IEA Heat Pump CENTRE
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Industrial Heat Pumps

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IEA
OECD
heat pump
centre

In this issue

Front cover:
Drying fruit with industrial heat pumps (see article on page 22).

Industrial Heat Pumps

Industrial heat pumps have great potential for contributing to CO_2 emissions reduction. However, low energy prices and the absence of a specific industrial heat pump market mean that industrial heat pumps are not yet used to their full extent. The articles in this issue of the IEA Heat Pump Centre Newsletter demonstrate several possibilities for successful applications, for example in refineries, distillation processes and drying processes.

TOPICAL ARTICLES

HEAT PUMP NEWS

FEATURES

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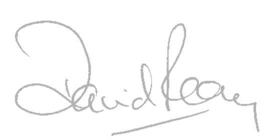
Industrial heat pumps in the new millennium

The theme of this issue, industrial heat pumps, is a fitting one with which to close the millennium. There are several reasons for this. Firstly, at the time of writing, the price of oil is USD 22.45/barrel, a substantial rise on prices earlier this year. Coupled with the observation by Sulzer Chemtech that 300 million litres of oil are used worldwide every day for distillation (a separation technology opportune for heat pumps), this gives us hope that perhaps the major drawback to wider take-up of industrial heat pumps – the perceived long payback period – may reduce in significance.

Secondly, industry is likely to be the battleground where the war for increased energy efficiency/environmental protection/reduced CO_2 emissions – call it what you will – will be fought. And the heat pump will be one of the weapons; at least many of us reading this issue of the Newsletter will hope so. We can, with some justification, argue that industrial heat pumps are a component of a strategy to reduce CO_2 emissions in industry, and thus can perhaps reduce or delay the impact of global warming.

My UK newspaper today carried two reports on global warming and energy – one headed: "…scientists see big surge in global warming" – coinciding with the Bonn Conference on the subject. The second report, in the 'business section', discussed the impending UK energy tax on companies. Responding on behalf of some sectors of industry, the chairman of the UK Energy Intensive Users Group is reported as saying: "This (tax) would be extremely bad news… Energy should be as cheap as possible." No doubt we all see such examples of incompatibilities in the energy scene, but it shows how we still need to educate sectors of industry in energy efficiency, the benefits of it, and the consequences of not taking emissions reduction seriously.

Energy supply deregulation, which encourages industry to shop around for the cheapest power, combined with calls for 'cheap energy' as above, do nothing to further the cause of CO_2 reducing technologies in industry. Perhaps carbon taxes in the new millennium will be combined with tax relief for improved efficiency – leading energy-intensive sectors to invest more in technology, including heat pumps!



David Reay

David Reay is a consulting engineer, and has Visiting Professorships in disciplines ranging from the Built Environment to Chemical Engineering at Heriot-Watt, Newcastle and Nottingham Universities.

Heat pump news

Austria launches installer certification programme

Austria – The LGW (Austrian heat pump association) has taken the first steps towards certification of installers of heat pump heating systems, complementing the DACH heat pump quality label (see Newsletter 16/4).

LGW has now developed criteria for heat pump installers wishing to apply for certification. Installers must have either three years heat pump installation experience or have completed a recognised heat pump course. They must also participate in a two-day practical course, pass a theoretical exam and give five reference installations, thereby providing evidence of experience using two different heat sources. Two of the reference installations will be checked. Individuals can obtain the certificate from the LGW, which is valid for a lifetime. However, the LGW can withdraw certification at its own discretion.

Source: LGW aktuell, 3/99

Energy for the future

Switzerland – The Swiss Heat Pump Promotion Group (FWS) is changing its formal status to become an association. This will further strengthen the basis for promotion of ambient heat utilisation. All organisations that believe in the potential of ambient heat in the new millennium are welcome to join.

The heat pump market in Switzerland has grown significantly since FWS was established in 1993. Predictions for 1999 are 7,000 installations, compared to 3,000 in 1993. This success is a result of the broad support by installers and utilities as well as federal and regional governments. This growth would not have occurred without the federal programme Energie 2000.

The change in formal status will make it easier for professionals and companies to join. FWS is aiming for a breakthrough in the retrofit market. The number of investors selecting technologies with future potential continues to grow. Field measurements by the Swiss Federal Office of Energy show that average SPFs have risen from 2.6 to 3.0. This reflects the increasing know-how and skills of installers and the higher efficiency of the equipment.

The new FWS will continue to be a professional network for the heat pump market, and will provide support in all relevant market segments. Exhibition material, training courses and a number of free publications are available. Questions can be put to the heat pump information centres in Bern and Lausanne. FWS also represents its members in the Energie 2000+ programme and at the Association of Renewable Energy and Efficiency (AEE). Using ambient heat is sustainable and opens new perspectives for the economy and society as a whole.

Source: Dieter Wittwer, FWS
Tel.: +41-1-2994141

ARI certification goes global

USA - In April 1999 ARI's Planning Committee voted to allow manufacturers who do not sell their products in North America to participate in ARI certification programmes. Before this, foreign manufacturers who wished to have their products certified by ARI also had to sell them in North America, but ARI's certification programmes are now positioned to assume the leading role in global certification.

Source: Koldfax, September 1999

European Heat Pump Association

Brussels – On 22 October some 20 participants from more than 10 European countries gathered in Brussels, Belgium, to discuss the formation of a European Heat Pump Association (EHPA). Representatives of national and regional heat pump associations, as well as other interested organisations discussed the pros and cons, the aims and potential tasks of a European Association. The meeting was organised under the framework of the EU Save programme.

A Heat Pump Association currently exists in the following countries and regions in Europe: Austria (LGW), Czech Republic, Denmark, Finland, France (ADPM), Germany (IWP), Netherlands (SWP), Norway, Scandinavia (Nordic Heat Pump Forum), Sweden (SVEAP and VET), Switzerland and the UK (HPA).

Participants agreed that the EHPA should be doing work that cannot be carried out at a national level. One of the most obvious tasks would be to coordinate labelling activities for heat pumps and advising on labelling of residences. Collaboration with related international organisations, such as the IEA HPC and the IIR, is also envisaged.

A declaration of interest was endorsed by all participants at the Brussels meeting. Preparatory work will continue, resulting in a draft agreement at the next meeting in Brussels on 18 February 2000. For further information please contact Mr R. Mayer of Sciotech, UK (tel.: +44-1252-873564).

Source: Jos Bouma, IEA Heat Pump Centre

New compressor performance certification programme

Germany – Approximately 130 people attended the symposium *Kyoto Protocol: reduction of HFC emissions – increase of energy efficiency*, organised by ASERCOM, the European association of compressor manufacturers on 6 October in Essen, Germany.

The Kyoto Protocol requires emissions reduction instead of a phase-out of specific substances, as in the Montreal Protocol, so different measures are needed. The advantages and difficulties of voluntary agreements by industry were addressed by Mr Strohm from DG Enterprise (formerly DG III) of the European Commission.

ASERCOM introduced its new performance certification programme, which will enable consultants, designers and users to compare compressors from the various participating manufacturers and be sure that the data has the same basis (e.g. a common refrigerant database, plus standard rating criteria and reference points). The programme accepts the manufacturers' own measurements according to EN 12900 and the standards for compressor tests, but they must be elaborated using the software developed for the programme. A certification committee will check the data for completeness and probability. The first listing of certified products will be available on the Internet in January 2000.

Other speakers discussed measures to promote energy efficiency and emission reduction. These include efficient design and operation, as well as product certification and labelling programmes. The possibilities of CO_2 as a refrigerant were also addressed, plus enhanced containment of the refrigerant.

Source: IEA Heat Pump Centre
More information: ASERCOM, Germany,
Fax: +49-30-21479871

Heat pumps to use only renewables

Germany – The German Federal Government only supports heat pumps if they use 100% renewable electricity. This must be shown when applying for subsidy. This requirement is part of the new guidelines for promoting renewable energy that came into force on 1 September 1999.

More information:
Bundesamt für Wirtschaft
Internet: http://www.bawi.de/
Fax: +49-6196-94226

Heat pump training programmes

France – Over 30 attendees took part in the EU workshop *Heat pump training programmes – the way to certification* on 8 November in Paris, France. Six speakers discussed training programmes in four countries and evaluated experiences gained. The workshop was organised by the *Concerted action group for the promotion of heat pumps in Europe* (Thermie B). Further details are given in the enclosed European Heat Pump Network Newsletter.

Source: IEA Heat Pump Centre

New IIR working parties start

France – *Ice slurries* and *Unitary heat pump and air conditioning test stations* are the subjects of two new IIR (International Institute of Refrigeration) working parties.

The working party *Unitary heat pump and air-conditioning test stations* aims to:

- study methods and results of measuring the operational performance of domestic heat pumps (heating-only and reversible type), and to exchange information relating thereto;
- encourage an increase in knowledge of unitary equipment performance among IIR members as well as among equipment manufacturers, suppliers, designers and users;
- provide advice, through the IIR, to parties involved in implementing heat pump systems;
- encourage the harmonisation of testing procedures and standards;
- encourage the publication of information through the IIR.

The working group was initiated by four organisations: DTI (Denmark), NOK (Switzerland), SP (Sweden) and TNO (the Netherlands). Membership by participants with other backgrounds and from other regions is encouraged. The Chairman of the working group is Mr P. Fahlén and the next meeting will be on 22 March 2000 in Sweden.

The working party *Ice slurry* was established in May 1999, with Dr P. Egolf as its Chairman.
During a two-day meeting, parties discussed their experience and a four-year working programme was established. The aim of the working party is to validate basic data and to draft new recommendations for the design and commissioning of manufacturing systems using ice slurry. Three subgroups will focus on:

- theoretical aspects, properties and modelling;
- experimental studies, conditions required;
- practical applications.

The working party will coordinate its work via the Internet. Their next meeting will be held 25-26 May 2000 in Paris, France.

A new IIR group was also established at the IIR Congress in Sydney, to exchange information about practices in heat pump drying. For further information please contact Mr G. Carrington.

More information from:
Test stations: Mr P. Fahlén,
E-mail: per.fahlen@sp.se
Tel.: +46-33-165520

Ice slurry: Mr P. Egolf
E-mail: peter.egolf@empa.ch
Tel.: +41-1-8234799

Heat pump drying: Mr G. Carrington
E-mail: gerry@physics.otago.ac.nz
Tel.: +64-3-4797794

Heat pumps for retrofit

Germany/Switzerland – In Switzerland, one out of every three new houses contains a heat pump. However, this number is 14 times lower in Baden-Württemberg, one of the German states along the Swiss border. To stimulate the use of heat pumps in this part of Germany, particularly in existing buildings, IZW organised a workshop entitled *Application of heat pumps in existing buildings* on 14 July 1999 in Karlsruhe.

Most retrofits with heat pumps in Baden-Württemberg are to replace existing heat pumps. However, replacing oil- and gas-fired boilers would offer increased envirinmental benefits. If low heat-distribution temperatures can be used, heat pumps reduce greenhouse gas emissions (otherwise gas-fired boilers and heat pumps are equally suitable).

Incentive programmes, by both federal and regional governments, and the regional utility, were discussed. Since the introduction of government incentives the heat pump market has grown by more than 20% annually. New energy standards promote the use of heat pumps in both Germany and Switzerland. The workshop ended with a discussion on training programmes, and experience gained with heat pumps in existing buildings in both countries.

Source: National Team Switzerland
More information: A. Lehmann
Fax: +49-7247-808666

Swiss project NTH on the Internet

Switzerland – The project *Low-cost low-temperature heat pump heating systems* (Swiss acronym NTH) now has a website (German). The Figure depicts the home page, which can be accessed at: http://www.waermepumpe.ch/fe under the topic Schlussbericht, or directly from http://www.waermepumpe.ch/projekte/nth.

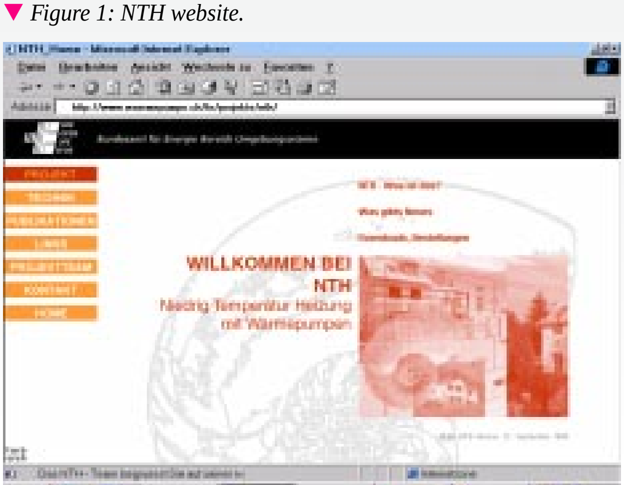
The main objectives of the project, implemented for the Swiss Federal Office of Energy, are to:

- increase the heat pump market for newly built low-energy homes (energy demand for heating < 160 MJ/m^2year);
- develop a complete system for space heating, domestic hot water and ventilation;
- distribute heat by water (hydronic system) and air (with recovery of ventilation losses);
- implement a smart control system integrated into the heat pump, as well as passive control by the building itself (self regulation).

The project has four phases, two of which have now been completed. Current work focuses on monitoring pilot installations and developing a design handbook for installers and planners, and a marketing handbook.

For more information please contact
Dr Thomas Afjei (contact details on back cover).

▼ *Figure 1: NTH website.*



Lithuania installs 4.8 MW absorption heat pumps

Lithuania – Four absorption heat pumps with a total thermal capacity of 4.8 MW were shipped to Klaipeda, Lithuania for a district heating plant in September 1999. The plant uses geothermal water (700 m^3/h) at 40-45ºC as a heat source, which leaves the plant at 11ºC. The heat pump evaporators have titanium tubes, so that the highly saline geothermal water can be used without intermediate circuits. The system design guarantees maximum heat recovery. Supply and return temperatures of the district heating network are 70-80ºC and 45-55ºC, respectively. The heat pumps are driven by superheated water at up to 200ºC.

More information: Mr J. Scharfe, ENTROPIE
Fax: +49-8122-983818

New dewatering laboratory in Trondheim

Norway – The Department of Refrigeration and Air Conditioning at NTNU/SINTEF has recently opened a new dewatering laboratory. Considerable investments have been made in equipment to develop optimal dehydration techniques for raw materials and end products. Applications range from drying fruit for cereals to preserving oil-eating microbes.

Techniques that can be tested include centrifugation and membrane filtration, spray drying, tunnel drying, drum drying, evaporative drying, vacuum freeze drying and fluidised bed heat pump drying (see article on page 22). The laboratory provides an excellent opportunity to find an optimal combination of method, quality, economy and environment. The new laboratory is financed by NTNU, SINTEF, the Norwegian Research Council, and commercial investors.

Source: Norwegian National Team

Next generation air cycle systems

Japan – Mycom (Mayekawa Mfg. Co. Ltd) in Tokyo, has launched the next generation of air-conditioning systems: the advanced air cycle system. The concept is being developed together with NTT Facilities and Waseda University.

The three development partners have been working on the concept since December 1997, and have succeeded in devising the world's first advanced air cycle system. According to Mycom, the COP is equal to or higher than that of a conventional vapour compression cycle.

The advantages of the system include:
- refrigerant with zero ODP and GWP;
- low system pressure;
- low-humidity capability;
- high efficiency system;
- widely applicable.

Mycom and its partners will now commercialise this new air-conditioning system for a communication equipment room (completion by 2002).

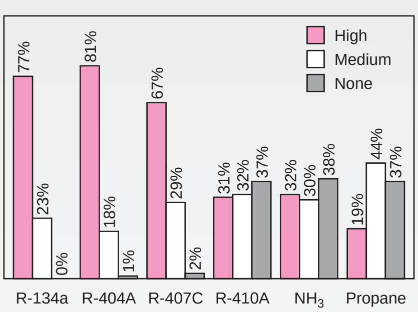
Source: JARN, 25 July 1999

Will Germany switch to HFCs?

Germany – The German air-conditioning journal CCI revealed that German installers regard HFCs as the refrigerants with the highest future potential for refrigeration and space conditioning applications. This was the result of a questionnaire to 1,500 members of the installers associations VDKF and BIV dated 1 September 1999.

Figure 1 shows the perceived future potential of refrigerants, which clearly indicates that the HFCs are regarded as the most likely working fluids for the future. R-410A, NH_3 and propane were rated less important. Twenty percent of respondents see a high potential for propane, compared with 80% for R-404A.

▼ *Figure 1: Perceived potential of refrigerants in Germany*



Experience with the refrigerants R-134a, R-404A and R-407C has been gained by 94%, 85% and 82% of the respondents, respectively. The percentages for R-410A, NH_3 and propane (25%, 22% and 21% respectively) were clearly lower.

In the meantime, the German government has decided that equipment manufactured before the end of 1999, plus new installations commissioned before the end of that year, will still be allowed to use HCFCs beyond 1 January 2000. In other cases, the use of HCFCs in new installations is banned from 1 January 2000 onwards.

Source: CCI Zeitung, 11/99

R-407C dominates at IKK

Germany – More than 500 exhibitors from all over the world promoted their products recently at the 20th IKK trade fair in Essen, Germany. R-407C was the dominant refrigerant choice for new reversible air conditioner products.

It was perhaps no surprise that reversible air conditioners far outnumbered heating-only applications. However, both York and Stulz presented heating-only brine-water heat pumps. The German company DK showed systems for heat recovery from refrigeration in retail applications. Entropie distributed fact sheets on new absorption heat pumps in the Megawatt range in Germany, plus others being built in Lithuania (see page 6).

Source: IEA Heat Pump Centre

Sanyo unveils CO_2 compressor

Japan – Sanyo Electric Co. Ltd has announced the production of a new hermetic compressor for CO_2 – the first of its kind. CO_2 as a refrigerant is non-toxic and non-combustible, with zero ozone depletion potential (ODP) and a global warming potential of one. However, high-efficiency compressors with high operating pressures are needed for successful application in a refrigeration cycle.

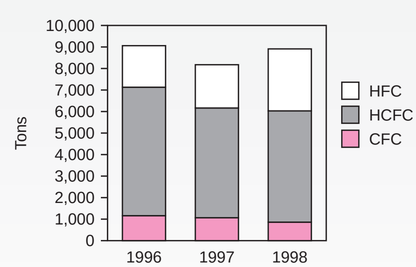
The new device is a two-cylinder rotary compressor with two-stage compression, driven by an AC inverter motor (20-120 Hz). Power output is rated at 750 W. Sample sales are scheduled for January 2000.

More information:
http://www.sanyo.co.jp/index_e.html

French HFC consumption increases

France – Consumption of HFCs rose decisively in 1998, compared to that of 1997 and 1996. However, CFC consumption only dropped slightly, and still accounted for 10% of the French refrigerant consumption in 1998. The relative share of HCFCs dropped to 58%, but in absolute amounts the consumption increased as a result of market conditions in 1998.

▼ *Figure 2: Consumption of CFCs, HCFCs and HFCs in France.*



Source: RPF, September 1999

Ground-source heat pumps on the increase in USA

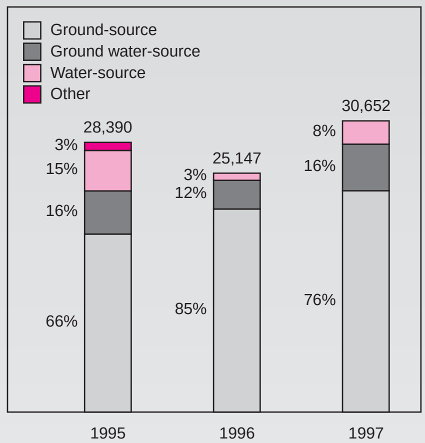
USA – The number of ground-source heat pumps installed in 1997 rose by 22% compared to 1996, from 25,147 to 30,652 units. This was the conclusion drawn by a study prepared last year by Penton Research Services for the Geothermal Heat Pump Consortium.

Ground-source heat pumps account for most of the installations – 76% in 1997. Ground-water-source heat pumps amounted to 16%, while only 8% were water-source heat pumps. Residential ground-source heat pumps use horizontal and vertical closed ground loops in equal numbers. For non-residential systems, vertical closed ground loops were far more popular (55% of total in 1997) than the horizontal option (15%). The estimated numbers installed over three consecutive years, plus details of the heat source, are shown in **Figure 1**.

The East North Central and West North Central regions were leaders in residential installations, the latter also leading the non-residential applications. The West contained the lowest percentage of ground-source heat pump installations.

This was the third in a series of annual studies. Information was gathered via questionnaires to installers.

▼ *Figure 1: US ground-source heat pump sales.*



Source: Penton Research Services
Fax: +1-216-6968130

Reversible AC in demand in Tunisia

Tunisia – Tunisia's air-conditioning industry is benefiting from economic growth and renewed consumer confidence. Several large manufacturers from Japan, USA and Europe participated in the ClimExpo trade fair held in Tunis, April 1999.

The market currently consists mostly of split units, though the trend is towards reversible heat pump versions.

Source: JARN, August 1999

Heat pump market continues to grow in Norway

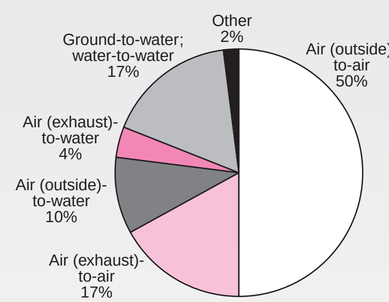
Norway – The growth shown in the Norwegian heat pump market during 1997 has continued into 1998, see **Figure 1**. The total sales were at least 2,313 units (including import and domestic production) according to NOVAP statistics (Norwegian heat pump association). Contractors for prefabricated houses importing their own heat pumps were not included.

Figure 2 shows various heat sources and distribution systems for 1998. Air-to-air heat pumps using outside air as a heat source show the highest percentage. In 1997 and 1998 outside-air units were more popular than in earlier years. Ground- and water-source heat pumps are also gaining popularity, with 17% sales in 1998. Though air remains the main heat distribution medium, water systems increased from 26% (1997) to 32% (1998) of new installations.

▼ *Figure 1: Norwegian heat pump sales.*

Homeowners with hydronic distribution systems are increasingly selecting ground water instead of outside air as a heat source. Up to a few years ago it was difficult to find skilled companies to install ground-source heat pumps, and drilling was rather expensive. As several companies now specialise in drilling for ground loops, prices have dropped and these systems are becoming more well known. The number of water-to-water units has increased, at the cost of outside air-to-water.

The following table shows the heating capacity distribution of the sales in 1998, compared with the total heat pump stock (24,585 units by the end of 1998). As in 1997, heat pumps in the 3-10 kW capacity range showed above-average sales. The smallest heat pumps sold less than average in 1998, but still more than in 1997.



▲ *Figure 2: Heat pump sales according to type (1998).*

▼ *Table: Capacity distribution of heat pumps in Norway.*

Heating capacity (kW)	Total stock (%)	Sales 1998 (%)
< 3	30	23
3-10	44	57
10–25	9	10
25–100	13	6
100–1,000	4	4
> 1,000	0.2	0.05

Source: Norwegian National Team

Successful workshop on natural working fluids

France – The HPC/EU workshop *Natural working fluids, a challenge for the future* was held in Paris, France, on 9 November. The EU (DG Environment), AREA (the European installers association), European heat pump manufacturers and refrigerant manufacturers were represented as well as standards committee members, risk analysis experts, and interested groups from overseas. Nine speakers presented a historical overview, policy issues, standards and regulations, legal and safety aspects, and industry experience with hydrocarbons and ammonia in heat pumps or air conditioners. See page 26 for more detail. The need for training, installation efficiency and future policy were some of the issues addressed during the lively discussions. There was consensus that successful introduction of alternative refrigerants, including R-410A, is not possible without adequate training of installers.

The workshop proceedings will be available from the IEA Heat Pump Centre (Order No. HPC-WR-21).

Source: IEA Heat Pump Centre

HPC work plan 2000

The Netherlands – The Heat Pump Centre (HPC) work programme for 2000 was determined at the latest National Teams Working Meeting held in Utrecht, the Netherlands. Newsletter topics for 2000 will be:

- Commercial and industrial refrigeration;
- Heat pump programmes and international heat pump organisations;
- Refrigerants: standards, regulations, safety and liability issues;
- Heating heat pumps for retrofit.

The first Newsletter issue in 2001 will be *Experience from operating heat pump systems: efficiency and reliability.*

New projects will also be implemented in the following areas:

- *Successful heat pump installations – case studies.*
- *Refrigerant choices and practices for heat pumps in an international perspective.* This project aims to present the benefits and drawbacks of new refrigerants; best practices for heat pumps will be presented in a balanced, unbiased way.
- *Designing heat pump systems - users' experience with software and handbooks.* The outcome of this project will aid engineers, designers and others in the building and industry sectors, to select suitable heat pump design tools available in handbooks and through software.

If you are interested to know more about these projects, please contact your National Team (in HPC member countries) or the HPC.

Source: IEA Heat Pump Centre

HPP Executive Committee meets in Paris

France – The IEA Heat Pump Programme Executive Committee met on 18-19 October at the IEA headquarters in Paris. Highlights of the meeting include:

- a new Strategy Plan for the period 2000-2003 is under development, based on input from industry, the energy sector, the research community and national energy policy makers;
- the stature and awareness of the programme could be enhanced. A new public relations programme will be developed to achieve this;
- the future organisation of the Heat Pump Centre will be analysed to produce a strong and broadly supported information activity within the Heat Pump Programme;
- the alliances with related international organisations, such as IIR and the EU, will be formalised;
- further work on the application of absorption technology with combined heat and power was proposed. A new Annex proposal (following Annex 24) may be developed;
- participation in Annexes 26 and 27 has now been confirmed by several additional countries (see Table).

Source: IEA Heat Pump Centre

Ongoing Annexes

Red text indicates Operating Agent.

Annex 16 IEA Heat Pump Centre	16	AT, JP, NL, NO, CH, UK, US
Annex 24 Ab-Sorption Machines for Heating and Cooling in Future Energy Systems	24	CA, IT, JP, NL, NO, SE, UK, US
Annex 25 Year-round Residential Space Conditioning and Comfort Control Using Heat Pumps	25	CA, FR, NL, SE, US
Annex 26 Advanced Supermarket Refrigeration/Heat Recovery Systems	26	CA, SE, UK, US (FR, NO, MX to be confirmed)
Annex 27 Selected Issues on CO_2 as a Working Fluid in Compression Systems	27	JP, NO, UK, US (AT, CH, SE to be confirmed)

IEA Heat Pump Programme participating countries: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), Mexico (MX), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).

Industrial heat pumps - an international overview

Gerdi Breembroek, IEA Heat Pump Centre and Onno Kleefkens, Novem

Industrial heat pumps can contribute significantly to the reduction of CO_2 emissions, yet in many countries they are not used to their full potential. Their development is hampered by low energy prices and the absence of an industrial heat pump market. However, environmental legislation is stimulating the installation of more heat pump systems. This article addresses industrial heat pump technologies, their market, and activities to stimulate their use.

A diverse family

An industrial heat pump is a system that upgrades thermal energy by recovering industrial waste heat and supplying it at a higher temperature for use in the industrial process or for space heating. Waste heat from industrial processes can occur at various temperature levels. An industrial cooling or refrigeration process produces low-temperature heat on the condenser side of the system, which can be used effectively elsewhere. On the other side of the spectrum, waste heat from industrial distillation or evaporation processes can be recovered via a heat pump for use in the same process.

The technical possibilities include mechanical vapour recompression (MVR), thermal vapour recompression (TVR), electric and gas-engine-driven closed-cycle compression and various absorption technology heat pumps. The Annex 21 report[1] provides a thorough overview of the technology and its applications in a large number of industrial processes. The article on page 18 of this Newsletter gives a more detailed overview of the possibilities and benefits of MVR systems. The article on page 16 discusses experiences with heat transformers in Japan.

Table 1 shows typical application areas in HPC member countries.

Process optimisation

In complex processes or plants the industrial heat pump must be integrated in a thermodynamically sound way. The 'multiple shell model' (**Figure 1**) is essential for designing or enhancing the efficiency of a process. Optimisation should be realised from core process to outer shell (import/export of utilities), with the principles of exergy and pinch analysis.

The concept of pinch analysis was used for the Annex 21 screening program[1]. This program was written to scan processes for economically viable heat pump applications. The program *Odessy*, which optimises industrial processes for minimum energy use, was introduced in Newsletter 17/2. It considers heat exchangers, heat pumps and combined heat and power (CHP) plants. The program has been used in several projects in Dutch industry and has shown unexpected energy-saving options, many of them involving heat pumps. The pinch analysis software tool *PINCHLENI*, developed for the Swiss Federal Office of Energy (SFOE), is another alternative (information via Swiss National Team, see back cover).

Figure 1: Multiple shell model for energy saving in industry.

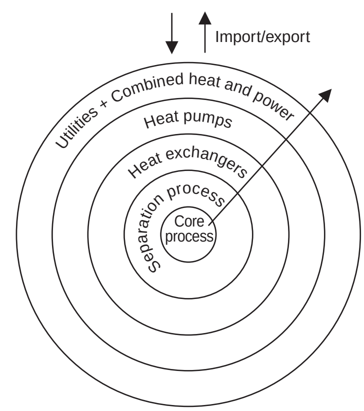


Table 1: Typical application areas in HPC member countries.

Austria	Cooling/waste heat utilisation in various industrial applications, salt production, breweries, paper mills
Japan	Chemical industry, food processing, drying, horticulture, fish farming, heat recovery; compression (91%) and sorption systems (9%)[1]
Netherlands	Chemical industry, dairy industry, bulb-drying, meat processing, sludge and manure drying, greenhouses
Norway	Timber/wood drying, fish farming (together 80% of installed units by number)
Switzerland	Chemical industry
UK	Drying/evaporation in food industry, chemical industry, metal, timber drying[1]
USA	Timber drying, dairy, corn milling, liquor, pulp and paper, chemical industry, food processing and storage

Hot technology

An important R&D target is to achieve high working temperatures and a high temperature lift. Some years ago experimental work on Alkitrate was implemented in the USA (Newsletter 8/4). An absorption/compression heat pump with NH_3/H_2O as the working fluid pair is currently being developed in Norway. The unit operates up to 110°C. Closed compression heat pumps, with CO_2 as working fluid, are also being developed. Both technologies allow high temperatures and a favourable temperature glide. Research in the Netherlands focuses on sorption technology. Isopropanol/ acetone-water is now being tested under laboratory conditions. Reverse rectification is also being studied. Examples of high-temperature IHP applications include the heating of process water for sterilisation in the food industry and the production of low-pressure steam.

Cooling down

The USA is now focusing on cooling processes, particularly in the food processing industry. As of 1996 the industrial/commercial market has approximately 42,000 installed units, with a total capacity of nearly 148 GW, most of them cooling-only. The article on page 13 describes how economic advances and reduced emissions were achieved at an oil refinery in Denver. Waste-heat-driven absorption refrigeration is used for product recovery and de-bottlenecking.

Significant CO_2 savings

The Annex 21 final report showed that a CO_2 emission reduction of 215 million tons of reduced CO_2 emissions per year can be achieved worldwide by 2010 through using industrial heat pumps (maximum scenario). This is 1% of current total emissions. Evidence from the Netherlands supports the fact that industrial heat pumps form a significant contribution to CO_2 reductions. One industrial heat pump at the Shell propylene/propane splitter saves 1.4 PJ of natural gas annually, which is equivalent to the energy used by 30,000 residences.

In the Netherlands, investments per ton CO_2 reduction in industrial heat pumps are lower than for other options, see **Table 2**.

Potential not realised

The *International heat pump status and policy review 1993-1996*[2] reports around 6,900 industrial heat pumps in 10 countries (see **Figure 2**). However, countries reported that statistics on industrial heat pumps are hard to find. IHPs are often not recognised as such, as they are installed as separate components, and commercial confidentiality also makes it difficult to obtain complete data.

Although investments in industrial heat pumps are a cost-effective way to work towards the Kyoto targets, none of the countries are realising the potential that they offer. Among the HPC member countries, Norway and the Netherlands are the most successful, realising over 10% of the 2010 potential. The US is somewhere in the middle. The situation regarding industrial heat pumps is probably the most challenging in Japan and the UK, as the numbers are fairly low (1% of the potential). Data from Austria and Switzerland are not available.

What needs to be done?

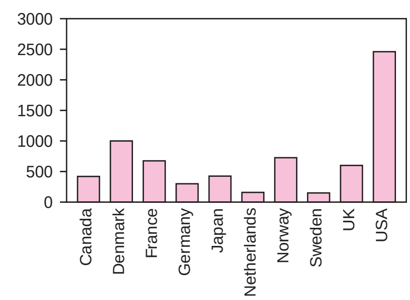
How can we increase the market for industrial heat pumps? An important impediment is the low energy price level, resulting in long payback periods on investments. But other factors also play a role. The examples discussed below concentrate on the situation in various market segments in the Netherlands. Comparable analyses can be made in other countries.

The Netherlands has carried out a detailed study of the market for industrial heat pumps in the chemical industry, by interviewing large and medium-sized chemical companies, contractors/manufacturers and a consultant. The study was reported in more detail in Newsletter 16/4. The interviews showed that there is neither market 'push' nor 'pull'. On the supply side, there are no companies marketing industrial heat pumps as a product.

▼ *Table 2: Investment cost of CO_2 reduction options in the Netherlands.*

	USD/ton CO_2 reduction
Industrial heat pumps	6 – 12
Industrial combined heat and power plants (CHP)	14 – 24
Residential heat pumps	37 – 47

▼ *Figure 2: Industrial heat pump stock, 1996.*



Companies either market components (e.g. compressors) or incorporate a heat pump into a larger system, such as a distillation column.

The study suggested three basic approaches to promote heat pumps:

- reduce installation costs;
- increase market pull;
- give subsidies and grants.

Reducing installation costs

Reducing installation costs for heat pumps is most viable in those applications that can be standardised. Standardisation should be sought in design and calculation procedures and in technology.

An example of both possibilities is combined cooling and heating in the food industry. Three segments are relevant in this market where heat is recovered by cooling the condenser:

1. direct heat recovery at 45ºC for space heating;
2. increasing the temperature of recovered heat to 65-70ºC for low-temperature processes;
3. increasing the temperature of recovered heat to 110ºC to generate low-pressure steam.

Examples

Fish farming is the most popular application of industrial heat pumps in Norway (see Newsletter 9/3). A heat pump heats process water from 5-10°C to 14°C, using waste or seawater as heat source. The fish grow faster at this temperature. The heat pump has a COP of around 20 because of the low temperature lift.

Worldwide, drying processes are a popular application for industrial heat pumps. These are very efficient, as they recover latent heat from the evaporated water. The article on page 22 covers a demonstration project using heat pumps to dry fruit in Norway.

An MVR evaporator was recently installed at a malt extract plant in Scotland. This installation is a good example of an opportunity revealed by careful plant assessments. The use of MVR enables an increased plant capacity that was impossible to realise with the existing boiler. It also shows that acceptable payback periods can be achieved, even under the current low energy cost regime.

The salt mine in Ebensee, Austria, is famous as the location of the world's first industrial heat pump. A third MVR system has recently become operational on the same site. Salt is now produced using three units of 4-6 MW electrical input and 100 MW thermal output.

The introduction of segment 1 applications is supported by a series of measurements confirming cost efficiency at example installations. A series of interviews with key end-users will identify the bottlenecks and suggest a strategy to overcome these. These initiatives add to the existing knowledge, improve the market structure, and aim to create an autonomous market. Response from market parties is very positive.

Segment 2 is more demanding. The market is in the application development phase, in which strong partners build expertise at industrial customers in the food industry. Several feasibility studies are underway. If successful, one of the customers will promote the heat recovery installation with a heat pump as standard technology for all its industrial sites.

It is important that large suppliers see opportunities and seek to develop the business potential in this market together.

Market pull

High energy efficiency requirements will increase the need for energy-efficient technologies in industry. A heat pump is one option. Potential customers should be aware of this option, otherwise there will be no market pull. Awareness among the Dutch chemical industry is good, but the economy of other energy-saving options is often better.

New opportunities for heat pumps can evolve from stricter environmental requirements, such as:

- requirements on waste heat recovery. In Sweden reusing condenser waste heat is common practice, except for specific cases;
- maximum discharge temperature for cooling water to surface water. In the Netherlands, discharge temperature below 30ºC is obligatory. At least two large new projects in the chemical industry use heat pumps instead of cooling towers;
- restrictions on the use of ground water for cooling gives opportunities similar to those for surface water;
- preventing air pollution. In Norway, heat pump drying processes (timber, wood, leather, fish) are popular because they prevent air pollution by recycling the process air.

The UK recently made some progress in stimulating the market pull. Until recently environmental legislation or 'voluntary agreements' have not encouraged investment in energy saving in process industries. Now, however, agreements on CO_2 emissions reduction between government and industrial sectors, perhaps the most significant involving the chemical industry, are likely to increase interest in heat pumps as a practical component of any plan to reduce energy use.

Market pull may also increase through additional demand for other heat pump benefits, such as:

- product quality improvement as a result of milder and/or more stable process conditions;
- reduction in cycle time (drying and dehumidification);
- full capacity in warm weather;
- less cooling water required.

Subsidies and grants

Industrial heat pump programmes are mostly embedded in today's energy efficiency programmes, e.g. in Norway, the Netherlands and the UK. The advantage of incentives is that they can create a genuine heat pump market. In Japan, the market for ice-thermal storage technology is growing thanks to government subsidies. This strategy can also be applied to industrial heat pumps. The disadvantage of incentives is that the market may collapse when incentives are withdrawn.

Conclusion

There is great potential for industrial heat pumps. Although small in number, they contribute significantly to world CO_2 emissions reduction. Low energy prices and high initial costs are important impediments to the application of industrial heat pumps, but also important is the fact that industrial heat pumps are not marketed and bought as a dedicated product. Reducing installation costs through standardisation, increasing market pull and providing subsidies and grants are all measures that can be used to promote industrial heat pump use.

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Novem

1 Annex 21 publications *Industrial heat pumps, experiences, potential and global environmental benefits*. Contact the IEA Heat Pump Centre for more information.
2 *International heat pump status and policy review 1993-1996*, IEA Heat Pump Centre, 1999.

Waste-heat-powered absorption refrigeration at a petroleum refinery

Donald C. Erickson, USA

A waste-heat-powered ammonia absorption refrigeration unit (ARU) has been installed at the Commerce City refinery of Ultramar Diamond Shamrock. The ARU provides 300 kW of refrigeration at -43°C to refrigerate and to treat gas from a reformer plant, thereby recovering 7,950 m^3 per year of liquefied petroleum gas (LPG) which was formerly flared or burned as fuel. The refinery's investment has already been paid back in the first two years of operation, from increased recovery of this saleable product. As an additional benefit CO_2 emissions in the Denver area have decreased by 10,000 tons per year. The project was initiated as a showcase demonstration under the Department of Energy (DOE) Office of Industrial Technologies, and received 30% funding from DOE. In 1998 this project was designated "Environmental Project of the Year" by the Association of Energy Engineers.

Waste-heat-powered ammonia absorption refrigeration can be a very efficient industrial refrigeration technology. However there have recently been few installations due to the high investment cost. Although comparative assessments indicate that absorption refrigeration should cost less to design and produce than mechanical refrigeration, the costs are often considerably higher due to the following factors:

- a low production volume,
- the use of antiquated and costly exchangers,
- low performance cycles; and
- poorly chosen applications.

However, this situation is now changing. The case study presented here uses a new cycle, with new components (newly designed heat exchangers), and is a new application: directly integrated into the very demanding environment of an oil refinery.

Problem definition

This refinery in Commerce City, Colorado, producing 4,300 m^3 of LPG per day, was both unprofitable and inefficient. Refineries produce a variety of combustible waste gases that are routed to a fuel header. If the amount of waste gas exceeds the requirements of the furnaces and boilers, the excess is flared.

A small fraction of the waste gas is propane or heavier (C_3+): about 4% by volume. As a liquid, the C_3+ is a saleable product from the refinery, as either LPG or petrol. The C_3+ in the waste gas is close to 30% – an inviting quantity of potentially saleable product. Calculations show that about half the C_3+ can be condensed by chilling the waste gas to -29°C. This recovered liquid hydrocarbon has roughly the same fuel value as the waste gas that is normally flared. Hence, by recovering this amount, the fuel header is balanced, thus eliminating the need for continuous flare. In effect, flare gas is converted to saleable liquids (petrol and LPG) at 100% efficiency.

Another problem was that the heavy crude available locally gave proportionately more heavy fractions that required processing in the fluidised catalytic cycle (FCC) plant. This meant that the FCC plant was a bottleneck for the entire refinery, as it limits the crude charge.

Problem solution

With financial assistance from the DOE Office of Industrial Technologies, the refinery convened a team of experts to quantify the above problems and devise the best solutions. Given the recent improved efficiency and cost-reducing developments in ammonia absorption refrigeration cycles, this was also included in the study. Apart from the efficiency characteristics, equally important issues, from a refinery perspective, include the robustness and reliability of absorption technology. Consisting only of heat exchangers and pumps, it can readily be built to refinery standards, and hence be directly integrated into refinery processes.

The essence of problem solving in process industries is finding the best of many competing solutions. The flare recovery problem provides a good example. Other options to recover C_3+ from fuel gas include compression, ambient temperature condensation, membrane separation etc. Mechanical refrigeration provides a marginal benefit over the other techniques, until the cost of the new electric service is included, when waste-heat-powered absorption refrigeration clearly becomes the best choice.

Another key factor involved in finding the best solution is determining where the refrigeration should be applied. The fuel header gas has low C_3+ content (4 volume percent) at low pressure (430 kPa), requiring very low refrigeration temperatures, and a large volume of gas to be processed. It is also water saturated, requiring glycol treatment to avoid freezing. All the streams entering the fuel header were considered to see if a better location could be found.

One stream – net gas/treat gas effluent from the reformer plant – proved to be ideal. The stream is dry, the C_3+ concentration is 7 volume percent and the stream pressure is 1,117 kPa. The C_3+ content is also large enough that the targeted recovery amount could be obtained from this stream alone. Chilling this stream to –29°C at nominal summer conditions recovers 32 m^3 per day of liquid C_3+, which is more than enough to extinguish the flare.

Solving the problem with a waste-heat-powered ARU also requires a suitable source of waste heat. Although refineries have a large number of waste heat streams, many are not practically or economically feasible. A good source was available locally at the reformer plant; the 143°C recycle gas en route to the air-cooled fin fans. The cooling curve showed that the required 1,758 kW of waste heat could be extracted from this stream while cooling it to 127°C.

Removing the FCC bottleneck meant determining that the wet gas compressors were the limiting components – both the FCC and the main column could accept up to 15% more feed, if the wet gas compressors could remove the added feed from the main column without increasing column pressure. Adding an extra wet gas compressor would be too costly. However, the capacity of the existing compressors increases by 15% if their inlet vapour is chilled to 4°C, which was accomplished by adding another absorber at the ARU. A key consideration was that compression is more energy efficient at this colder temperature, so electric power consumption does not increase. The 4°C limit was selected to prevent hydrate formation in the water-saturated hydrocarbon gas.

Implementation

The net gas/treat gas chilling requires 300 kW of refrigeration at -32°C, and the wet gas cooling requires 600 kW at -4°C. Given a waste heat supply temperature averaging 135°C, the ARU maximum temperature is limited to around 127°C. Achieving this from such low-temperature waste heat requires some unconventional techniques. First, the ARU was directly integrated into the refinery processes. There was insufficient temperature driving force to accommodate either an intervening steam generator at the hot end, or a pumped brine system at the cold end. One result of this was that all ARU components had to be full refinery grade, meeting very stringent design, manufacture, testing, and safety specifications. Offsetting this additional cost, however, was the avoidance of a brine system or steam generation system. The integration of the ARU into the refinery is illustrated in **Figure 1**.

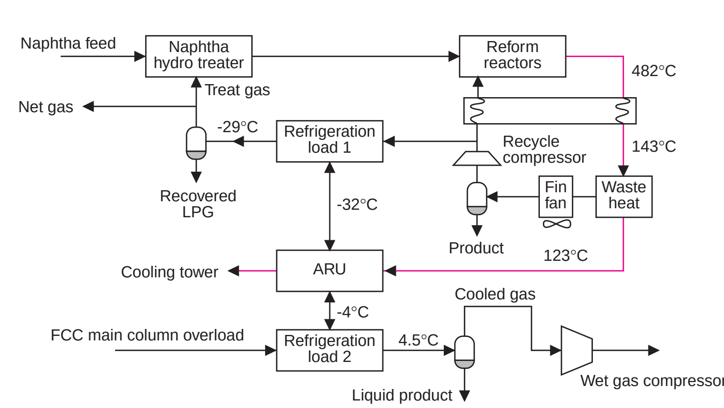
Even with the ARU directly integrated into the refinery processes, additional measures were required to supply the high lift from the low driving temperature. The ARU cycle requires three pressure levels as refrigeration is at two different temperatures. However, the characteristics of the waste heat source (essentially hot high-pressure hydrogen) made it economically impractical to have more than one ARU generator. A variety of advanced cycles were conceptualised to address these constraints, and were compared and evaluated to yield the best. The resulting flowchart is shown in **Figure 2**. Conventional shell-and-tube heat exchangers were specified for all exchangers in contact with refinery fluids. All remaining exchangers were a new design that is highly enhanced and compact. For example, the new plate-fin type absorbers require only one-sixth of the volume of conventional shell-and-tube absorbers.

Results

Initial startup of the ARU was implemented in early August 1997. LPG recovery commenced immediately, and averaged around 24 m^3 per day. Although this was sufficient to accomplish the targeted two-year payback period, it was less than the anticipated 32 m^3 rate. One major problem was that the vapour flow in the absorber was being channelled through a few preferred pathways rather than across the entire heat exchange surface. A solution was devised that involved redesigning the vapour injectors in the absorber. The new injectors were tested (one-tenth scale prototype), and shown to be effective.

Since valuable LPG was being recovered, the refinery deferred this ARU injector modification until late October 1997. Cold weather and reduced crude charge mean that recovery is much lower during the winter, so the four-day ARU shutdown (necessary for injector replacement) had less impact. Several other minor modifications were accomplished at the same time, simplifying operation by increasing the level of automation. For example, one flow stream that had previously required several manual throttle valve adjustments per day could now be automatically controlled from the control room.

Figure 1: ARU refinery integration.



After these modifications the ARU achieved the design LPG recovery rate of 32 m^3 per day, as well as the design chilling temperature (-29°C). The peak recovery recorded so far is 50 m^3 per day. The chiller is always operated to achieve the lowest possible temperature, and routinely achieves -46°C during the winter.

It is now rare for any gas to be released from the refinery fuel header into the flare header. The average LPG recovery is at least one and a half times the amount that was formerly flared, so it is usually necessary to import natural gas to make up the deficit. Gas chromatographic analysis shows that the recovered liquid contains 60% petrol, and 40% LPG. The liquid is separated into these two products in an existing column – the crude overhead stabiliser. Thus, the natural gas is therefore converted into petrol and LPG at effectively 100% thermal efficiency, with excellent economic added value. Refinery-wide, the recovered saleable liquid product has increased by 0.6%, with a proportionate improvement in the Energy Intensity Index, and direct increase in profits.

With regard to atmospheric emissions, the flare reduction alone has reduced CO_2 emissions into the Denver basin by over 6,000 tons per year. Another 2,000-ton reduction is achieved by substituting natural gas for part of the waste gas, since natural gas has a lower carbon content. A third CO_2 credit, also about 2,000 tons per year, is achieved from the “free” LPG and petrol, by avoiding the emissions that would otherwise be associated with producing it. The net result is a 10,000-ton per year reduction, plus proportionate reductions of other combustion-related emissions (NO_x, VOC, and CO).

Conclusions

This project has demonstrated valuable lessons both specific to the refinery application as well as generic to all waste-heat-powered refrigeration applications. These include:

- new absorption cycles are capable of using much lower waste heat temperatures to reach lower refrigeration temperatures;
- new heat and mass exchangers are reducing size and costs, as well as increasing the performance of ARUs;
- refineries can benefit from creative applications of refrigeration (to improve profits, increase efficiency, and decrease emissions);
- with many waste-heat sources available, waste-heat-powered absorption is frequently the best way to produce refrigeration at an oil refinery;

▼ *Figure 3: Absorption refrigeration unit equipment skid.*

- an outside study team, assisted by a refinery engineer, can identify new efficiency measures for increased profits;
- an ARU can be directly integrated into refinery operations.

This project paves the way for further demonstration of this cost-effective energy conservation technology, both in other refinery or petrochemical applications, as well as in mainstream industrial refrigeration applications such as cold storage warehouses and frozen food processing.

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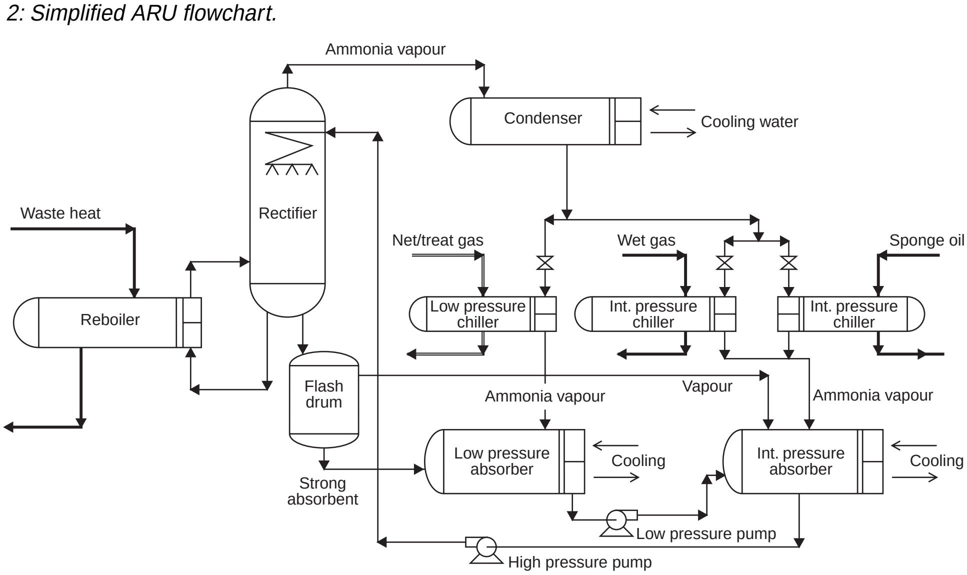


▼ *Figure 2: Simplified ARU flowchart.*

Heat transformers for industrial processes in Japan

Katsuyuki Mashimo, Masashi Izumi and Yonezo Ikumi, Japan

The absorption process is considered a promising method for recovering low-temperature thermal energy. Heat transformers can upgrade low-level waste heat so that hot water can be supplied at a higher temperature or steam can be obtained. Heat transformers with working fluids H_2O/LiBr have been used in Japanese industrial processes since 1981. This article describes a typical installation at a distillation plant. The available heat output of the heat transformer is around 50% of the waste heat input. Heat recovery systems using heat transformers contribute to CO_2 emission reduction.

Principle

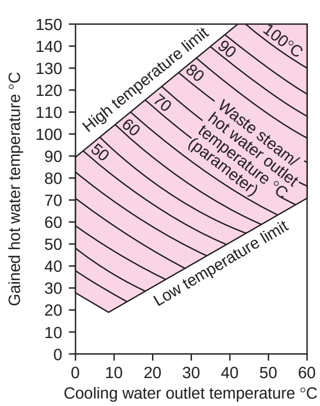
Using absorption processes in reversible absorption machines was originally proposed by Altenkirch before 1920. In a heat transformer (or type 2 absorption heat pump), the generator is heated at a medium temperature. Some of this heat is rejected to the environment, while the rest is transformed into high-temperature heat.

R&D on absorption heat transformers was conducted as part of the "Moonlight Project" (1976-81), sponsored by the Industrial Technology Institute at the Ministry of International Trade and Industry, Japan. H_2O/LiBr is generally used as the working pair because it is non-flammable, the working pressure is less than the atmospheric pressure and it has been widely used for conventional absorption chillers.

Heat transformers include an absorber, an evaporator, a generator, a condenser, a solution heat exchanger, a solution pump, a refrigerant pump and the piping to connect these. The operating cycle of the heat transformer starts with the supply of waste heat to the evaporator. The refrigerant (water) is heated by the waste heat until it evaporates. The refrigerant is then absorbed in the absorbent. This process generates heat that is used to heat water or to generate steam. The absorbent, which has been diluted by absorbing the refrigerant vapour, is then sent to the generator through the solution heat exchanger. In the generator, the diluted absorbent is heated by the same waste heat and the refrigerant is vaporised. The vaporised refrigerant is cooled by the cooling water and condensed, while the concentrated absorbent is returned to the absorber through the solution heat exchanger. The refrigerant is then returned to the evaporator.

The lower the water or steam temperature supplied by the heat transformer, the better these results will be. The system temperature difference is influenced by the temperatures of the hot water or steam, waste heat and cooling water, as well as by the heat transfer area and the flow rate of the absorbent in the heat transformer. Therefore, when considering whether to use a heat transformer, it is important to calculate the temperature and flow rates that correspond with the temperature conditions of the hot water, waste heat and cooling water. These are depicted in **Figure 1**.

▼ *Figure 1: Characteristics of temperature rise.*



▼ *Table 1: Operating conditions of heat transformers.*

Item		Data
Heat production	Output	2,670 kW
	Inlet temp.	106°C
	Outlet temp.	111°C
Waste vapour (alcohol vapour)	Input	5,570 kW
	Inlet temp.	78°C
	Outlet temp.	78°C
Cooling water	Output	2,900 kW
	Inlet temp.	23°C
	Outlet temp.	31.5°C
	COP	0.48
Dimensions	Length	8,000 mm
	Width	3,900 mm
	Height	6,000 mm
	Weight	68 ton

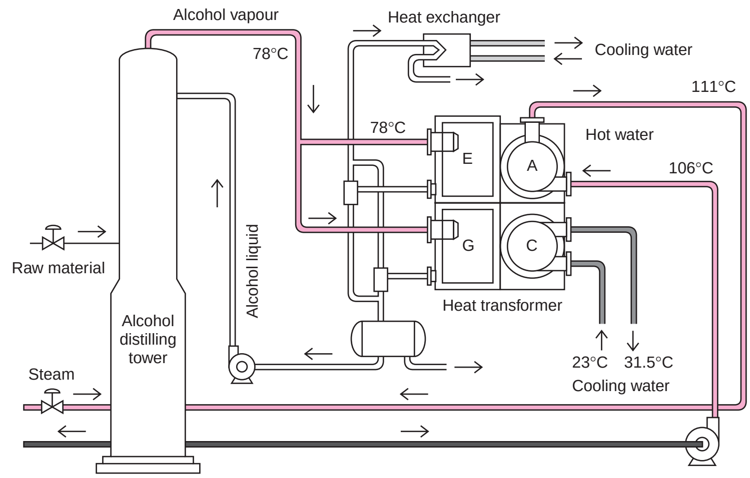
Operating experiences

Chemical plants are perhaps best suited to heat transformers for waste heat recovery. One such system was introduced for heat recovery from alcohol vapour discharged from an ethyl alcohol distillation plant, which has resulted in considerable energy savings.

The distillation tower is used to increase the concentration of alcohol. Steam for heating, needed to operate the tower, is supplied at the bottom of the tower, resulting in high-purity alcohol vapour being discharged from the top of the tower as a half-finished product. The operating conditions of the heat transformer are shown in **Table 1**.

In conventional systems, the vapour from the top of the distillation tower is usually liquefied in a special condenser, where latent heat is rejected to the cooling water. Alternatively, the released heat is used to heat the water for the boiler. By introducing the heat transformer about half the latent heat from top the vapour is recovered and the heat generated is used for reheating the distillation tower.

In this process integrated system, strong alcohol vapour from the distillation tower is fed in parallel into the generator and evaporator of the heat transformer, while heating water (to heat the bottom of the tower) is circulated directly into the absorber. Since the liquid is heated in the absorber and returned again to the bottom of the tower, boiler fuel can be saved. Ground water, which has a low temperature even in summer, is used as cooling water for the condenser (see **Figure 2)**.



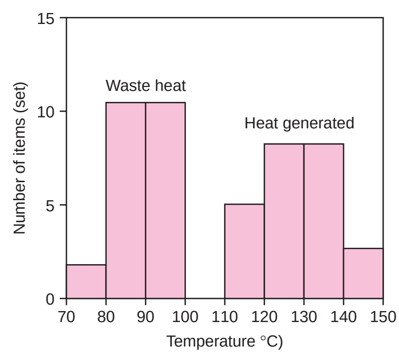
▲ *Figure 2: Heat recovery system for alcohol distillation plant using a heat transformer.*

Other installations

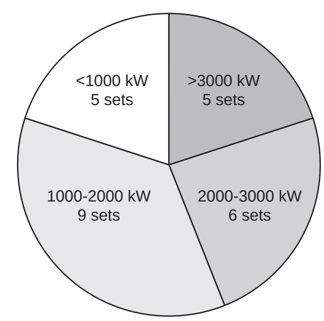
In total 25 heat transformers have been used for industrial waste heat recovery, including 17 in Japan and the rest exported. Three of these were installed after 1992.

Most units are used for heat recovery from distillation columns. In 16 cases the waste heat was recovered from column vapour, in five cases from hot water, with no data available for the rest. There are many examples of heat collection from output fluids such as low-temperature steam (15), hot water (5) and process fluids (1). It appears that collecting heat from vapour at the top of the distillation column is considered the best way of utilising this technology.

Figure 3 shows the temperature distributions of waste heat and heat generated which could be identified for the installed heat transformers. The percentages of 80-90°C and 90-100°C waste heat are largest. Generated heat is greatest at 120-140°C, but temperatures are evenly distributed between 110°C and 150°C. **Figure 4** shows the distribution of heat transformer output capacities. Although they range widely from 200 to 6,000 kW, most are 1,000-2,000 kW units.



▲ *Figure 3: Distribution of waste heat and generated heat temperatures.*



▲ *Figure 4: Distribution of heat transformer output capacities.*

Conclusion

Environmental protection, global warming, and CO_2 emission reduction have attracted great attention, and heat recovery systems are considered an important technology in reducing emissions. Heat recovery with heat transformers is gaining attention as a way of reducing the amount of fossil fuel used and effectively utilising unused energy. However, the number of units currently installed is limited.

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Vapour recompression: distillation without steam

Daniel Hänggi and Istvan Meszaros, Switzerland

Distillation is not only the most frequently employed separation technique in the chemical and petrochemical industry; distillation plants are also the largest consumers of energy in many installations. This huge energy consumption is unnecessary. Heat pumps can "recycle" a major part of the energy input and thus protect the environment and reduce energy costs.

Energy saving is one of the most important measures for controlling global environmental problems such as the greenhouse effect. However, energy saving is also financially attractive. Environmentally friendly technologies are also being supported through national or EU subsidies.

Using heat pumps provides one of the best opportunities for drastically reducing the energy consumption. In the industrial field, distillation is by far the most frequently used process for separating mixtures (**Figure 1**). An estimated 300 million litres of oil are used to generate heat for distillation, worldwide, every day. The energy-saving potential is correspondingly large.

▲ *Figure 1: A distillation plant with heat pump in Ulsan, South Korea, that separates 1-butene.*

Energy recovery

Figure 2 shows the advantages of a distillation plant with heat pump compared to a conventional unit. In the latter, energy is fed into the system via the re-boiler, to create the gas load needed in the column for the separation process. The vapours from the column are liquefied in the condenser. About 95% of the energy needed for the re-boiler leaves the system without being used any further.

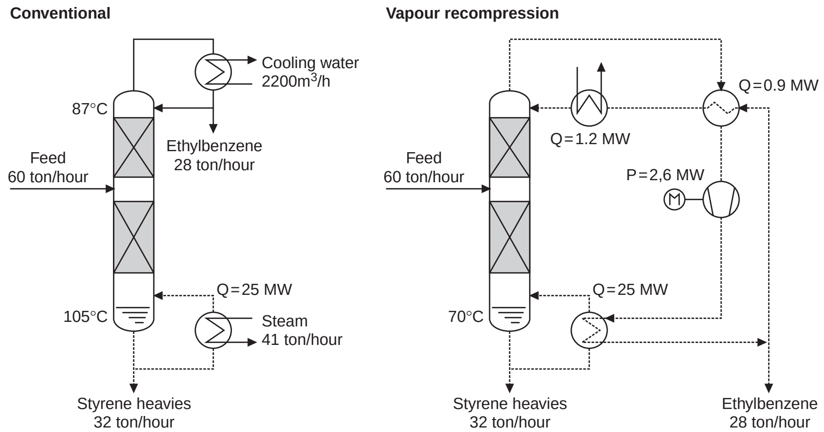
However, in a distillation plant with a heat pump, the re-boiler is linked to the condenser. The heat pump uses the existing energy in the column head, which is normally dissipated, and transfers it into the re-boiler, where the vapour is condensed. In comparison with conventional distillation units, this process requires only a fraction of the thermal energy for the distillation process and does not need any heating steam or large quantities of cooling water.

System types

Various heat pump types are available. Direct thermal vapour recompression (i.e. heat pumps with an auxiliary circuit and a steam ejector), are the most frequently used heat pump types in distillation plants. Direct vapour recompression saves the most energy, while the steam ejector entails the lowest investment costs.

With *direct vapour recompression*, the vapour from the column head is compressed to such an extent that the resultant temperature is sufficient to heat the re-boiler. If the top product is not suitable for compression, e.g. in a styrene-finishing column, *heat pump systems with an auxiliary circuit* are

▼ *Figure 2: Styrene/ethylbenzene distillation plant scheme. In comparison with a conventional system, in a plant with a heat pump, the larger part of the energy remains in the system.*



used. A condenser liquefies the head product and re-boils the auxiliary medium with the released energy. In the heat pump, this is compressed to the necessary pressure and then condensed in the re-boiler, whereby the bottom product is re-boiled. The *steam ejector*, driven by medium-pressure steam or product vapours, compresses a part of the head vapour from the column to the pressure necessary for heating the re-boiler. The vapour mixture is condensed in the re-boiler and the bottom product re-boiled using the released energy. An auxiliary condenser liquefies the residual vapour from the top of the column.

Compressor

The compressor forms the heart of the heat pump system. Depending on the separation task and the capacity of the plant, various compressors (such as turbo-blowers, radial turbo compressors, screw-type or axial compressors) can be used (see **Figure 3**). The column filling has a major influence on the selection of the compressor. Appropriate internal design, e.g. structured packings, random packings or, in some cases suitable trays, reduce the pressure drop in the column, allowing single- or two-stage radial compressors to be used.

Experience shows that compressors are very reliable and require minimum maintenance.

Styrene/ethylbenzene distillation

	Conventional system: costs in million USD/year	Vapour recompression: costs in million USD/year
Steam	4.10	-
Electricity	-	1.04
Cooling water	0.88	0.04
Total	4.98	1.08
Savings (million USD/year)	-	**3.90**

Assumed energy prices:

Steam:	USD 12.50/ton	Electricity:	USD 0.05/kWh
Cooling water:	USD 0.05/m³	Operating hours:	8,000 per year

Successful techniques

Heat pump technology has already been applied successfully in many distillation plants, but systems are continually being developed and improved. The important thing is that the individual components of the system are fine-tuned, since it is not the sum of the individual equipment designs, but their perfect interplay that determines the magnitude of the energy savings. Direct vapour recompression can reduce energy consumption up to 90%. In large plants this can mean financial savings amounting to several millions of USD per year. Investments in a heat pump system are paid back within a few years; in many cases within one year. In Switzerland these types of heat pumps are generally economical for plants with thermal energy requirements of more than 2 MW, with a temperature difference of up to 40ºC between top and bottom products.

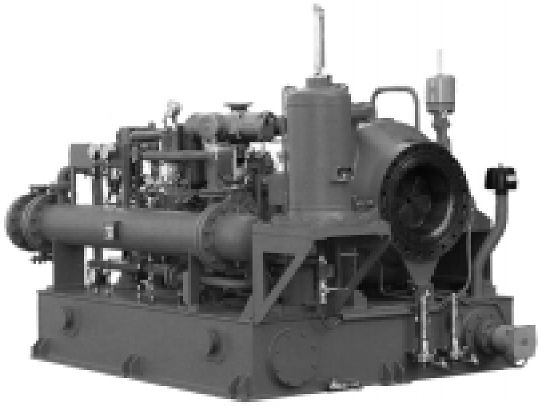
Heat pump systems can be used for both new installations and for retrofitting in existing plants. Typical applications include 1-butene, chlorobenzene, ethanol, propylene and several other substances. The case study of a styrene/ethylbenzene distillation (see box) indicates the cost savings that can be made with a vapour recompression system.

Solution

Heat pump technology can be an energy-saving solution for new and existing plants. There is no steam consumption, and little cooling water required. Using this technology also allows higher cooling water temperatures. The move towards CO_2 taxes and environmental management systems, e.g. ISO14000, plus increasing availability of national or EU subsidies are also factors that can accelerate the implementation of industrial heat pumps.

Please note that, on request, this article is also available in German, French, Spanish and Chinese.

▼ *Figure 3: A single-stage radial turbo compressor suitable for 1-butane and isobutane.*



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Watery silt stream effluent treatment using mechanical vapour recompression

Onno Kleefkens and Frank Das, the Netherlands

Industrial heat pumps are mainly used to save on energy costs by upgrading thermal energy from recovered process heat. In the Netherlands their use in industrial processes is rather limited, due to the relatively high capital costs and rather small cost savings. However, there are other important reasons for installing mechanical vapour recompression (MVR) systems. Environmental legislation is increasing the need to integrate industrial process cycles to produce less waste heat or waste products. However where waste effluents are produced, heat pumps can be used to effectively reduce this stream before it is processed further. The Fapona plant handles industrial waste materials whereby an MVR system is used to efficiently remove water from the effluent. This type of system has great potential in the textile and food industry.

Fapona Milieu Service bv, based in Apeldoorn, specialises in recycling industrial cleaning cloths, e.g. from garages, metal and printing industries, etc. Recycling these reusable cleaning cloths prevents a certain amount of chemical waste material such as paper and contaminants. The recycling process generates a considerable effluent stream containing several pollutants with a high water content. After pre-filtration this must be treated at the local sewage treatment plant, at considerable cost.

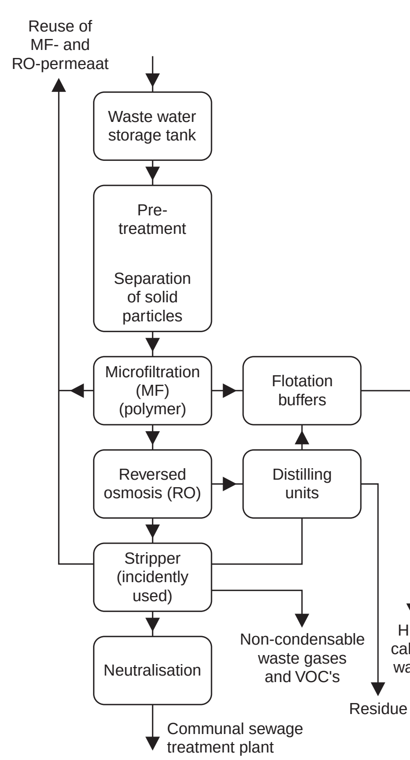
Original process

The cloths are cleaned via a wet washing process. The effluent has an average temperature of 30-60°C and contains mineral oils, hydrocarbons, (heavy) metals, chemical compounds, etc. An on-site effluent treatment plant (see **Figure 1a**) cleans the effluent through sifting, settling, microfiltration, reverse osmosis, separating volatile and non-condensable gases (stripping), concentration (evaporation) and neutralisation. The remaining solid particles from the flotation buffers are sold as waste with a high caloric value. Distilling units, as used in the chemical textile treatment industry, evaporate the water from the concentrate, which comes from the microfiltration and reverse-osmosis units. The final effluent meets the necessary quality standards and can be released to the local sewage system.

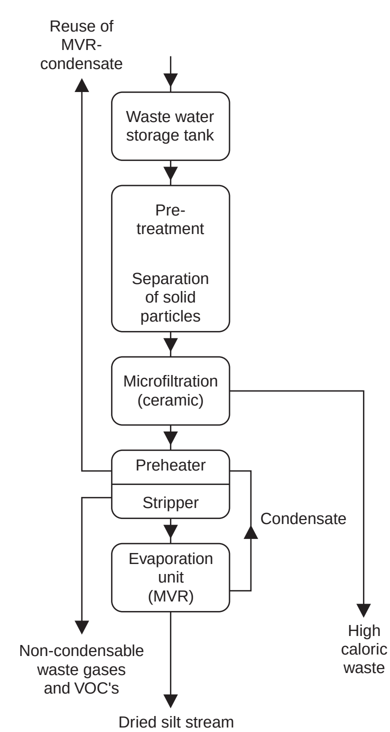
However it is the energy use of the complete process that should be considered. Although processes in filtration units are very energy efficient, the after-treatment consists of steam to evaporate the water from the concentrates in the distilling units.

The throughput of 3,000 tonnes of cleaning cloths means using at least 13,000 tonnes of steam. As the membranes in the filtration units are sensitive to clogging and have a short life cycle, the distilling units have high operational costs due to high evaporation temperatures (high energy use) and the inevitable scaling due to the high temperatures. The relatively

▼ *Figure 1a: Old effluent treatment process.*



▼ *Figure 1b: New effluent treatment process.*



high water content of the effluent still caused increased treatment costs at the Apeldoorn sewage plant.

New situation

The company has now expanded production capacity by installing a secondary washing process. One line will wash cleaning cloths from the printing industry and the other will wash cloths from garages and the (metal) surface treatment industry. However, a solution was needed for the increased costs of the effluent treatment process. The capacity of the effluent treatment unit needed increasing so that it could treat the effluent from both lines. The pre-treatment, (e.g. sifting and settling), remains unchanged, but ceramic microfiltration and MVR have replaced the existing microfiltration and distilling units (see **Figure 1b**).

The pre-filtered effluent is heated in a heat exchanger and induced in a counterflow gas stripper, where non-condensable gases and volatile components are removed. From the stripper the effluent is led to the vacuum evaporation unit and sprayed on the heat exchanger of the evaporator.
The heat exchanger surface is made of synthetic plastic material. The contact surface is thin and large, thus minimising the temperature difference between both media and the energy used by the compressor. The effluent is sprayed in such a way that a thin film of liquid forms on the plastic surface, which gradually drips down along the surface and evaporates. A compressor removes the vapour from the evaporator and superheats it a few degrees to let it condense on the other side of the plastic surface, thus passing on the heat to the evaporative side. The condensate is led to the preheater before the gas stripper, which preheats the effluent to be reused in the washing process. This important water loop in the washing process is practically closed, making a 90% water reduction possible! Because the working temperature in the MVR is approximately 55°C, lime scaling is minimal. The capacity of the evaporator is approximately 8.3 m^3 flowing in per hour. The effluent concentration factor is approximately 20.

Applications

This technology can be used to concentrate all sorts of effluent and wastewater streams, although each application should be considered carefully to see what available technique can be used. In this case a number of energy consuming steps, such as distillation, were used to concentrate the effluent.

MVR can be used in various industries in the Netherlands, starting at 8,000-10,000 tonnes of effluent per year, due to the economics of the Dutch circumstances. Important additional advantages include reduced disposal and transportation costs of effluents, either through local handling and/or avoided waste disposal levies.

A study by TNO and Novem showed that if MVR was used in the waste processing chain for organic waste from food, pulp and paper, and agriculture, the waste could be dried to a level where it could be used as an energy source. MVR in the evaporation stage of this process chain is crucial in achieving a positive energy balance.

Expected savings

Reusing hot water saves energy for heating the washing process, while replacing the distilling units eliminates the need for steam to drive the evaporation process. In total thermal energy from the steam boiler is reduced, but electricity use is increased. Based on a capacity of 3,000 tonnes per year total savings amount to approximately 1,160,000 m^3 natural gas equivalents, with net electrical savings amounting to 175,000 kWh and 1,300 tonnes of steam at 85 m^3/tonne.

With the increased surface area of the evaporator it was possible to obtain a coefficient of performance (COP) of 40 for the MVR system. Higher investment in these heat exchangers means immediate paybacks and increased cost savings. Due to the Dutch electricity tariff system it is very important to optimise the design of the installation. With MVR this is possible for most installations.

Using MVR techniques enables the main (washing) process to be extended. The evaporation unit replaces the distilling and reverse-osmosis units. The project has enabled the maintenance, water, energy and chemicals used for cleaning to be reduced, thereby reducing total running costs.

Total project costs amount to approximately USD 1,535,000. Energy savings amount to USD 236,000 per year at an electricity price of USD 0.08 per kWh and a steam price of USD 17 per ton. Additional annual maintenance savings amount to USD 185,000 plus another USD 400,000 on water savings and reduced sewage treatment costs. The payback period for this project is approximately 1.9 years, provided that a production level of 3,000 tonnes of cleaning cloths is reached.

Government support

This project was sponsored by a 40% grant on the investment costs from the TIEB programme (Tender for Industrial Energy Saving, now replaced by the Tendem programme). Replication of this type of project in the textile industry has already begun.

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(see back cover)

Heat pumps dry food products in Norway

Odilio Alves-Filho and Trude Tokle, Norway

Arctic Aroma AS in Norway has installed a heat pump system used for drying various fruit and vegetable products in a fluidised bed. The system was designed and built by Kværner Eureka, in close cooperation with the Norwegian University of Science and Technology (NTNU) and SINTEF Energy Research.

Quality and savings

The heat pump dryer is flexible and combines drying above and below the freezing point of the product, to produce material of a high quality with improved physical, nutritional and chemical properties. The product is first frozen and then dried, maintaining both taste and aroma. Shrinkage is minimised compared to simple drying, so the product maintains its original size and shape throughout the drying process. The heat pumps can easily be adjusted to preset conditions, which take the freezing point of the product into account. This allows handling of sticky and delicate products.

The drying air is recirculated in the heat pump dryer, and the heat pump recovers heat from the drying process. The energy savings typically range from 50-80%, compared with traditional drying methods. There are also environmental benefits, as the process does not exhaust polluted air.

This application is one of several spin-offs of heat pump drying technology developed at NTNU/SINTEF. Arctic Aroma was established in 1994, and specialises in drying fruit and vegetables to be used in soups and cereals. The products are dried in cubes and other shapes, packed and sold in large quantities. Apples, strawberries, carrots and leeks have been dried successfully, and the company is also looking at drying other fruits and vegetables. Tests are also being carried out on meat and fish products in smaller capacity pilot plants.

The heat pump dryer was installed in 1996, and the first products to be dried were apple cubes. However, the drying unit soon experienced operational problems. Due to the high sugar content, the apple cubes became sticky and difficult to transport. Some conveyor belts were therefore replaced by air-based transport. But the moisture absorbed from the apples into the drying air was below expectations, and capacity had to be increased by increasing the airflow. After a period of extensive product development and modifications, the unit is now operating successfully.

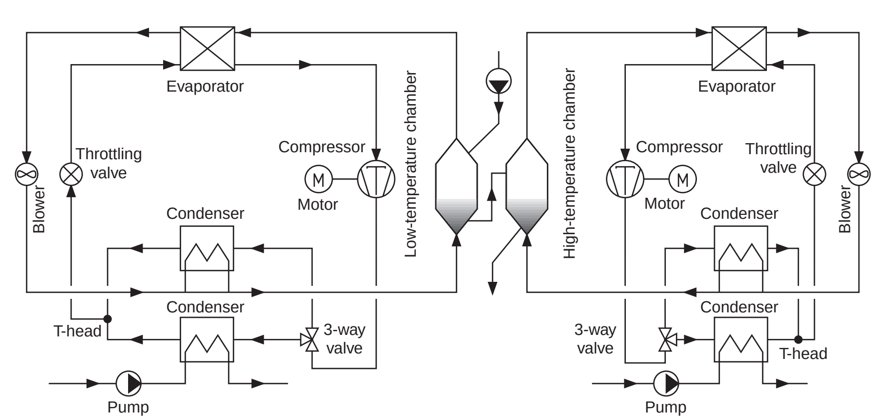
The heat pump system

The heat pump dryer contains a double fluidised bed, and has two closed loops (for air and refrigerant) in which energy can be recovered (see **Figure 1).** The two fluidised beds are connected in series on the product side, while the two heat pumps are connected in parallel, providing conditioned air to their respective drying chambers.

The first chamber receives the wet product and drying air at an appropriate velocity to fluidise the product. In order to avoid melting and unstable fluidisation, the drying conditions are controlled by adjusting the capacity of the heat pump components. The air temperature is kept below the product's freezing point. The product stays in the first drying chamber until it attains the critical moisture level, after which the air temperature can be increased without disturbing fluidisation. Other product qualities are also considered. Apples must remain in the first dryer long enough to avoid discolouration of the product when entering the second drying chamber. The semidried product is then transferred to the second drying chamber, where it is fluidised by higher temperature airflow. The air velocity is adjusted to attain good fluidisation and until the drying process is completed.

The advantage of having two chambers is that the low-temperature stage operates at temperatures under the product freezing point, reducing product moisture while providing excellent quality. The high-temperature stage increases the overall heat pump

▼ *Figure 1: Diagram of the heat pump drying system.*



dryer capacity. Drying conditions can be regulated over a wide temperature range, from -20°C up to 80°C. Due to high energy costs when operating in the lowest temperature range, the heat pump dryer is usually operated above -10°C.

The dryer consists of two heat pumps with identical components: evaporator, internal condenser, external condenser, three-way valve, throttling valve, reciprocating compressor, motor, super-heater, sub-cooler, piping and fittings. However, the components are set up for different operating conditions.

The refrigerant evaporates by absorbing latent heat available in moist air leaving the drying chamber. The condensed liquid from the drying product is removed from the drying circuit. The cold saturated air moves through the condenser and recovers heat, before being fed through a blower to reach the preset drying temperature. The air re-enters the chamber and the drying process is repeated. The external condensers are fresh-water cooled in order to provide nearly constant inlet/outlet conditions. The heated water can also be used for several purposes in the food processing plant.

The refrigerant used is ammonia, which is often preferred in larger heat pumps in Norway, due to its favourable thermodynamic characteristics. The fluid is also environmentally friendly with both zero ozone depletion and zero global warming effect.

▼ *The heat pump drying unit.*

Simulation model

The R&D work at NTNU/SINTEF involved developing a component model to simulate a multiple fluidised bed heat pump, with two independent drying loops and two refrigerant circuits. The component model is an essential tool in simulating industrial dryer performance and changes in the product characteristics in accordance with modified inlet/outlet temperatures of heat pump drying and modified components or boundary conditions. Input data include the chambers' geometrical data and product properties, such as moisture content, size, drying curve and isotherm constants. The heat pump and mass balance equations are converted to mathematical equations to be solved for each heat pump component. The model predicts the effects of drying conditions on moisture, coefficient of performance (COP), specific moisture extraction ratio (SMER), drying rate, and water mass flux versus time or moisture content, for both drying chambers.

The simulations indicate that the drying rate and water mass flux are constant while the drying product is in the low-temperature drying chamber, but there is a sharp increase in both variables when the drying product is transferred to the high-temperature drying chamber. When the product has reached its critical moisture level, both the drying rate and water mass flux rate drop quickly towards their respective equilibrium moisture contents. The results show that the critical drying time not only depends on the temperature and air humidity, but that it also increases according to the initial moisture content.

The simulation performed for this particular plant was carried out using apples, but other food products can be simulated as long as there are reliable drying characteristics that are obtained under specific conditions in the heat pump dryer. The results from the model were stable and predicted values that converged adequately to observed values in the industrial dryer. The model is used to assist in heat pump dryer plant design and is a useful tool for studying the effect of drying conditions on the product.

Conclusions

Heat pumps can be used for food processing for various purposes, such as drying and other water removal methods. Heat pumps have advantages over conventional drying techniques in many aspects, giving considerable energy savings and environmental benefits through reduced air pollution, due to control and reuse of the drying air from the process. But the main reason for using heat pumps and low-temperature drying is the improved quality of the dried product.

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Report on the 20th International Congress of Refrigeration

Jos Bouma, IEA Heat Pump Centre

The Australians and New Zealanders joined forces to arrange the 20th IIR Congress in Sydney, Australia. The result was a successful event with many participants from over 40 countries. Around 545 papers were presented, covering all areas within the scope of the IIR.

Around 40 papers relating to heat pumps were presented at the conference. These covered topics ranging from modelling studies and pilot installations based on transcritical cycles with CO_2, to circulated composition measurement and capacity control of refrigerant mixtures. Other topics included energy efficiency of ab/adsorption systems, high-temperature hybrid systems, drying applications, advanced thermal storage technology, natural working fluids and domestic gas-engine-driven heat pumps. CO_2 technology for heat pumps was well covered by at least seven papers and a workshop.

CO_2

A US paper presented the results of a project to build and test a prototype of an air conditioning/heat pump system that operates on a transcritical cycle using CO_2 (R-744). The system utilises aluminium microchannel heat exchangers with folded louvered fins and an open reciprocating compressor. The compressor used was designed for automotive systems because no hermetic compressors were available at the time of the experiments. The prototype components for the CO_2 system were designed to approximately match the external dimensions of a conventional R-410A system. The CO_2 system operates with the same or slightly higher COP at lower ambient temperatures (26/27°C) and a slightly lower COP at higher ambient temperatures (26/35°C indoor/outdoor) for tests performed at equal capacity and compared to a baseline R-410A system with hermetic scroll compressor.

Applications

A Norwegian paper considered different application areas including air (space) heating, dehumidification and water heating. Tests on a heat pump water heater in Oslo showed that a seasonal performance factor (SPF) of 4 can be achieved at water heating temperatures from 8-60°C and with ambient air as the heat source (at an evaporation temperature of 0°C). Under these conditions, 75% energy can be saved compared to direct electric heating. The system can produce water temperatures of 90°C at a reasonable efficiency (COP around 3, at 0°C and -10°C evaporation temperature). For countries with a large proportion of hydropower, this type of water heating is a promising alternative. Investigations into a monovalent ground-coupled air-heating system for a house in Graz, Austria, showed COPs ranging from 3 to 5 between -20°C and 12°C and at a constant compressor discharge pressure of 70 bar. If extrapolated to the overall system and an entire heating season, the system SPF would be 6.2 and 4.2 respectively just for the heat pump.

Compressors

Another Norwegian paper presented the results of semi-hermetic compressor development. A pre-series of CO_2 compressors has been developed for 1.7-10.7 m^3/hour swept volume. These comprise single- and two-stage compressors with two cylinders. The corresponding cooling capacities are 3-25 kW at –10°C evaporation temperature. Isentropic and volumetric efficiencies of 0.69 and 0.77 respectively were achieved at a pressure ratio of 2.6 (for water heating). Although valve losses are at an acceptable level, there is considerable room for improvement.

Heat pump water heaters using CO_2 typically reject heat with a temperature glide in the gas cooler. A new type of hot water storage system has been developed to make optimum use of this glide phenomenon. This paper from Germany discussed an optimised integrated gas cooler design for such a heat pump and presented measurement results of the stratified water storage system. Although quantitative data were not given, it was concluded that a low gas-cooler outlet temperature could be maintained during the entire tank charging process. Measurements will be taken to investigate the overall system efficiency.

Another German paper demonstrated the use of CO_2 in a transcritical cycle for a dryer application. The design and construction of the laboratory-type laundry heat pump dryer were presented, as well as results of experimental study. It was concluded that the energy-saving potential of this type of dryer could be as high as 60% compared to conventional laundry dryer systems.

Safety aspects

The safety aspects of a residential CO_2 air conditioning ductless split unit were analysed and compared with R-22 during a third Norwegian paper. It was concluded that, although the system

New presidents and vice-presidents were appointed at the IIR Congress, as well as a new director of the IIR, i.e.:

Prof. Eric Granryd - President of the general conference (1999-2003)
Prof. Alberto Cavallini – President of the Scientific Council (1999-2003)
Prof. Henk van der Ree – President of the Executive and Management Committee (1999-2003)
Dr Francois Billard – Director of IIR

Mr Gerald Groff – Head of Section E
Prof. Peter Novak – President of Commission E1 (air conditioning)
Prof. Hermann Halozan – President of Commission E2 (heat pumps and heat recovery)

pressure in CO_2 circuits is much higher, the explosion energies (released via refrigerant expansion in a system or component) of the two units are the same at around 60°C. At higher temperatures, the explosion energy of R-22 systems becomes higher than CO_2 systems, while the reverse happens at lower temperatures. This is because the internal refrigerant volume and charge is much smaller for CO_2 .

Simulation model

A US paper presented the results of a computer simulation model of a complete CO_2 cycle for military space conditioning, heat transfer of super-critical CO_2 in a horizontal tube and testing of a hermetic compressor modified from R-22. The US Army intends to exploit current CO_2 research and produce a unitary 11 kW heat pump prototype within three years.

Zeotropic refrigerants

Two papers from Sweden looked into the problem of measuring the zeotropic refrigerant mixture composition in refrigeration and heat pump systems. The circulated composition may change from the nominal to a different value, which can be caused by leakage or blockages in the liquid or vapour phase, solubility in oil, or incorrect system charging. The method developed enables fairly accurate in-situ composition measurement and shows that, by measuring only two system temperatures and pressures and using an equation valid for R-407C, it is possible to estimate the composition of the circulated refrigerant mixtures. It was claimed that a change in composition, of only 1-2% in the mass percentage of R-134a, can be detected.

The second Swedish paper discussed a computer model used to estimate possible deviations in circulating composition. Important indicators of potential composition shifts include heat transfer flux in the evaporator and condenser, the amount of superheat and subcooling, and compressor efficiency. These indicators can be identified by measuring representative parameters during operation.

Storage

An Australian paper gave the results of an analysis into the use of phase-change storage systems for enhanced heat pump performance. The performance of ground-coupled heat pump systems could be improved under a range of climatic conditions with various heating and cooling loads. The idea is to provide additional thermal storage; possible on either side of the heat pump system. Paraffin waxes are commercially available with phase-change temperatures appropriate for both cold- and hot-side thermal storage. Based on simulation studies for the Australian continent (temperate, tropical and arid climates) the study concluded that it is possible to redesign conventional ground-coupled heat pumps to reduce the size and cost of the ground coil. Use of full thermal storage was found not to be a viable option and preference should be given to partial thermal storage in optimising designs.

Adsorption

The present (and future of) adsorption heat pump technology was discussed in a French paper. An area of potential interest for adsorption technology is air conditioning, especially when waste heat is available. However, a good compromise between heat recovery efficiency and energy efficiency (COP) is required. Here adsorption meets strong competition from absorption technology. Automotive air conditioning is one area where adsorption defeats absorption technology. Another potential area is space heating and cooling, where reversible heat pumps are mainly used at present. Absorption heat pump technology (water/lithium bromide) cannot compete here with adsorption. Finally, adsorption technology could also be used in refrigeration and freezing.

21st IIR Congress

The 21st IIR Congress will be held on 17-22 February 2003 in Washington DC, USA.

Jos Bouma
IEA Heat Pump Centre (see back cover)
Member of Commission E2

Workshop: Natural working fluids – a challenge for the future

The workshop articipants agreed that successful introduction of alternative refrigerants in small heat pumps and air conditioners is not possible without adequate installer training programmes. Political focus on natural refrigerants is higher in northern Europe than elsewhere in the region. A brief summary of the workshop presentations is given below. Proceedings will be available from the IEA Heat Pump Centre.

Background

Hydrofluorocarbons (HFCs), hydrocarbons (HCs), ammonia, CO_2, water and air are refrigerants with zero ozone depleting potential, which can be used as long-term solutions for air conditioning and heat pump applications. The Kyoto Protocol demands the reduction of global warming substances, which include HFCs. Alternative technologies (sorption, evaporative cooling etc.) that do not have an impact on global warming will likely be used in niche markets.

EU phase-out policy

The phase-out schedule for HCFCs will be put to a second vote on 2 December 1999. An accelerated ban on HCFCs for maintaining existing installations may result (2007 instead of 2010). A future phase-out of HFCs throughout the EU is highly improbable. Denmark is considering to phase-out HFCs in 2004-2006.

Standards

The European refrigeration safety standard EN378 was approved for publication in October 1999 and includes requirements for the safe use of ammonia and HCs in refrigeration and heat pump applications.
A joint working group from IEC SC 61D and ISO TC86 SC1 is working on international requirements. A draft should be available from April 2000.

Liability

For a homeowner, there is negligible risk in using an ammonia or propane state-of-the-art heat pump with less than 1 kg refrigerant. This is one of the conclusions of a Swiss study. In Swiss law, equipment manufacturers are only liable for accidents if their product is defective and if this defect causes an accident. The use of HCs is not considered defective. Similar conditions apply in some other European countries.

Installers

According to AREA, the European installers' association, their members install what the customer specifies. Ammonia and HCs require safety measures, but implementation poses no structural problems. Labelling of equipment is essential.

Manufacturers experience

NIBE is successful with its residential exhaust-air heat pumps, containing < 500 g HCs. Around 20,000 units are installed in Sweden. An important hurdle for exporting is the lack of established regulations. Stiebel Eltron showed what measures were being taken to develop successful heat pumps with HCs. Both manufacturers noted that the support of compressor manufacturers is a problem with HC refrigerants. York Refrigeration presented safety measures for ammonia chillers, and gave their views on natural working fluids.

CO_2 risk analysis

Research shows that the explosion energies of CO_2 and R-22 are comparable for small split air-conditioning systems of equal capacities, even though the pressure in CO_2 systems is much higher.

Gerdi Breembroek
IEA Heat Pump Centre

Ammonia as a refrigerant (1999 edition)
Available from: IIR, 177 Boulevard Malesherbes, 75017 Paris, France. Fax: +33-1-47631798. E-mail: iifiir@ibm.net
120 pages, published 1999. Price: USD 24, excl. postage.
This new edition contains tables of thermodynamic properties and behaviour, exposure to ammonia, plant design, standards and safety precautions and perspectives, as well as comparisons with HFCs, diagrams, references and an index.

An introduction to absorption cooling (Good Practice Guide 256)
Available from: Energy Efficiency Enquiries Bureau, ETSU, Harwell, Didcot, Oxfordshire, OX11 0RA, United Kingdom.
Fax: +44-1235-433066. E-mail: etsuenq@aeat.co.uk
Published May 1999, GBP 3 per copy, excl. postage.
This guide is prepared to help decision makers identify whether this is a suitable technology, which may save money and reduce environmental impact of cooling plants. Topics covered include the essentials of absorption cooling, combinations with combined heat and power plants, other applications of absorption and technology and adsorption cooling, maintenance and reliability, financial aspects and design and installation.

Water purification heat pumps
Available from: E&FN SPON, 11 New Fetter Lane, London, EC4P 4EE, UK, or 29 West 35th Street, New York NY10001, USA
Price: USD 55. ISBN: 0-419-24710-6.
This book charts the development of heat pump technology from the theoretical principles to the operation of practical systems for purifying water, both for human consumption and for a wide variety of industrial processes.

Energy efficiency of room air conditioners
Available from: Mr Adnot, Centre d'Energetique, Ecoles des Mines de Paris. Fax: +33-1-46342491. E-mail: adnot@cenergy.ensmp.fr
This report is compiled by representatives of 14 European energy agencies, consultancies, manufacturers and utilities. It covers the growing AC demand in Europe, discusses RAC types, the current energy efficiency and policies and technical means that could increase efficiency.

INTERNET SITE

For a list of all publications and events, visit the HPC Internet Site at

http://www.heatpumpcentre.org

Available from the HPC

PLEASE USE THE ATTACHED RESPONSE CARD WHEN ORDERING HPC PRODUCTS

International Heat Pump Status and Policy Review: 1993-1996
Analysis Study, August 1999
Order No. HPC-AR-7, NLG 480 or NLG 160 in HPC member countries

Guidelines for Design and Operation of Compression Heat Pump, Air Conditioning and Refrigerating Systems with Natural Working Fluids
Final Report, December 1998
Order No. HPP-AN22-4, NLG 100 in Ca, Ch, Dk, Jp, Nl, No, Uk and US.
(Not available for other countries until 5 June 2001)

Environmental Benefits of Heat Pumping Technologies
Analysis Study, April 1999
Order No. HPC-AR-6, NLG 240 or NLG 80 in HPC member countries.

Ab-Sorption Machines for Heating and Cooling in Future Energy Systems Workshop Proceedings, April 1999
Order No. HPP-AN24-2, NLG 180 or NLG 60 in HPC member countries.

The Role of Heat Pumps in a Deregulated Energy Market
Analysis Study, October 1998
Order No. HPC-AR-5, NLG 240 or NLG 80 in HPC member countries.

Heat Pump Systems for Single-Room Applications
Final report, January 1999
Order No. HPP-AN23-2
Price NLG 300, or NLG 100 for HPC member countries and Ca, Fr and Se.

For further publications and events, visit the HPC Internet site at http://www.heatpumpcentre.org

Technological Solutions to the Environmental and Ground Water Emergency: Ground Water Heat Pumps for Large Building Conditioning
2 February 2000 / Milan, Italy
Contact: M. de Renzo, FIRE, Milan.
Tel: +39-2-4812959
Fax: +39-2-4818964

ASHRAE Winter Meeting
5-9 February 2000 / Dallas, USA
Contact: ASHRAE Meetings Section, 1791 Tullie Circle NE,
Atlanta, GA 30329, USA
Fax: +1-404-3215478
E-mail: jyoung@ashrae.org

Air Conditioning, Refrigeration and Building Services Exhibition
30 March - 1 April 2000
Contact: ARBS Secretariat, 52 Rosselyn Street, West Melbourne, VIC 3003, Australia
Fax: +61-3-93284116
E-mail: slteh@airah.org.au

ASHRAE Annual Meeting
24-28 June 2000 / Minneapolis, USA
Contact: ASHRAE Meetings Section, 1791 Tullie Circle NE,
Atlanta, GA 30329, USA
Fax: +1-404-3215478
E-mail: jyoung@ashrae.org

4th IIR-Gustav Lorentzen Conference on Natural Working Fluids
and
2000 International Refrigeration Conference
and
International Compressor Engineering Conference
25-28 July 2000 / West Lafayette, USA
Contact: Cynthia Quillen, Purdue University, 1077 Ray W. Herrick Laboratories,
West Lafayette, IN 47907-1077, USA
Fax: +1-765-4940787
E-mail: herlconf@ecn.purdue.edu

4th International Conference on Heat Pumps in Cold Climates
14-15 August 2000 / Ottawa, Ontario, Canada
Contact: The Organzing Committee
c/o Caneta Research Inc.
7145 West Credit Avenue
Suite 102, Building 2
Mississauga, Ontario, Canada, L5N 6J7
Tel: +1-905-5422890
Fax: +1-905-5423260
E-mail: caneta@compuserve.com

Heat pipes, heat pumps and refrigerators
September 2000 / Minsk, Belarus
Contact: CIS Countries Association Heat Pipes
Luikov Heat and Mass Transfer Institute,
220072, P. Brovka 15, ITMO, Minsk, Belarus
Fax: +375-172322513
E-mail: allusr@avtlab.itmo.by

International Sorption Conference 2002
23-27 September 2002 / Shanghai, China
Contact: Dr Wang Wen, Institute of Refrigeration & Cryogenics,
Shanghai Jiao Tong University,
1954 Huashan Road,
Shanghai 200030, China
Fax: +86-21-62933250
E-mail: ISHPC@sjtu.edu.cn

ACHRB 2000 - Air conditioning in high-rise buildings
October 2000 / Shanghai, China
Contact: IIR, 177 Boulevard Malesherbes,
75017 Paris, France
Fax: +33-1-47631798
E-mail: iifiir@ibm.net

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International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among its participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

IEA Heat Pump Programme

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

IEA Heat Pump Centre

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

The IEA Heat Pump Centre is operated by

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Netherlands agency for energy and the environment

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