of primary energy input. The SMER for a simple recirculation dryer in the considered field could be 0.166 kg/MJ [Ed: all energy measurements in this article are relative to the lower heating value (net calorific value) of the fuel].

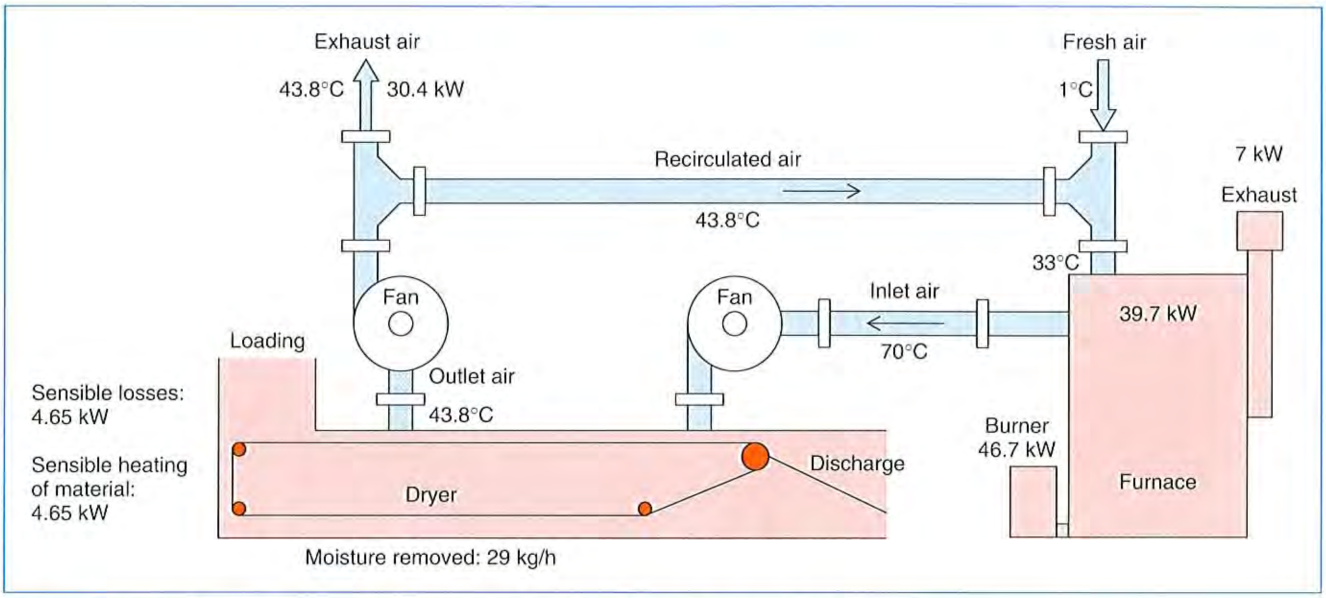


Figure 1: Block diagram of an open-loop dryer with exhaust air recirculation.

The large losses must be attributed to the exhaust of air at an enthalpy usually well above that of the outside air (higher temperature and humidity). The obvious way to save energy in a dryer is to provide a heat exchanger between the exhaust process air and the fresh air (see Figure 2). A fraction of the sensible heat of the exhaust air can then be recovered. However, no latent heat is reclaimed. With this method, the SMER could rise to 0.208 kg/MJ with an air-to-air heat exchanger of 60% efficiency.

The use of closed-cycle heat pumps can sometimes be recommended for better energy results. However, the high installation costs have limited their widespread utilization in this application.

Recovering Latent Heat

Another possibility is to employ sorbent substances to recover some of the latent heat from the exhaust air [1]. Figure 3 illustrates an absorption dehumidification dryer. In this system, the process air is dehumidified by a liquid sorbent in a packed-bed tower before being exhausted via heat exchanger HX1. Incoming fresh air is preheated by the dehumidified exhaust air in heat exchanger HX1, and then by the strong sorbent coming from the regenerator (heat exchanger HX3). In Figures 2 and 3, the temperatures shown illustrate a typical drying process in winter. In the absorption dehumidification dryer shown in Figure 3, the temperature of the fresh air is raised from 1°C to more than 36°C in the first heat exchanger (efficiency 60%), and to more than 62°C in the second heat exchanger (efficiency 70%). In Figure 2, the fresh air is heated to just under 27°C after heat recovery in the simple recirculation system. The improved performance of the absorption de-humidification dryer is due to the heat development in the absorption process and the high temperature of the strong sorbent.

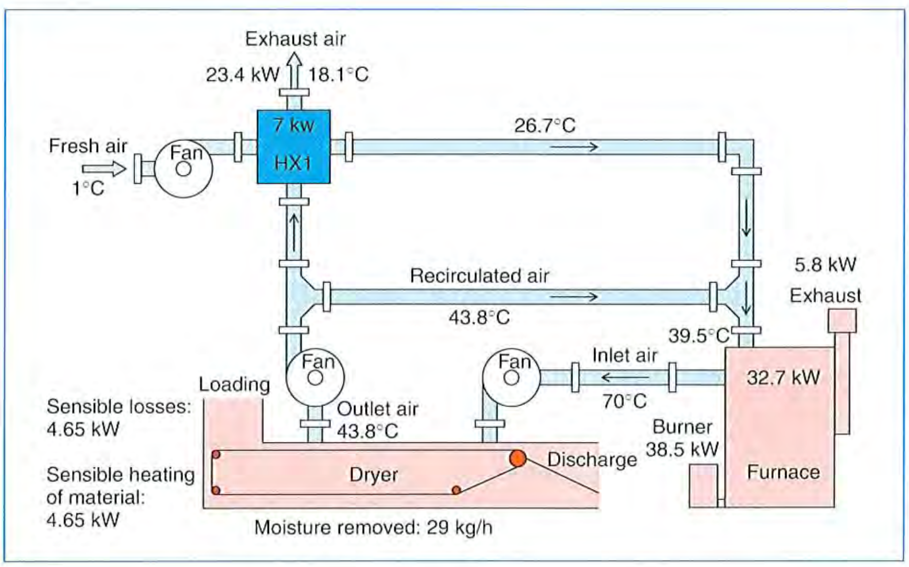


Figure 2: Block diagram of an open-loop dryer with exhaust air recirculation and heat recovery.

In the absorption dehumidification dryer, the inlet air reaches the process temperature of 70°C after mixing with the recirculated air and taking up heat from the condensed water vapour in the condenser (efficiency 70%) and from the combustion gases of the regenerator in heat exchanger HX4.

In the absorption solution circuit, the absorption solution, in this case a mixture of lithium bromide and water, leaves the packed-bed tower rich in water and at a temperature of about 10°C higher than at the inlet. It is then preheated by the regenerated solution in heat exchanger HX2 (efficiency 85%) before entering the regenerator where it is heated by a traditional burner. The regenerator separates the water, as vapour which passes to the condenser where it is cooled by the inlet air. The water condensate is rejected at a temperature of 61°C. The hot regenerated solution (strong sorbent) is cooled in two heat exchangers before entering the packed-bed tower.

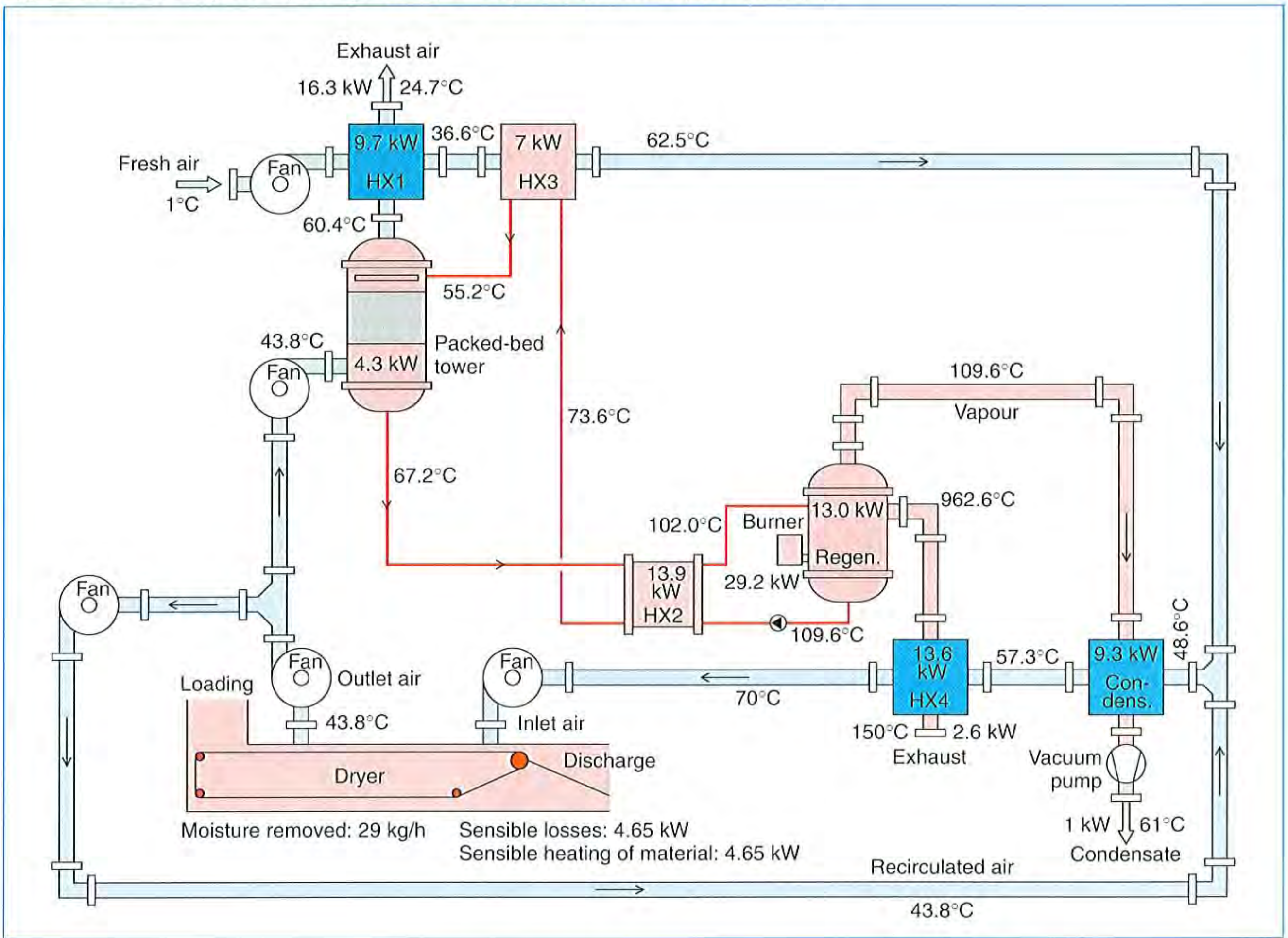
An Open-cycle Heat Pump

It is apparent that the system as a whole operates as an absorption heat pump: the heat source is the exhaust air, and the evaporator is the dryer where water is vaporized. The water vapour is absorbed in the packed bed as in an absorber with the useful heat development recovered partly by the solution and partly by the hotter exhaust air. The latter allows a better performance of the fresh air preheater. The correspondence to the absorption heat pump of the regenerator and condenser is obvious.

The only energy supplied to the process is that for regenerating the solution and for the final air heating in heat exchanger HX4. Heat exchanges with the solution (HX3), the condensing vapour (condenser) and the exhaust gases (HX4), heat up the air in order to meet sensible heat demands for heating the product to be dried, and for compensating for radiation and convection losses from the dryer.

The system can be adapted for applications in air conditioning as has been described in an earlier issue of the *IEA Heat Pump Centre Newsletter* [2]. In drying, the temperature range of the operation exceeds 100°C and the ratio between sensible and latent heat loads is reversed - in air conditioning it can be estimated at 3:1; in drying it is 1:2.

Figure 3: Block diagram of an open-loop absorption dehumidification dryer.



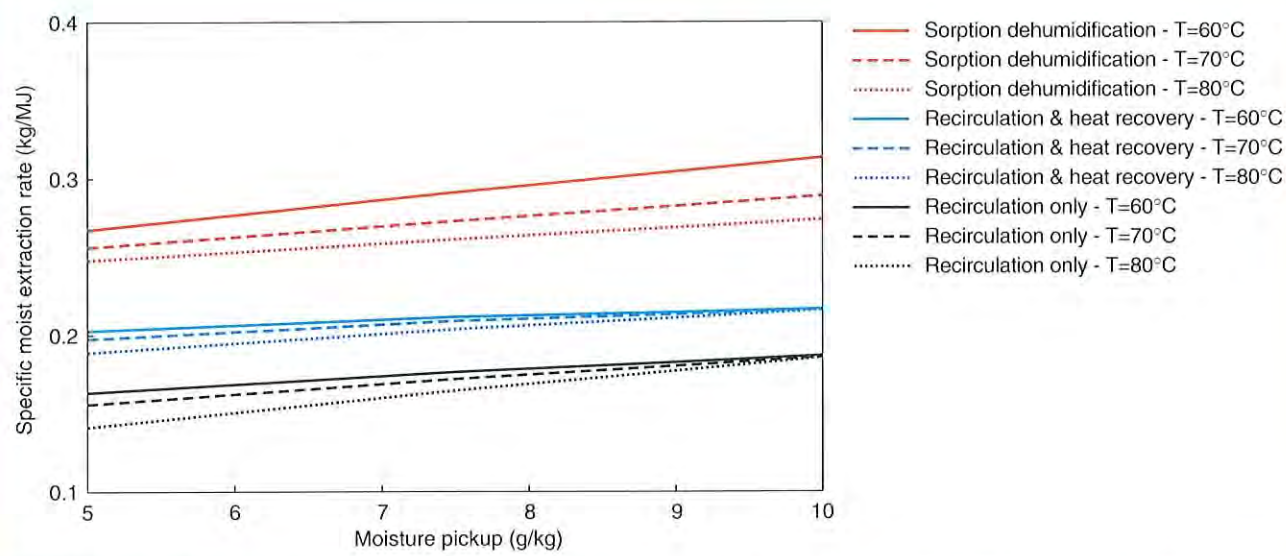


Figure 4: Specific Moisture Extraction Rate (SMER) as a function of inlet temperature and humidity change of the air in the dryer.

Performance

The COP of this open-cycle heat pump is not particularly high. A value of 1.35 (relative to the lower heating value of the fuel) is arrived at if all the heat exchanges are considered, but it is as low as about 1.1 if only the exchange in excess to the recirculation system with heat recovery is evaluated. The system is however simple and in principle cheap.

In the application field under consideration (air process temperature in the range 60-80°C and specific moisture pick-up rate in the dryer of 5-10 g kg_{air}), a comparison of the primary energy costs reveal a definite superiority of the open-cycle heat pump system, particularly for lower process temperatures. The savings can exceed 30%, arriving at an SMER of 0.31 kg/MJ (see Figure 4).

An experimental rig has been built to verify the predicted values, particularly the heat and mass transfer rates within the packed-bed tower, that have been computed in accordance with Reference [3]. The photograph on page 22 shows the tower and the electrically heated regenerator (upper horizontal cylinder) and the condenser (lower horizontal cylinder).

Good Prospects

The proposed open-cycle absorption dehumidification dryer uses significantly less energy than traditional open-loop dryers, even those employing recirculation and heat recovery. The simple and cheap construction, together with the use of an environmentally safe working fluid, makes this system applicable to a wide range of medium to low-temperature drying applications. These include industries such as food, textiles, building materials, paper, chemical and pharmaceuticals.

The energy saving prospects of this system can be judged by considering the following. In Italy, the total energy demand from dryers has been evaluated at 100 PJ/year. For the United Kingdom a figure of 150 PJ/year has been evaluated. For both countries this represents about 2% of total final energy consumption. It can be assumed that more than half of these processes are at temperatures lower than 100°C.

References:
[1] Lazzarin, R.M., Longo, G.A., Piccininni, F., 1992. "Sorption Dehumidification and Heat Recovery: Applications in Industrial Processes". Heat Recovery Systems & CHP, Vol.12. No.5, pp. 397-405.

[2] Lazzarin, R.M., Longo, G.A., 1992. "Open cycle Absorption - A Simple Route to Gas-Fired Cooling and Heating. IEA Heat Pump Centre Newsletter, Vol.10, No.4, pp. 12-15.

[3] Treybal, R., 1993. "Mass Transfer Operations". McGraw Hill. New York, USA, pp.187-209.

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Global Environmental Benefits of Industrial Heat Pumps

A Status Report on Annex 21

Steven Williams, USA

Generally viewed as a means to conserve energy, industrial heat pumps (IHPs) can also improve plant productivity and expand process heating capacity at low costs compared to boilers. And because of their energy savings potential, IHPs should also be viewed for their potential to reduce pollution (both air and water) by decreasing the combustion of fuels. To assess the potential environmental benefits of IHPs, eight countries are currently conducting Annex 21 of the IEA Heat Pump Programme entitled "Global Environmental Benefits of Industrial Heat Pumps".

* * *

Like all Annexes of the IEA Heat Pump Programme, Annex 21 is helping to expand knowledge on heat pump technologies through the collaboration of several countries. The participating countries and operating agent are shown at the end of this article.

The objective of Annex 21 is to provide potential IHP users with a tool to initially screen opportunities at their plants and to provide policy makers with information on the benefits of IHPs. To meet these objectives, a personal computer-based program has been developed to identify, on a preliminary basis, the technical and economic fit of IHPs with different industrial processes. The computer program and other Annex 21 tools are being used by the participating countries to conduct detailed market studies on the potential energy and environmental benefits of IHPs.

This industrial heat pump is used for timber drying in Canada.

Screening Program

The IHP screening computer program, developed by Chalmers/ETA (Sweden) as part of Annex 21, has four main features:

- It contains data on the technical performance and cost characteristics of some 50 IHPs, including electric-, prime-energy and waste-heat driven technologies, divided into four categories: closed-cycle; thermal vapour recompression (TVR); mechanical vapour recompression (MVR); and absorption;
- It will determine IHP opportunities using data on more than 100 industrial processes and unit operations, or using site-specific data entered by the user;
- It will determine the technical and economic feasibility of different heat pumps in various industrial processes;
- It will outline possible heat pump configurations, heat pump costs and payback, using user-specified inputs regarding fuel prices.

This program, which will be available to interested parties in countries participating in the Annex, can select IHPs that can operate at the sink and source temperatures specified by the user. Furthermore, it can identify the largest heat pump (for the maximum energy savings) that can operate at these temperatures, and can determine the heat pump's lifetime cost and payback.

The Annex 21 program provides a method by which industrial firms can screen their process operations for IHP opportunities. The program allows the user to work with the generalized process data contained in the program's database or allows the user to input data to work with actual process data for that site.

Country	No. of Processes Analyzed	HP Energy Savings as % of Total Process Heat Demand	Total Energy Savings in Processes Analyzed	Range of Energy Savings for Processes Analyzed
Canada	11	1-2%	5-15 PJ/yr	<1-20%
Japan	11	3-7%	35-70 PJ/yr	<1-40%
Norway	6	6-12%	1-2 PJ/yr	<1-40%
Sweden	6	1-2%	1-2 PJ/yr	<1-30%
United States	24	2-6%	40-80 PJ/yr	<1-25%

Table 1: Preliminary study results.

Market Studies

The countries conducting Annex 21 are now in the process of analyzing the environmental benefits of heat pumps by conducting country-specific market studies on IHP potential. Focusing on five main industries - chemicals, food, petroleum refining, pulp and paper, and textiles, but also covering major domestic industries in each country, such as lumber drying or fish processing, each study is examining the future potential for IHPs and the associated energy savings. Estimates of energy savings are being used to determine the potential reductions in SO_x, NO_x, CO_2, CH_4, CO and particulate emissions.

To date, preliminary study results have been completed for five countries. As shown in Table 1, the preliminary findings indicate that IHPs have the potential to save upwards of 10% of total industrial process heat energy consumption, with average savings in the 2-7% range. For some individual industrial processes, IHPs have been found to have the potential to save as much as 40% of current process heat energy consumption.

Reductions in Emissions

The environmental benefits of IHPs are directly linked to the fuel mix of the process being analyzed. Findings to date, however, show that the energy savings from IHPs can lead to major reductions in CO_2 emissions in all countries. Net NO_x and SO_x emissions, taking into account electricity generation, can be reduced to the greatest extent in those countries that are not heavily reliant on coal and oil based power generation. In all cases, however, IHPs can provide net reductions in emissions, even allowing for the increased use of electricity.

Knowledge Transfer

The work of Annex 21 will be completed in 1995 with the publication of results and the organization of international workshops in Europe and in North America. The IEA Heat Pump Centre will publish the proceedings of these workshops along with a detailed report on the work of Annex 21. It is envisaged that this knowledge transfer will help to increase the use of industrial heat pumps with subsequent benefit for the environment

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Participating Countries: Canada, France, Japan, The Netherlands, Norway, Sweden, United Kingdom and the United States.

Operating Agent: United States Department of Energy.

Recovering Industrial Waste Heat

Experience Shows the Heat Pump's Potential

Shigeru Sakashita, Japan

With its high energy efficiency, coupled with its use of electric power instead of burning fossil fuels at a local level, the industrial heat pump has the potential to make significant reductions to both energy consumption and pollution. This is particularly true for conventional industrial production processes, where vast quantities of fossil fuels are consumed to meet heating needs, while low temperature heat is either wasted or used ineffectively.

Nevertheless, it is to be regretted that the utilization of heat pumps for the recovery of industrial waste is very limited today. This article looks at the factors which determine the merits of industrial heat pump systems in terms of economic, energy saving and environmental benefit. The blue boxes show two examples of successful Japanese heat pump installations that confirm the potential for industrial applications.

* * *

If heat pumps are to fulfil their potential for reducing energy consumption in industrial applications, then a number of obstacles must be overcome:

- the low return on investment;
- that heat pump engineers have insufficient understanding and limited experience of production processes;
- that production process design engineers have insufficient understanding of the heat pump system;
- the operational difficulty of heat pump systems in comparison to conventional boiler systems.

Conventional Design

With conventional process design, the thermodynamic control is based on the provision of boiler steam for heating, and a cooling tower for cooling. The conventional system therefore operates with a temperature difference of some 100°C. Should the heat pump system be utilized for such a high temperature lift, its economic advantage would be considerably affected by the extremely poor COP.

Total System Design

Nowadays, studies are carried out to try to decrease these temperature differences in industrial processes. This leads to the development of the most suitable total system that not only takes the characteristics of heat pump systems into consideration, but also offers other benefits. These benefits include improvements in product quality and a reduction of operating costs and equipment costs, especially the cost of heat exchangers. In the development of such total systems, it is essential to have cooperation between the heat pump development engineers and the end users of the heat pump system.

The economic effect of using heat pump systems depends largely on the trend in the cost of power, petroleum, coal, natural gas, etc. The economic advantage of the heat pump has been greatly obstructed by the fall in petroleum costs since the autumn of 1986.

Of course the energy saving effect and reduction in fossil fuel consumption remains unchanged, as does the environmental preservation effect of the heat pump system. It is therefore desirable that the industrial heat pump's potential contribution towards energy saving and environmental preservation is encouraged through administrative policy and changes to the electricity tariffs.

Critical Performance

To judge the merits of a heat pump system it is useful to define the critical COP which must be exceeded in order to bring benefits. The following critical COPs are defined:

- economically effective COP;
- energy saving COP;
- environmentally effective COP.

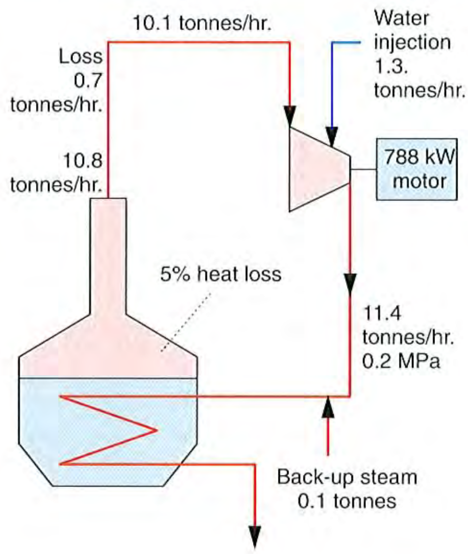
Economically Effective COP

A key factor affecting the economics of industrial heat pump installations is the ratio between the price of electric power and the price of alternative fuels. This ratio gives the economically effective COP (COP_{ec}) which an electric heat pump must exceed in order to

(continued on page 26)

Box 1: Heat Recovery in a Beer Brewery

The steam requirements of a conventional beer brewery account for as much as 30% of the total energy consumption, with vast quantities of heat needed for the fermentation process. While some of the exhaust heat is commonly used for making hot water or for driving an absorption chiller, energy utilization is far from optimal. With an open-cycle heat pump system, energy consumption is primarily the shaft power needed to run the steam compressor, with a minimal amount of steam needed for back-up. Furthermore, a heat exchanger is not required at the top of the column, nor is a cooling tower. With a COP of just over nine, the heat pump well exceeds the critical performance levels for energy saving (COP_{es}) and environmental effectiveness (COP_{env}) in Japan. And with the more favourable economic conditions of the 1990s, this heat pump also surpasses the critical COP for economic effectiveness (COP_{ec}).



Operating conditions

Heat source temperature:	100°C	Condensing heat:	7.2 MW
Condensing temperature:	125°C	COP:	9.15

Specifications

Compressor:	788 kW screw compressor; compression ratio 2.3
Motor:	VVVF inverter driven variable-speed; 2000 to 4000 rpm; 1 MW shaft power

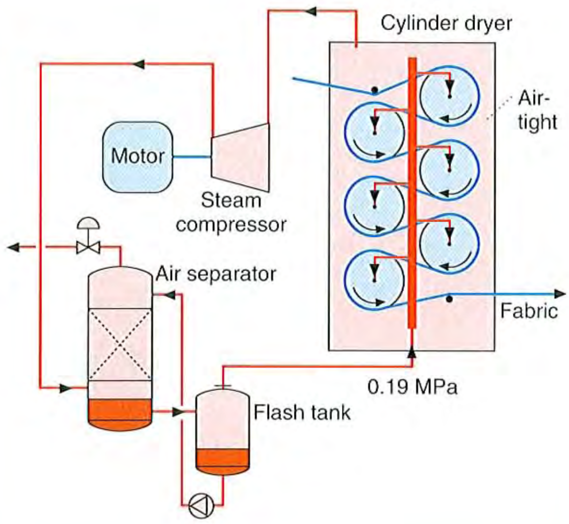
Energy Saving and Environmental Benefit

	Hourly consumption/emission			Annual reduction[3]
	Conventional system [1]	Heat pump system [2]	Difference	
Steam (tonnes)	11.5	0.1	11.4	
Electricity (kWh)		788	788	
Primary energy (GJ)	26	7.35	18.65	55,950
CO_2 (tonnes)	1.860	0.096	1.764	5,292
NO_x (kg)	1.699	0.244	1.455	4,365
SO_x (kg)	5.642	0.203	5.429	16,287

[1] Primary energy consumption is fuel oil
[2] Primary energy consumption is based on a power generation efficiency of 38.6%
[3] Based on a production time of 3000 hours

Box 2: Heat Recovery in Fabric Dyeing

In fabric dyeing, the drying process is the most critical phase and the one which consumes the most energy. In a conventional dyeing plant, the exhaust steam from the dryer is for the most part discharged inside the plant, wasting heat and creating an unpleasant environment. With the heat pump system shown, the cylinder dryer is housed in an air-tight box. The fabric is transported over cylinders where it is heated by compressed steam. All steam, including that from the moisture which evaporates from the fabric, is transferred through piping to a steam compressor and then supplied back to heat the cylinder dryer. With this system, steam energy utilized for drying the fabric is almost completely recovered and reutilized. While the COP of this plant is lower than for the beer brewery described in Box 1, it is still sufficient for energy, environmental and economic effectiveness.



Operating conditions

Heat source temperature:	100°C	Condensing heat:	517 kW
Condensing temperature:	132°C	COP:	6.9

Specifications

Compressor:	75 kW screw compressor; compression ratio 2.9
Motor:	VVVF inverter driven variable-speed; 3000 to 10,000 rpm; 100 kW shaft power

Energy Saving and Environmental Benefit

	Hourly consumption/emission			Annual reduction[3]
	Conventional system [1]	Heat pump system [2]	Difference	
Steam (tonnes)	1.186		1.186	
Electricity (kWh)		75	75	
Primary energy (GJ)	2.68	0.700	1.98	7,920
CO_2 (kg)	191	9	182	728,00
NO_x (kg)	0.320	0.023	0.297	1,188
SO_x (kg)	3.514	0.019	3.495	13,980

[1] Primary energy consumption is kerosene
[2] Primary energy consumption is based on a power generation efficiency of 38.6%
[3] Based on a production time of 4000 hours

be economically competitive with the conventional technology using an alternative fuel. COP_{ec} is defined as:

$$COP_{ec} = \frac{\text{Electric power cost per kWh}}{\text{Fuel cost per kWh heating value}}$$

Figure 1 shows the change in COP_{ec} for kerosene and fuel oil between 1985 and 1990. As shown, fuel costs began to decline during the latter part of 1986 and the COP_{ec} increased measurably. At the end of 1986, due to the considerable change in the price of crude oil, the COP of a heat pump would have had to exceed 12 in order to maintain any economical advantage over oil-fired systems. By 1990, the COP_{ec} had dropped to around six for fuel oil and three for kerosene.

Energy Saving COP

The energy saving COP (COP_{es}) illustrates the COP needed in order to save energy. It is defined as the reciprocal function of thermal efficiency at the power station, i.e.:

$$COP_{es} = 1/(\text{thermal efficiency at power station})$$

For a large-scale thermal power station with a power generation efficiency of 38.6% (average for Japan in 1990), the COP_{es} is 2.59. For a cogeneration system with a thermal efficiency of 80%, the COP_{es} is 1.25.

Environmentally Effective COP

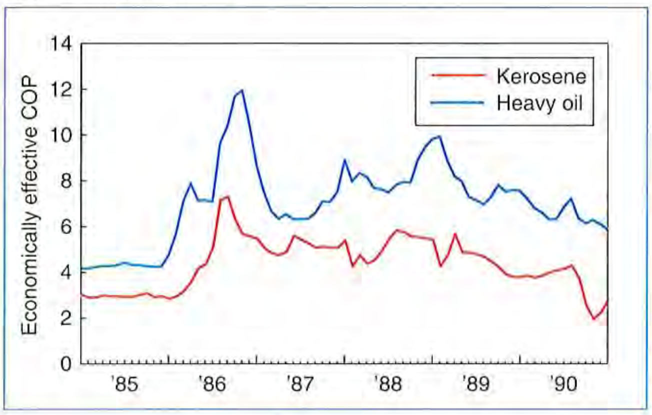
Considering that NO_x, SO_x, CO_2, smoke and soot are only emitted by thermal power stations, the COP needed to bring about environmental benefit is less than COP_{es}. The environmentally effective COP (COP_{env}) has thus been defined as:

$$COP_{env} = \frac{\text{fossil fuel power generation rate}}{\text{thermal efficiency at power station}}$$

According to data available for 1990, the power generation rate in Japan was 62.6% for fossil fuel plants, 24.1% for nuclear power plants and 13.3% for hydroelectric plants. So for an average power generation efficiency of 38.6% (fossil fuel plants), COP_{env} can be calculated as follows:

$$COP_{env} = 2.59 \times 0.626 = 1.62$$

Figure 1: Trends in economically effective COP (COP_{ec}) of fuel oil and kerosene.



Exhaust gas	Fuel oil	Kerosene	Electricity
CO_2(kg/kWh)	0.26	0.24	0.122
NO_x (g/kWh)	0.24	0.19	0.310
SO_x (g/kWh)	0.79	0.023	0.258

Table 1: Emissions from various energy sources.

Experience in Japan

Two examples of actual plants constructed and utilized in Japan are described in Boxes 1 and 2. Table 1 shows the emission rates used to calculate the environmental effect of these projects. The values for exhaust gases from electric power generation are average values based on data from nine major power generation companies in Japan.

Realizing Broad-Based Benefits

On the evidence of these two heat pump applications, it may be concluded that the energy saving efficiency and environmental protection effect of industrial heat pump systems can be considerable and of significant economic value. However, such favourable results cannot be realized in all applications. In order to expand the application of industrial heat pumps, the economic advantage of such systems should be improved through design improvements which increase the capacity and the COP of the heat pump, while decreasing the investment cost. Furthermore, support and promotion of heat pumps through such measures as government tax incentives would go a long way towards increasing their use in various industrial fields and in helping to realize broad-based benefits.

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District Heating from a Yeast Factory

HFC-134a Heat Pump Yields Many Benefits

Hendrik Enström and Hans Kenne, Termoekonomi, Sweden
Peter Bailer and Peter Moser, Switzerland

At the Jästbolaget yeast factory in Sollentuna, Sweden, a district heating heat pump using the environmentally compatible refrigerant HFC-134a, was commissioned in September 1992. This article describes the technical conditions, the system design of the plant, and the necessary changes to the district heating network that were required. It discloses measured performance data and economic calculations and discusses the environmental impact of the heat pump. Apart from reporting operational and other experiences of interest, it emphasizes the importance of an overall optimized system design.

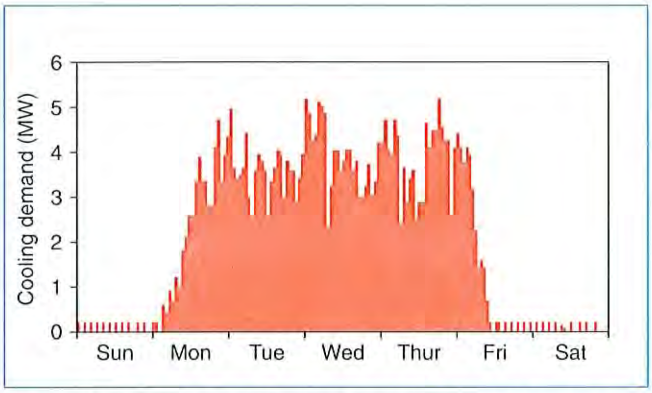


Figure 1: Weekly variation in cooling demand at the yeast factory. Each bar shows the hourly mean value.

* * *

In the yeast production process, a large amount of heat is developed which must be disposed of. As shown in Figure 1, this cooling demand varies significantly over one week due to process start-up on Mondays and shutdown on Fridays. Prior to the retrofit described in this article, ground water at a temperature of 8°C was used for process cooling at the Jästbolaget yeast factory. The cooling water left the factory at a temperature of roughly 20°C and was dumped into a nearby lake. Waste heat was not utilized and valuable ground water was wasted. This prompted the yeast producer, Jästbolaget AB, to evaluate environmentally better solutions.

The HFC-134a heat pump.

Studying the Possibilities

At the end of 1989, Jästbolaget AB and the local district heating company Sollentuna Energi agreed to initiate a study on whether the waste heat could be fed into the existing district heating network of nearby Rotebro. Early in 1990, they awarded a contract to Termoekonomi to study possible technical solutions and to evaluate their economical and environmental impact.

It was found that connecting an electric heat pump with roughly 3.5 MW of cooling capacity to the district heating network was the best alternative. For the high temperature demand (80°C), and with conventional technology, CFC-12 would have been used as refrigerant. However, in Autumn 1990 the use of CFC-12 was practically prohibited for new plants in Sweden. Since neither HCFC-22 nor ammonia can be used at the high temperature level required, the choice of a suitable refrigerant was very difficult. At that time, Sulzer Ltd. was the only company which was prepared to supply a heat pump for the required operating conditions and using HFC-134a.

For this project a new company, Jästenergi HB, was established, jointly owned by Jästbolaget AB and Sollentuna Energi. In July 1991, a contract was signed between Jästenergi and Termoekonomi for delivery of a complete "turn-key" heat pump plant, using HFC-134a as refrigerant.

Table 1: Technical data of the heat pump.

	Working days	Weekends
Refrigeration capacity	3.5 MW	2.5 MW
Heat source	process cooling water	ground water
Water flow	251 m^3/h	400 m^3/h
Water temperatures	20/8°C	8/2.6°C
Heating capacity	5 MW	3.471 MW
Heat sink	district heating network	district heating network
Water flow	223 m^3/h	223 m^3/h
Water temperatures	60/80°C	55/68.6°C
Power consumption	1.725 MW	1.131 MW
Coefficient of performance (COP)	2.90	3.07

Adapting the Network

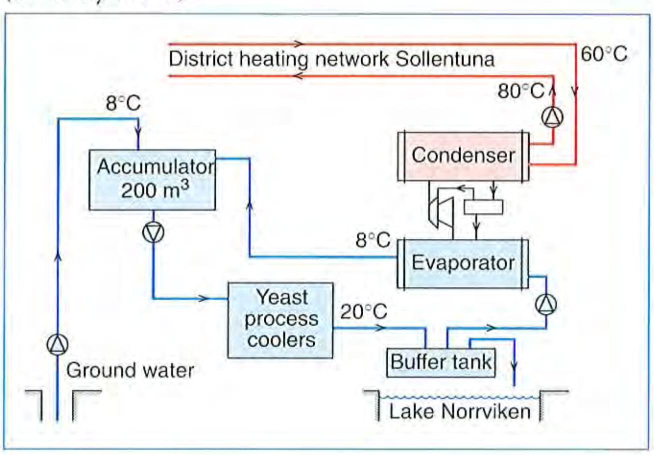
The district heating network to which the heat pump is connected has a yearly heat demand of 72 GWh. Before the heat pump was installed it has mainly been supported by an oil-fired boiler station, 4 km away from the Jästbolaget factory. Heat from the boiler plant was distributed to the consumers through three loops of pipes. Jästbolaget is situated at the end of one of these.

With this arrangement, only a minor part of the return flow would have reached the heat pump. It was therefore necessary to redesign the distribution system such, that the return flow from all three loops is transported down to the heat pump. This was possible by adding some valves and couplings at the station, and with an extra pipe between the boiler plant and the heat pump.

Without this work, the economics of the heat pump installation would have been poor. This illustrates the importance of examining the complete system design when considering heat pump installations.

The project was strictly realized on a commercial basis, with conventional guarantees and without external support. It is a very good example of cooperation between private industry and a publicly owned company.

Figure 2: Schematic of the heat pump installation (weekday mode).



Technical Features

The Jästbolaget yeast factory produces 19,500 tonnes of yeast per year and originally used 29,000 m^3 of ground water per week. A small heat pump, installed some years ago, led to a 15% reduction of ground water consumption.

Today, the cooling water is pumped via a buffer tank to the evaporator of the heat pump where it is cooled to 8°C (see Figure 2) before being recirculated to the process coolers. Theoretically, no ground water is needed. In reality, however, the variation in cooling demand means that some extra ground water is required occasionally. The consumption of ground water in production periods is reduced by approximately 90%. During weekends, the heat pump uses ground water of 8°C as the heat source. This is cooled down to 2.6°C and discharged into the lake. It is planned to extend operation of the yeast factory to the weekends, thus increasing the heat production. The use of ground water would then be eliminated almost completely.

The heat pump is a two-stage electrical unit with centrifugal compressors manufactured by Sulzer (see photograph). It is probably the first heat pump with HFC-134a to be designed for this type of application. Table 1 gives the main technical data of the heat pump installation.

The plant was formally handed over to its operators on 15 September 1992. The "running-in" period of a heat pump normally lasts through the first year since it often takes this time to encounter or test all operating conditions. However, most problems will usually be detected and solved within a few months. The "running-in" problems experienced at this plant are outlined in the box overleaf. Notably, none of these were related to the choice of refrigerant.

Running in problems

The following problems were encountered during the first year of operation:

Control System Errors
Errors in the external control system often occur in new systems - they have been corrected.

Refrigerant Levels
Some problems were encountered in controlling the refrigerant levels in the condenser and the intermediate pressure vessel. These levels must be held fairly constant by two expansion valves. Because of rapid fluctuations in the signal from the measuring equipment, the unit was stopped occasionally by the "evaporation pressure low" alarm. After replacement of the measuring equipment, the signals have been stable.

Oil Transport
Some transport of oil occurred from the oil tank on the low pressure side into the refrigerant. The oil accumulated in the evaporator and resulted in an abnormal formation of foam. This was solved by replacing a check valve in a draining pipe between the compressor and the oil tank.

Leakage
Disturbances to the heat source flow were caused by leaks in the old pipes of the factory.

Measurements
Adjustments and repositioning of measuring devices caused some stoppages.

Energy Performance

Table 1 shows the design data for the two modes of operation of the heat pump for operating during the week and at the weekend. Based on this data and some statistical material from the factory and the district heating network, the annual heat delivery amounts to 35 GWh. The SPF (Seasonal Performance Factor) will be about 2.9, resulting in almost 4000 m^3 of oil saved per year. Experience has confirmed these preliminary calculations, although with an anticipated availability of 95% the heat delivered is reduced to 33 GWh.

Economic Performance

The heat pump system achieves annual savings of SEK 4 million (US$ 500,000). This is based on the following actual energy prices paid to the respective suppliers:

- conventional heating at SEK 230/MWh (US$ 29/MWh);
- electricity at SEK 250/MWh (US$ 31/MWh) plus a standing charge of SEK 140,000/yr. (US$ 18,000/yr.) and a load charge of SEK 560,000/yr. (US$ 70,000/yr.).

The total investment cost for the plant was about SEK 18 million (US$ 2.3 million). This sum, however, includes a larger building than required for the heat pump installation. A more realistic investment figure for the heat pump installation alone would be approximately SEK 16.5 million (US$ 2.1 million).

The payback period (defined as investment cost divided by annual savings) of 4.1 years is quite satisfactory for a municipal company providing district heating. However, for other sectors this time period might be too long and differences in profit strategy would often prevent cooperation between a private company and a community.

Since the ground water is available free-of-charge to the yeast producer Jästbolaget, no costs for cooling water entered into the calculation. However, with a possible future increase of production to seven days per week, ground water consumption would exceed the permitted level and cause problems. With the heat pump now installed, Jästbolaget is free to run the

	Without heat pump	With heat pump
Heat demand (GWh/a)	72.2	72.2
Heat from heat pump (GWh/a)		35
Oil consumption (m^3/a)	8000	4100
Emissions:		
SO_2 (tonnes/a)	73.1	37.6
NO_x (tonnes/a)	46.9	24.1
CO_2 (tonnes/a)	21,700	11,100
Dust (kg/a)	4800	2500
Hg, Pb etc. (kg/a)	4.8	2.5
Polycyclic aromatic hydrocarbons (PAH) (g/a)	160	80
Global warming potential (GWP) (%)	100	52
Ozone depletion potential (ODP) (%)	0	0

Table 2: A summary of emission data, before and after heat pump installation.

factory continuously. In a different situation, where costs are incurred for cooling water, the economy of the heat pump installation would be further improved.

Environmental Performance

Table 2 summarizes the environmental aspects of the heat pump installation. In this evaluation only the environmental aspects of reduced oil consumption and refrigerant leakage are taken into account. Additional environmental benefits resulting from the reduction of ground water consumption are not accounted for.

For this comparison an annual leakage of 5% of the refrigerant charge was assumed. This value is higher than would be expected from leakage through the shaft seals; it also includes a margin for possible leakage due to extraordinary events. Using today's techniques and routines for handling refrigerants, as required by Swedish standards, the leakage rate might well be as low as 1 to 2%.

Since the global warming potential (GWP) of HFC-134a is only slightly lower than that of HCFC-22 it would, of course, be preferable to use a refrigerant such as ammonia which has no impact on the greenhouse effect. Since this is not possible today for this type of application - and will not be for some time - it is important to fully understand the global warming potential of this HFC-134a plant.

The global warming effect of 1 kg of HFC-134a corresponds to that of 1200 kg of CO_2 if an integration time of 100 years is assumed [1]. This apparently alarming figure is put into perspective by considering the fact that 1200 kg of CO_2 roughly corresponds to the combustion of 0.4 m^3 of fuel oil. So the assumed annual leakage of 120 kg of HFC-134a from the Jästenergi plant corresponds to just 50 m^3 of oil. Since over 4000 m^3 of oil are saved over the same period, it is obvious that the overall effect with respect to environment is extremely beneficial. If a refrigerant with zero GWP were used - or zero-leakage stipulated - the value for the global warming potential in Table 2 would only drop from 51.8% to 51.2%.

A Successful Project

The success of this project suggests that there are many applications for which the installation of a heat pump would offer an economically attractive and environmentally friendly solution. This is especially the case where heat can be supplied to a nearby heating network or to industry.

As shown in this article, it is important that not only the heat pump, but the whole system is studied. Such a project requires close cooperation between the client, the consultant and the heat pump manufacturer, at all phases of its development - from the start of conceptual studies until the plant is successfully commissioned. And when the supplier and the user of the heat are two different companies, it is also important that the commercial and legal arrangements are agreed upon early in the design stage.

This project also provides an important insight into the refrigerant issue. The reduction in global warming achieved by this project proves that it is much more important to have a well functioning heat pump plant with HFC-134a, than to experiment with other refrigerants. Today's aim must be to replace harmful refrigerants in existing plants. In new heat pump installations - for all applications, including air conditioning - heat recovery should be applied wherever feasible. This will save large amounts of fuel oil and reduce air pollution accordingly. The new refrigerant HFC-134a can play an important role in protecting the environment. If the use of HFC-134a were restricted because of its minor impact on the greenhouse effect, the environment would be the looser again.

References:

[1] Fischer, S.K.; Fairchild P.D.; Hughes P.J.; "Energy and Global Warming Impacts of CFC Alternative Technologies in HVAC Equipment" IEA Heat Pump Centre Newsletter Vol.10, No. 3, 1992.

[2] Enström, H.; Kenne, H.; "Experiences from a 5 MW Heat Pump Using HFC-134a" from the Proceedings of the Fourth IEA Heat Pump Conference, Maastricht, 1993.

[3] Bailer, P.; "Chiller with Heat Recovery for Jästenergi, Sollentuna, Sweden" poster paper presented at the Fourth IEA Heat Pump Conference, Maastricht, 1993.

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Mr Peter Bailer and Mr Peter Moser, Sulzer Friotherm Ltd., Switzerland, Fax: +41-52-262-0003

Heat Recovery in a Pasta Factory

Pinch Analysis Leads to Optimal Heat Pump Usage

Frédéric Staine, Pierre Krummenacher and Daniel Favrat, Switzerland

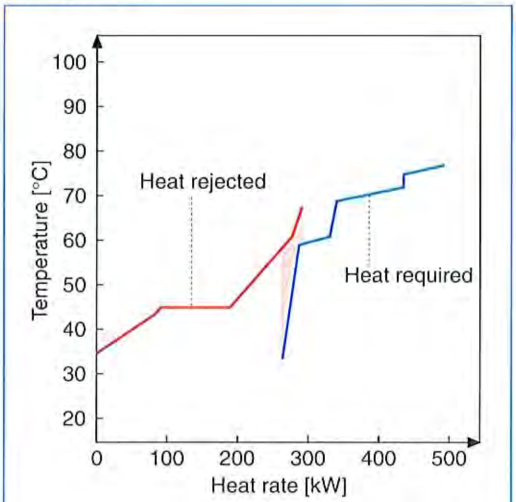
In the previous issue of the IEA Heat Pump Centre Newsletter (Vol, 12, No.3, pp. 29-31), an article by these authors described the use of pinch analysis (also known as pinch technology) in a buildings application. This article describes a similar procedure for integrating a heat pump into a pasta production process.

Many industrial processes, and particularly those dealing with drying, are characterized by an overabundance of low-grade heat which often cannot be efficiently recovered by means of simple heat exchangers. Heat pumps thus represent the primary means of upgrading the energy of moisture loaded streams into useful process energy. Powerful process integration tools based on pinch analysis allow the assessment of the heat recovery options and will lead to the optimal use of heat pump technology.

* * *

Pinch analysis works on the general principle that for the optimum process, heat pumps should ideally only be used to upgrade energy across the pinch temperature of the process or site considered.

Figure 2: Composite curves of the existing drying process.



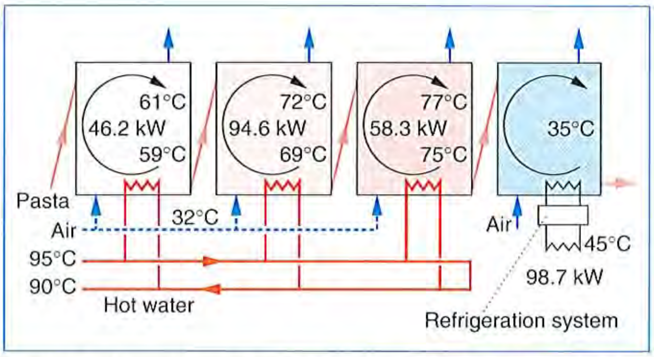


Figure 1: Simplified flowsheet of the pasta drying line.

However, this requires that several parameters, such as the heat pump evaporation and condensation temperature levels and heat rates, should be optimized with respect to the drying process. At the Swiss Federal Institute of Lausanne, a dedicated heat pump optimizer included in the process integration computer program PinchLENI, has been applied to one of the drying lines of a pasta production factory.

Pasta Production

Figure 1 is a simplified flowsheet of the pasta drying line. After kneading and wire-drawing, the pasta is dried in three drying zones with controlled temperature and humidity. Afterwards, the pasta passes through a cooler before packaging. Presently, the air used for drying is heated by hot water (95/90°C) from an oil or natural gas boiler. The cooling water is supplied by a refrigeration system. The essential economic data for the drying line are:

- operating time: 5600 h/y;
- heat cost: CHF 0.06/kWh (US$ 0.04/kWh);
- electricity cost: CHF 0.11/kWh (US$ 0.07/kWh).

Pinch Analysis

Pinch analysis involves two graphical tools, namely the composite curves and the grand composite curve. An important step in pinch analysis is the collection of data on the heating needs and recovery opportunities. This phase of the analysis of the pasta production process results in the composite curves of Figure 2. The right curve summarizes the heating needs of the drying air of the three successive sections of the drying line. The left curve represents the energy recovery opportunities, with the "plateau" at 45°C

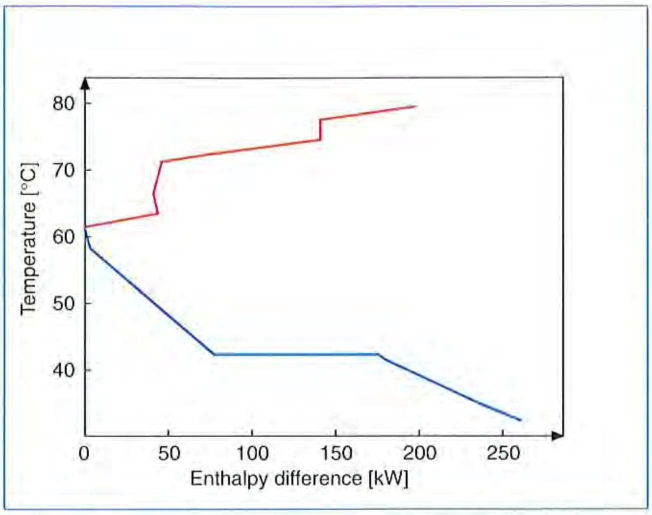


Figure 3: Grand composite curve of the drying process.

characterizing the heat released from the condenser of the refrigeration system. It is obvious from this representation that, without a heat pump, there is little margin for internal heat recovery.

The grand composite curve is useful for determining the temperatures and capacities of the evaporator and the condenser [1,2]. Note that the capacities depend directly on the temperatures and on the analyzed process. Figure 3 shows the grand composite curve for the pasta production process. For this process, the evaporator of the heat pump can exchange heat with the exhaust air only, or with the exhaust air and refrigeration system condenser. The condenser of the heat pump can heat one, two or three drying zones. The latter proposition has been analyzed using the process integration program PinchLENI.

Using PinchLENI

The PinchLENI software includes a heat pump optimizer module which is applicable to closed cycle compression heat pumps.

The evaporator or condenser capacity can be chosen by the user or can be calculated from the grand composite curve at the corresponding temperature. For a fixed value of the condenser or evaporator capacity, the module can, for instance, scan the evaporator and/or condenser temperatures to find the minimum payback time. The derived investment cost includes the cost of all heat exchangers and the cost of the heat pump compressor. The new operating cost includes the cost of electricity and back-up heating. The heat pump optimizer module of PinchLENI offers 12 possible heat pump calculation and optimization scenarios. The heat pump module also provides a graphical representation of how the various parameters (temperature, capacity, electric power, payback time, COP, investment cost, operating cost, etc.) vary with the temperature or with the capacity of the evaporator or condenser.

Results

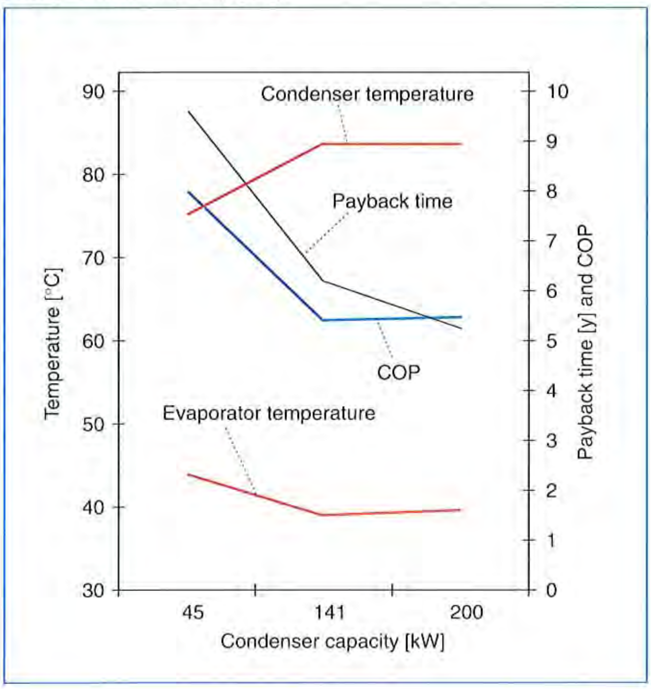
Figure 4 plots the evaporation and condensation temperatures, and the corresponding payback times, against the capacity of the condenser. The COP of the heat pump cycle is also shown. This illustrates that the optimal solution (for a minimum payback time) is with a fixed evaporator capacity of 200 kW. The results of optimization with PinchLENI indicate that this solution corresponds to a heat pump with a condenser covering all the dryer needs (three zones), and with an evaporator heated by the exhaust air and the heat from the refrigeration system condenser. The boiler is only used for the start-up of the process or for back-up. The composite curves relative to the pasta production process with the heat pump are shown in Figure 5.

The calculations presented here are based on refrigerant HFC-245ca, a potential substitute refrigerant for CFC-11, that would be well adapted to the working domain. HCFC-123 is another possible refrigerant (with final results similar to HFC-245ca) but with an ozone depletion potential and a higher toxicity level than the CFC.

Considering the economic criteria, heat pump integration is always a tradeoff between the following:

- lowering the temperature lift to minimize the electric power consumption of the compressor;
- increasing the temperature differences in the heat exchangers (higher pinches) to allow the use of lower-cost heat exchangers with small exchange areas.

Figure 4: Variation of different parameters with heat pump condenser capacity.



This tradeoff is very sensitive to the economic parameters (energy cost and equipment cost). In the analyzed case, the value of the payback time indicates that on the basis of typical industrial economic requirements, the integration of a heat pump at the pasta factory is not profitable enough. However, it would become more attractive if a new pasta drying line were envisaged, or if the operating time of the process were extended, or if the costs of energy were increased.

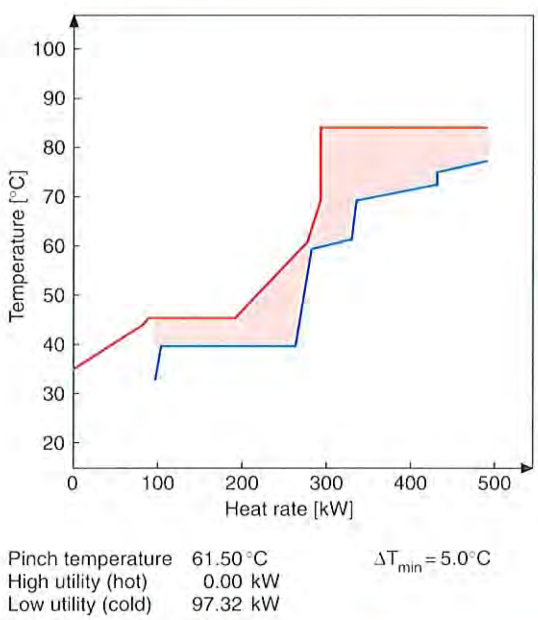
Exergy Losses

When introducing heat pumps, the classical representation of the original pinch method does not graphically highlight the resulting exergy losses in the system. Figure 6 shows the extended composite curve in which the heat flows are plotted against Carnot Factor instead of temperature. The dimension less Carnot Factor is calculated from the absolute process temperature T_1 and an absolute reference temperature T_0 via:

$$\text{Carnot Factor} = 1 - \frac{T_0}{T_1}$$

If T_0 is the ambient temperature, the Carnot Factor represents the fraction of a process heat flow that can be theoretically converted into work - i.e. its exergy. Thus the pink area in figure 6 represents the exergy losses in the heat exchangers. Using the same scales, it is also possible to show the exergy loss in the compressor. This loss is represented by the blue area bounded by the electric power and the compressor efficiency factor (1 - exergetic efficiency). These extended composite curves thus portray all exergy losses and provide a useful tool for comparing different systems [3].

Figure 5: Composite curves of the process with the optimal heat pump.



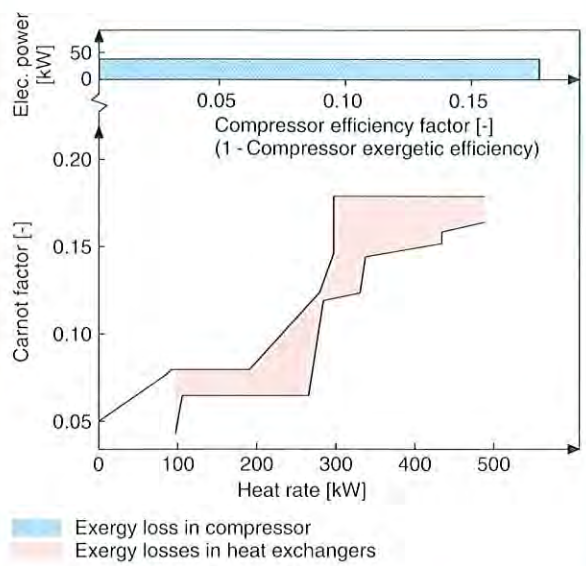


Figure 6: Extended composite curves of the process with the optimal heat pump.

Overcoming Obstacles

Predesign of industrial processes with optimal placement of heat pumps can be significantly accelerated by using process integration tools with dedicated heat pump optimizers. In the particular case of pasta drying, pinch analysis shows how significant energy savings can be made. However, several major obstacles must be overcome before such technology will be put into practice. These include the current low price of energy, the present uncertainty regarding refrigerants condensing in the 80 to 100°C range and, to some extent, the present trend towards higher drying rates and higher temperature, which is, unfortunately, favoured by present low energy prices.

References:

[1] Loeken P.A., 1984, "Process Integration of Heat Pumps", 2nd International Symposium on The Large Scale Applications of Heat Pumps, York, England, pp. 223-236.

[2] Wallin E. and Berntsson T., "Integration of Heat Pumps in Industrial Processes", Heat Recovery Systems & CHP, vol. 14, No.3, pp. 287-296, 1994.

[3] Staine F. and Favrat D., 1993, "Energy Integration of Industrial Processes Based on a Graphic Representation of Exergy Factors", Proceedings of the International Conference Energy Systems and Ecology, Cracow, Poland, pp. 427-437.

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Heat Pump Developments in 1994

An annual review of trends and events

Jos Bouma, IEA Heat Pump Centre

From organizing workshops to the publication of this Newsletter, the activities of the IEA Heat Pump Centre (HPC) reflect many of the key issues in the heat pump field. Drawing on this experience, this article looks back on 1994 to summarize the major developments concerning heat pump technology.

* * *

The topics chosen for the four issues of the twelfth volume of the *IEA Heat Pump Centre Newsletter* are shown in the pink box overleaf. These subjects were chosen by National Teams to address some of the key issues facing the member countries of the IEA Heat Pump Centre.

Working Fluids

Without doubt, the search for safe and environmentally-sound working fluids continues to be the dominating subject. And with the introduction of phase-out dates for HCFC-22 as early as the year 2000 in some countries, this subject is becoming ever more urgent.

There are marked differences in the approach of different countries to this issue. In North America and Japan, effort is concentrated on finding appropriate blends of HFCs. However, several European countries are showing a clear preference for natural working fluids (mainly ammonia and hydrocarbons). Propane heat pumps are now being offered by German manufacturers, whereas ammonia heat pumps are increasingly used in Norway and the Netherlands.

The work of the IEA Heat Pump Programme is looking at both these options. Annex 18, "Thermophysical Properties of Environmentally Acceptable Refrigerants", now in its second phase of operation, is focusing on HFC mixtures. And Annex 22 "Compression Systems with Ecologically Safe Working Media" is expected to begin work soon on systems using ammonia, CO_2, hydrocarbons, air or water.

A key issue surrounding the choice of working fluid is safety. The report "Working Fluid Safety", produced under Annex 20, and available from the HPC, makes an important contribution to the international debate.

The use of new refrigerants presents a technical challenge to all those concerned with heat pump manufacture and the retrofit of existing equipment. The HPC's Workshop "Consequences of (H)CFC Replacement in HVAC Applications" held in Gothenburg, Sweden, in September 1994 provided a timely opportunity for the exchange of knowledge on this subject.

Demand Side Management

By focusing on demand side management, the June issue of the Newsletter highlights the increasing interest of utilities in heat pumps. The support from utilities appears to be growing, with many utilities offering incentive programmes for heat pumps.

The IEA Heat Pump Centre built on this momentum by holding a joint workshop with the International Power Utility Heat Pump Committee in September. Titled "Utility Aspects of Heat Pumps for Retrofit and New Applications in Buildings" this workshop attracted many participants from utilities.

Waste Heat Recovery

An important stimulus for using a heat pump in either a building or industrial application is its ability to utilize waste heat. Application examples of waste heat recovery heat pumps in buildings and industry are highlighted in issues 3 and 4 of the 1994 *IEA Heat Pump Centre Newsletter.*

In buildings, ventilation heat recovery heat pumps are playing an increasingly important role, triggered by regulations which mandate the use of heat from ventilation air. Moreover, in both residential and commercial buildings, waste heat recovery heat pumps are seen as important components of optimized, integrated energy systems, combining space heating, cooling, waste heat recovery, water heating and even heat storage functions.

In industry, limitations on the use of ground-water for process cooling are stimulating heat recovery heat pump applications. And new markets for heat pumps are opening up in the area of waste disposal. Mechanical vapour recompression (MVR) heat pumps are being developed for the drying of sludge, and absorption heat pumps are utilizing heat from waste incinerators.

Technology Developments

Efficiency regulations, such as in Switzerland and the US are leading to increased SPFs from space conditioning heat pumps. Further improvements are likely to result from increased attention to system design. There is growing interest in the development of low-temperature heat distribution systems. And projects, such as the Japanese "Unused Energy Project" are developing improved technologies for exploiting heat sources.

For industrial applications, new developments will allow heat pumps to operate at higher temperatures. Alkitrate has emerged as a working fluid that allows absorption heat pumps to work up to 260°C. Actual installations should now be built to demonstrate the potential of this new fluid.

Plotting an Upward Trend

For those of us involved in HPC activities, a major highlight of 1994 was the publication of the Analysis Report "International Heat Pump Status and Policy Review". The compilation of new data to plot the major trends concerning heat pumps was a mammoth task requiring the cooperation of many people and organizations. The availability of such information will play a vital role in determining future activities and policies on heat pumps. Let's hope that in 1995, interest in heat pumps will continue to rise, so that future data on heat pump applications will show an increasingly upward trend.

Author:
Mr Jos Bouma, IEA Heat Pump Centre

Article Overview HPC Newsletter Volume 12 / 1994

Note: in addition to the articles listed, each issue includes an extended international overview article on the topic.

Bibliography

Working Fluid Safety
Published by the IEA Heat Pump Centre; Order No. HPP-AN20-1; November 1994; English; Price NLG 100.

This Final Report of Annex 20 of the IEA Heat Pump Programme addresses all potential hazards and consequences associated with alternative working fluids. Covering natural refrigerants such as propane and ammonia, as well as synthetic substances such as HFCs, the report examines fire, explosion, intoxication and asphyxiation. Risks are assessed firstly by examining accident records, and secondly by applying calculation techniques to predict the effect of accidents.

CFCs, The Day After
Published by AICARR Servizi, Milan, Italy, Fax: +39-2-2900-0004; September 1994; 870 p.; ISBN 88-86281-09-9; US$ 120; English/French.

This joint meeting of Commissions B1, B2, E1 and E2 was organized in Padua, Italy on 21-23 September 1994 by AICARR (Italian Association of Air Conditioning, Heating and Refrigeration) on behalf of the International Institute of Refrigeration (IIR). The 93 papers address a range of topics concerning research and development work on finding alternatives to CFCs and HCFCs.

Non-Fluorocarbon Alternatives for Refrigeration and Air Conditioning
United Nations Environment Programme (UNEP), Fax +33-1-44-371474; English.

This special supplement was issued in September 1994 with UNEP's quarterly newsletter "OzonAction", which focuses on the implementation of the Montreal Protocol. The September 1994 issue of the supplement includes a comprehensive overview of non-fluorocarbon alternatives for refrigeration and air-conditioning equipment. It summarizes the refrigerant options of hydrocarbons, ammonia, carbon dioxide and water. It also looks at technologies other than vapour compression, such as absorption, Stirling cycle and thermoaccoustic cooling.

World-wide Experiences in Using New Refrigerants
A Purdue refrigeration short course published by Ray W. Herrick Laboratories, Purdue University West Lafayette, IN 47907-1077, USA; 1994; 354 p.; English.

This short course was held in conjunction with the 1994 International Refrigeration Conference at Purdue University, USA on 17-18 July, 1994. The course covers near- and long-term options and addresses issues such as flammability and global warming. Field experiences with CFC substitution are also included.

Potential for Medium and Large Sized Industrial Heat Pumps in Europe
Laue, H.J., Reichert J.. Published by Fachinformationszentrum Karlsruhe (FIZ), Germany, Fax: +49-7247-808-134; June 1994; 50 p.; English.

This market study has been produced under the THERMIE Programme of the European Union. It gives a basic introduction to industrial heat pump technologies. It discusses the market potential for heat pumps in European Union countries and the barriers that limit this potential. The findings of the report are illustrated by nine case studies.

Heat Pumps in Industry
Lazzarin L.M., "Heat Recovery Systems and CHP" Volume 14, No.6, published by Elsevier Science Ltd., Oxford, UK, Fax: +44-865-843010; English.

In the first of two papers, industrial heat pump equipment is reviewed and classified. Both open- and closed-cycle systems are covered, including mechanical and absorption technologies. The second paper considers some typical application examples.

Directory of China Refrigeration and Airconditioning Industry 1994
China Refrigeration Association; May 1994; 431 p.; Price US$ 60; English and Chinese.

This is the first large-scale authorized professional reference book which systematically and completely reflects the overall situation of China's refrigeration and air-conditioning industry. For information on this publication, plus the "Japan HVAC&R Directory", contact Mr M. Yamasaki, JARN Ltd, Fax: +81-3-3584-4708.

Conferences

1995 ASHRAE Winter Meeting
28 January - 1 February 1995, Chicago, USA.
Contact: ASHRAE Meetings Section.
Tel: +1-404-636-8400; Fax: +1-404-321-5478

Design and Application of Ground-Coupled Heat Pump Systems
19-24 March 1995 / Hawaii, USA.
Held in conjunction with the 1995 ASME/JSME JSES International Solar Energy Conference.
Contact: Prof. Dennis L. O'Neal, Texas A&M University.
Tel: +1-409-845-8039; Fax: +1-409-862-2762

**AIRAH 1995 International Conference and Exhibition*
April 30 - May 3 1995 / Melbourne, Victoria, Australia.
Organized by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH).
Contact: AIRAH
Tel: +61-3-328-2399; Fax: +61-3-328-4116

Indoor Air Quality, Ventilation and Energy Conservation in Buildings
May 10-12 1995 / Montreal, Canada.
Contact: Fariborz Haghighat, Centre for Building Studies.
Tel: +1-514-848-3200; Fax: +1-514-848-7965

Asia-Pacific Conference on the Built Environment
June 1-3 1995 / Republic of Singapore.
Contact: Conference Secretariat, APCBE.
Fax: +65-336-3613

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

1995 ASHRAE Annual Meeting
June 24-28 1995 / San Diego, California, USA.
Contact: ASHRAE Meetings Section.
Tel: +1-404-636-8400; Fax: +1-404-321-5478

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

24th National Heat Transfer Conference
5-9 August 1995 / Portland, Oregon, USA.
Sponsored by the American Society of Mechanical Engineers (ASME).
Contact: Prof. James R. Welty, HTD Conference Chairman, Dept. of Mechanical Engineering, Oregon State University, Corvallis, Oregon, USA.

19th International Congress of Refrigeration - For a Better Quality of Life
20-25 August 1995 / The Hague, The Netherlands.
Organized by the International Institute of Refrigeration.
Contact: Van Namen & Westerlaken Congress Organisation Services.
Tel: +31-80-234471; Fax: +31-80-601159

**Greenhouse Gases: Mitigation Options*
22-25 August 1995 / London, United Kingdom.
Deadline for abstracts: 2 March 1995.
Contact: Dr Pierce Riemer, IEA Greenhouse Gas R&D Programme.
Tel: +44-242-680753; Fax: +44-242-680758.

International Symposium on Two-Phase Flow Modelling and Experimentation
9-11 October 1995 / Rome, Italy.
Contact: Dr Tommaso Setaro, ENEA Casaccia.
Tel: +39-6-3048-6466; Fax: +39-6-3048-3026.

**1995 International Gas Research Conference*
6-9 November 1995 / Cannes, France.
Deadline for abstracts: 31 July 1995.
Contact: Gas Research Institute, Chicago, USA.
Tel: +1-312-399-8300; Fax: +1-312-399-8170

**Symposium on Heat Pump and Refrigeration Systems Design, Analysis and Applications*
12-17 November 1995 / San Fransisco, California, USA.
Deadline for abstracts: 31 January 1995.
Contact: Dennis L. O'Neal, Texas A&M University.
Tel: +1-409-845-8039; Fax: +1-409-862-2762

** Call for papers.*

HPC Events

Seminar

International Heat Pump Status and Policy Review

25th August 1995 / The Hague, The Netherlands
One-day Seminar within the 19th International 'Congress of Refrigeration'

Available from the HPC

Title	*Publication type*	*Order No.*	*Price (NLG)**
International Heat Pump Status & Policy Review	Analysis Report (Vol. 1, 2A & 2B)	HPC-AR3	250
	National Position Papers	HPC-NPP**	40
Heat Pump Water Heaters	Workshop Proceedings	HPC-WR12	60
Consequences of (H)CFC Replacement in HVAC Applications	Workshop Proceedings	HPC-WR-13	60
Heat Pumps for Retrofit and New Applications in Buildings	Workshop Proceedings	HPC-WR-14	80
Heat Pumps - An Opportunity for Reducing the Greenhouse Effect	Promotion Brochure	HPC-BR1	free
Heat Pumps - Better by Nature	Promotion Brochure	HPC-BR2	free
The Behaviour of HFC-134a, HFC-152a and HCFC-22 in Evaporators	Annex 17 Report	HPP-AN17-1	100
Working Fluid Safety	Annex 20 Report	HPP-AN2O-1	100

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CFC and HCFC Replacements - March 1995

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