IEA Heat Pump CENTRE
NEWSLETTER
VOLUME 18
NO. 1/2000

Commercial and Industrial Refrigeration

In this issue:

Low-charge refrigeration for supermarkets

Secondary refrigeration in a UK supermarket

Cooling to -100°C with cascade system using natural refrigerants

IEA
OECD
heat pump
centre

In this issue

Commercial and industrial refrigeration

Commercial and industrial refrigeration comprises various sectors and applications, from supermarket refrigeration to ice rinks and from industrial freezing to biomedical applications. This IEA Heat Pump Centre Newsletter focuses on energy efficiency and global warming impact of commercial and industrial refrigeration applications, with the emphasis on supermarket refrigeration. Energy saving via heat recovery and secondary systems is also included.

Front cover:
Sainsbury's Millennium Store, Greenwich, UK

TOPICAL ARTICLES

HEAT PUMP NEWS

FEATURES

COLOPHON

Publisher:
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Production: Novem Support Group

Frequency: quarterly
Printed March 2000

HPC Newletter subscriptions are automatically renewed unless written cancellation is received by 1 October

ISSN 0724-7028

NON-TOPICAL ARTICLES

Sustainable refrigeration and heat pumps

Some of our readers will have knit their brows when they read the title of the first Heat Pump Newsletter in the year 2000, Commercial and Industrial Refrigeration. Has the IEA Heat Pump Centre merged with the International Institute of Refrigeration (IIR), following a trend in international business? Have heat pumps finally lost the battle with other renewable heating technologies?

The answers clearly are no. Heat pumps are on the move and will find their rightful place in Europe, Asia, North America and other regions of the world. The Heat Pump Centre continues as always: ready to take on the new challenges that lie ahead of us, with the ultimate goal of achieving broad acceptance of heat pumps as a reliable and sustainable heating and cooling technology.

There is no merger with the IIR, and our fruitful collaboration will be enhanced further. Why then this topic? Simply because a lot of energy is used in refrigerating food, products and industrial processes, and refrigeration technology is closely linked to heat pumps. Heat rejected from refrigeration can be directly used for space and water heating, or by using heat pump technology. Analysis shows that considerable energy efficiency improvements can be achieved in refrigeration and the safe use of alternative working fluids, e.g. in supermarkets, requires new and sustainable solutions.

Regular readers of the Newsletter may have noticed that refrigeration has never before been selected as a theme. But this seemed to be the right time, and it emphasizes the growing visibility of sustainable refrigeration within the IEA Heat Pump Programme.

The 21st century should see the widespread breakthrough of most sustainable energy technologies. Energy supply systems will change drastically with a central role being played by renewable energy. Scenarios by authoritative bodies indicate that this may happen around the middle of the century. Renewable energy will probably not take over entirely and some fossil fuels will still be needed. This means that the efficient and innovative use of energy in heating and cooling equipment remains a necessity. The future of heat pump technology looks bright. The major challenge is to make heat pumps 100% renewable, with electricity and gas from sustainable sources. The Heat Pump Centre Newsletter will keep you informed of this progress, with outstanding information on heat pumping technologies from our network and beyond.

Jos Bouma
Director IEA Heat Pump Centre

21-CR programme awards 13 projects

USA – The Air Conditioning and Refrigeration Technology Institute (ARTI) recently announced that the HVACR Research for the 21st Century Programme (21-CR) has selected contractors for 13 research projects valued at approximately USD 1.5 million.

21-CR is a long-term research programme bringing together representatives from industry, government and academia. This mixed company determines ways to improve equipment efficiency and indoor air quality associated with air conditioning and refrigeration equipment and services. The programme was introduced in the Heat Pump Newsletter 16/3.

The 13 projects in the Table are being initiated in five areas. Additional projects will be initiated over the next 5-7 years of the programme.

Further information: http://www.arti-21cr.org
Source: ARI News service

21-CR January 2000 – 13 projects in five focus areas

1. Alternative equipment (investigations of HVAC&R cycles other than today's fluorocarbon vapour compression cycles):
   - 1.1. Micro-channel heat exchangers with CO_2;
   - 1.2. Efficiency limits of H_2O vapour compressors suitable for air-conditioning applications.
2. High-efficiency equipment (improved heat exchangers, motor systems, compressors, controls and sensors, air handlers, testing, diagnostics, pumps and pump controls, etc.):
   - 2.1. High-temperature mould materials to die-cast copper motor rotors for improved motor efficiency;
   - 2.2. High-performance heat exchangers for AC&R applications - non-circular tubes;
   - 2.3. Evaluating the ability of unitary equipment to maintain adequate space humidity levels.
3. System integration (improved distribution systems, zone control, waste heat recovery, integration of envelope and lighting with mechanical systems, advanced controllers, communications, etc.):
   - 3.1. state-of-the-art review, whole building and building envelope simulation and design tools;
   - 3.2. state-of-the-art review, HVAC component and system simulation and design tools;
   - 3.3. energy-saving potential of flexible and adaptive HVAC distribution systems for office buildings.
4. Indoor environmental quality (enhanced control of temperature, moisture, indoor contaminants, ventilation, etc.):
   - 4.1. investigation of the causes of "black soot phenomena";
   - 4.2. health, energy and productivity in schools.
5. Environmentally friendly working fluids (refrigerants, lubricants, secondary heat transfer fluids, eutectics, process fluids, etc.):
   - 5.1. investigation of AC&R systems operated near and above the refrigerant-critical temperature;
   - 5.2. determination of refrigerant lower flammability limits in compliance with ASHRAE 34p;
   - 5.3. ARTI Refrigerant Database.

New German heat pump newsletter

Germany – The first issue of *Wärmepumpe aktuell*, the new German newsletter on heat pumping technologies was issued December 1999 by IZW eV, the German heat pump information centre. The group aims to stimulate research and development of heat pumping technologies, for energy efficiency and environmental protection. Their Internet site (http://www.izw-online.de) features information on their activities, *Wärmepumpe aktuell*, information on incentive programmes and an ordering service.

Source: IEA Heat Pump Centre

Industry supports the heat pump association (HPA)

UK – The Heat Pump Association (HPA), an active member of the Federation of Environmental Trade Associations (FETA), recently held a press conference to announce its new two-year Strategic Plan.

Two prominent members from the HPA endorsed the industry's responsibility to produce environmentally friendly energy-efficient products, such as heat pumps, in order to contribute in the reduction of CO_2 emissions.

Jos Bouma, Manager of the IEA Heat Pump Centre in the Netherlands delivered an interesting overview of the benefits of 'Heat Pumps for Buildings in Europe'. This presentation raised the audience's awareness of events and opportunities beyond – but not out of reach of – the UK market organisations and served as a useful catalyst to the questions and answers period. The UK is now a member of the Heat Pump Centre and a close collaboration is developing between HPC, HPA and the UK National Team.

Source: James Gilbert Burlison, President HPA

Japan's Top Runner Programme

Japan – The Top Runner programme is the striking name of Japan's new policy initiative to make Japanese domestic appliances the most energy efficient in the world.

A general outline of the programme was given on page 4 of HPC Newsletter Vol. 17, No. 3. MITI's (Ministry of Trade and Industry) new energy efficiency legislation for appliances defines certain minimum energy efficiency targets. These targets require the sales-weighted average brands of appliances sold on the Japanese market to be at least as efficient as the most efficient products available at the time of legislation. These targets are quasi-mandatory.

Average ownership of heat pump and air-conditioner units in Japan is 1.8 units per household. Ownership has increased almost linearly since the early 1970s and is growing at around 0.07 units per household per year. The popularity of these appliances and their potential for energy efficiency improvement are the reason that room heat pumps and air conditioners have been singled out as two of the key end-uses requiring regulation. Japanese products are already among the most efficient in the world. The new Top Runner Programme should ensure that the Japanese room unit market continues to be the global energy efficiency pace setter. The heat pump targets (63% COP improvement in 2004) are much stricter than the cooling-only targets (14% cooling COP improvement in 2007), because more units are sold (80% sales) and they have higher year-round energy consumption. The target for refrigerators and freezers is 22.5% improvement in annual electricity consumption in 2004. Here new energy-saving technologies, such as enhanced compressors and variable-speed drives, together with vacuum insulation panels, should bring about this improvement.

▼ *Figure 1: Top Runner (TR) energy efficiency targets for reversible room air conditioners (heat pumps) in 2004.*

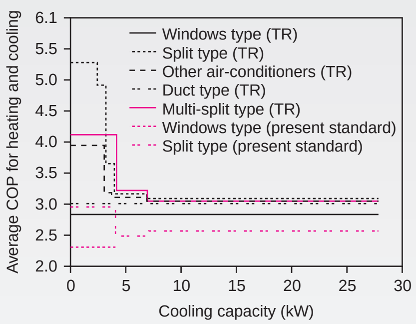

Figure 1 shows the targets for the different types of heat pumps. Apart from their challenging levels, the new targets are also notable in setting appreciably tougher efficiency thresholds for lower capacities than for higher capacities. These capacity-differentiated targets have been chosen, not because smaller-capacity units are more efficient, but because smaller units dominate the Japanese market and, in some cases, have already attained the minimum thresholds.

Japan is looking to develop its domestic policies to meet the environmental and economic challenges of this new century. The Top Runner programme can potentially provide a stimulus to both.

Source: Appliance Efficiency, issue 3/volume 3/99

GHPC earns commitments in USA

USA – The United States Postal Service builds 400-500 new facilities each year, all of which will consider using ground-source heat pump systems for their heating and cooling needs. This is just one example of the momentum that can build from a memorandum of understanding (MOU).

The Geothermal Heat Pump Consortium (GHPC) works to develop MOUs with a number of local, state and federal agencies as well as school governors and commercial companies. As of October 1999, 17 MOUs had been signed by three companies, six school authorities and eight local, state and federal agencies. By signing the MOU, the partner agrees to evaluate the feasibility of a ground- or water-source heat pump system and install the system at its facilities. In return, the GHPC provides training and design assistance.

Since 1997 10 Maryland US Postal (USPS) facilities have replaced existing HVAC systems with ground-source heat pumps. USPS is enthusiastic as it records energy savings of over 40%, consistently higher comfort levels, elimination of the need for special operators or service contracts and improved morale and productivity.

Source: Earth Comfort Update 6/5

European Heat Pump Association

The European Heat Pump Association was officially established 18 February 2000 in Brussels. The Association will promote awareness and proper deployment of heat pump technology in the European market. Activities include education, strategic studies, labelling and certification initiatives, in cooperation with other organisations with similar aims in Europe and worldwide. An article on the Association will be published in the next Newsletter.

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First official meeting

First UK school to install ground-coupled system

UK – A junior school in Cornwall has become the first in the UK to be heated and cooled using a ground-coupled heat pump system. The system was installed over the 1999 summer holidays and is the largest closed-loop ground-coupled heat pump system in the country.

Cornwall County Council decided to replace the roof-mounted air-handling unit employing direct electric heater batteries and a conventional chiller, with a completely integrated unit that incorporates dual reverse cycle, water-source heat pumps. It is packaged in a welded aluminium frame and casing, providing very high resistance to the elements – particularly important in this location (close to the sea). The unit is connected to an array of 10 boreholes, 70 metres deep drilled in the school grounds, which are now fitted with closed-loop ground heat exchangers. The air is heated or cooled before being circulated around the building. The air-handling unit allows for passive cooling and is capable of using options ranging from circulation using all fresh air, through to complete air recirculation.

Source: Rosemary Rawlings, UK National Team
More information: http://www.earthenergy.co.uk

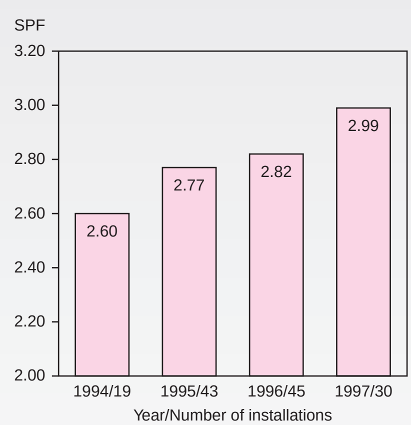
Field measurements of SPFs

Switzerland – First results of a field analysis of the SPFs (seasonal performance factor) of residential Swiss heat pumps were presented at a seminar in Burgdorf, Switzerland, May 1999. At that time, 130 heat pumps were analysed for user satisfaction, operation, problems and possibilities for optimising the operation. The programme started in 1996. User satisfaction was very good in 65% of the cases.

The SPFs varied between 1.69 and 4.48, a broad distribution with low-end values that are cause for concern. **Figure 1** shows the average SPFs per installation year, weighted by produced energy. The graph clearly shows that the newer installations are more efficient. Air-source heat pumps were found to have an SPF of only 0.4 less than other tested installations, which is a relatively small difference. Among the tested installations, monovalent heat pumps were more efficient than bivalent ones. The key to optimising heat pump installations is not the manufacturer, but the installer and the way they integrate the heat pump into the (hydronic) heat distribution system.

Source: HeizungKlima 9-99

▼ *Figure 1: Measured SPFs per installation year.*



Manure as heat source

The Netherlands – The Dutch company R&S Systems markets a heat pump with floating heat exchanger, using manure as a heat source. The heat can be used for air or floor heating on pig farms, e.g. for breeding sows and piglets. The system is already being used on poultry farms. Cooling manure results in reduced ammonia emissions.

More information: R&S Systems,
Tel.: +31-492-322437

Peltier refrigeration

Australia – The *Hydrocool* heat pump, developed in Australia, uses the Peltier effect for cooling. The Peltier effect occurs when an electric current passes through a circuit made of dissimilar metals. The method of heat transfer used in the Hydrocool is very efficient, i.e. similar to a conventional compressor-based refrigerator. The heat pumps are also very small; a 50 W unit is not much larger than a box of matches.

The first version of the Hydrocool, manufactured by National Panasonic, came on the market in Japan during 1997 and was designed for use in bars, hotels and restaurants, where quiet operation is essential. There are now plans to move into the portable refrigerator market, e.g. for travelling, camping and caravans.

More information: Hydrocool Pty Ltd
Fax: +61-8-93353004
E-mail: mail@hydrocool.com

Radiant heat grows in USA

USA – The number of US contractors involved in radiant heating (floors, walls and ceilings) is steadily rising. Those who are active in the business report a growing market. According to one contractor, radiant heat is the fastest-growing segment of the heating industry with double-digit growth for the past eight years. The radiant panel association (RPA) acts as a forum for interested US parties.

Source: The Air Conditioning, Heating and Refrigeration News, 13 December 1999
More information: http://www.rpa-info.com

Rectification

The 21st IIR Congress will be held **17-22 August 2003** in Washington DC, USA, and not 17-22 February, as stated on page 25 of the December 1999 issue of this Newsletter.
We apologise for any confusion this may have caused.

ARTI Refrigerant Database expanded

USA – The ARTI Refrigerant Database, including 507 refrigerant profiles, has been updated to provide additional information. This database, a unique information system on alternative refrigerants, associated lubricants and their use in air conditioning and refrigeration, offers users easy and comprehensive access to information such as refrigerant properties, compatibility, safety, environmental facts, applications etc.

The database now contains the equivalent of over 8,000 pages of reference material, all of which can be searched and selectively printed. It contains data summaries, refrigerants and blends, detailed toxicity reviews for common refrigerants, tabular compatibility summaries for plastics and elastomers, bibliographic citations from over 6,100 documents, an automated search system and a collection of documents (many of them unpublished).

The new update includes significant revisions and additions to over 6,700 records. These include 14 new refrigerant profiles, new atmospheric lifetime data, ozone depletion potential (ODP) and global warming potential (GWP) data, as well as revised recommended exposure limits.

The update also includes:

- preliminary values for the proposed recommended concentration limits (safety classification);
- 267 new citations concerning non-fluorocarbons;
- additions to the thesaurus file for synonyms and related terms.

Information and order form:
http://www.arti-21cr.org/db/qa.html
Questions: database@spectrum-internet.com

IIR on CO_2 as a refrigerant

France – CO_2 technology is very attractive as it is environmentally benign and locally safe, but needs a breakthrough enabling mass production of the necessary components in order to be cost-competitive compared with conventional refrigeration, air conditioning and heat pump technology, with either global environmental or local safety problems. This is the conclusion of the new informative note issued by the International Institute of Refrigeration (IIR) in February 2000.

Extensive R&D work, particularly within two large European Community projects, has shown that CO_2 technology can compete with common technology in automotive and transport air conditioning, in heat pumps providing higher temperatures and for industrial drying processes. However, there are some applications where the nature of the less efficient transcritical cycle cannot be compensated for by taking advantage of the particular operating conditions of the system.

Source: IIR
More information: iifiir@ibm.net

Actions on HFCs delayed

Germany – Ministers and officials from 166 governments attended the 5th Conference of the Parties (COP-5) in Bonn, Germany, October-November 1999. The COP is the supreme body of the UN FCCC (United Nations Framework Convention on Climate Change) and most of the world's nations are members. COP-3 (1997) adopted the Kyoto Protocol.

During the Bonn summit delegates decided to delay any decision on HFCs, which are in the so-called "basket of gases" by 18 months. This delay means that HFCs will not be discussed at COP-6, to be held in The Hague in 2000, where many key decisions are due to be made.

Source: ASHRAE's Issues Update

ARAP: low HFC contribution to global warming

USA – A recent report to the Alliance for Responsible Atmospheric Policy (ARAP) states that the contribution of HFCs to global warming is low (below 1% for the US) and is likely to remain so (2.3% in 2030). The net warming impact of most HFC technology is close to zero or produces a net global warming reduction due to better energy efficiency. The report *Global comparative analysis of HFC and alternative technologies for refrigeration, air conditioning, foam, solvent, aerosol propellant, and fire protection applications* was prepared by Arthur D. Little, Inc. It uses LCCP (life cycle climate performance) to compare different options.

ARAP is a coalition of companies producing CFCs, HCFCs and HFCs, manufacturing products that use these chemicals, and organisations whose services rely on these chemicals. The aforementioned report is available from the ARAP Internet site.

Source: The Air Conditioning, Heating and Refrigeration News, 25 October 1999
More information: http://www.arap.org

China acts for ozone protection

China – In 1999 China began closing its CFC manufacturing facilities. This is the first time that a country with a developing economy has closed down chemical plants in an effort to comply with an international environmental agreement. China is also the first country in this group to have developed its own process for manufacturing the non-ozone-depleting refrigerant R-134a to international standards. While closure of the CFC production plants received financial assistance from the Multilateral Fund, efforts to develop and manufacture R-134a are solely funded by China.

Source: Ozonaction 32, November 1999

Ice storage and gas-fired heat pumps up in Japan

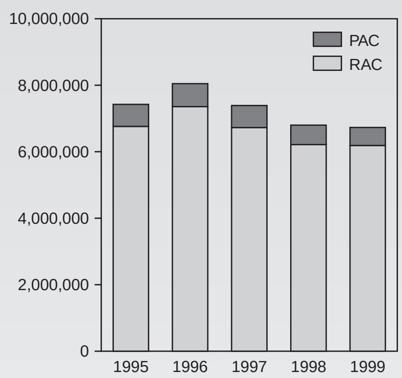
Japan – The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) announced domestic shipments of refrigeration and air-conditioning equipment for refrigeration year (RY) 1999 (October 1998 – September 1999).

Ice-storage-assisted packaged air conditioners (PACs) totalled 7,741 units, up 79.6% on the previous year. The appliance, supported by the government, electric power companies and the refrigeration industry, had a high profile as a result of introducing the Eco-ice mini system. Gas-fired heat pumps also showed favourable results, totalling 42,187, up 7.1% on 1998.

Heat pump type room air conditioners (RACs) were down slightly (0.4%) and heat pump type PACs were down 7.2%, continuing the downward trend that has been seen in Japan since 1996 (see **Figure 1**). Overall, shipments of air conditioners were 1.2% lower than the year before.

A slight market increase is expected this year. Manufacturers aim to increase sales outside the summer period. New models for 2000 feature further improvements in heating capacity, air quality and energy-saving performance. The replacement and add-on market is becoming increasingly important, with 80% of the current total RAC demand.

▼ *Figure 1: Japan heat pump type RAC and PAC shipments (RYs).*



Source: JARN, November/December 1999

Swiss heat pump market continues to grow

The past year has seen further increases in sales of heat pumps to some 6,000 units (excluding heat pump water heaters) compared to 7,000 conventional heating systems. Courses and information services are also popular. In western Switzerland, almost 100 installers and energy consultants have enrolled for training courses. The information office in Bern dealt with around 10,000 enquiries in 1999, around 50 per day.

Although these successes are significant, FWS (Swiss heat pump association) has not yet achieved its goal in the heating renovation market which, despite vigorous marketing efforts, remains at around 1,100 systems. Higher investment costs are still preventing a breakthrough in this market. Improvement is probably only possible by offering promotion grants to essentially reduce the investment obstacle. As far as quality is concerned, heat pump systems carrying the international quality seal have achieved something of a breakthrough. Efforts for standardisation of system types will continue in 2000.

Source: Dieter Wittwer, FWS
Tel.: +41-1-2508825

Daikin and Matsushita agree on global strategy

Japan – Daikin Industries Ltd and Matsushita Electric Industrial Co. Ltd have signed a memorandum of understanding on comprehensive collaboration in the air-conditioning business. The alliance covers manufacturing and R&D and will strengthen and expand both companies' air-conditioning operations globally. Daikin is an important manufacturer of full-line air-conditioning products in Japan. Matsushita is one of the world leaders in the residential air conditioner industry.

Source: JARN, December 1999

New studies on European air conditioning

UK - BSRIA's (Building Services Research and Information Association) worldwide market intelligence division has recently completed three major studies on different aspects of the European air-conditioning industry:

- packaged air conditioning;
- central plant air conditioning;
- chilled ceilings.

The *packaged air conditioning* market in Europe continues to outperform the rest of the world. The market has been boosted by falling prices, as a result of the Asian crisis and the hot weather, particularly on the small splits market in Spain, Italy and Greece. Split systems now have complete supremacy in the European market, with window and portable units losing share rapidly, and larger packaged and close control systems remaining as niche markets. Sales of split systems rose by 26% in 1998 and 11% in 1999.

The market for *chilled ceilings* is dominated by Germany, the Netherlands and Switzerland. Active ceiling beams are expected to show sharp increases.

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Annex 27: Sweden joins; activities planned

The Netherlands – Sweden has joined Annex 27 *Selected issues on CO_2 as working fluid in compression systems*. The decision was taken after Electrolux, a Swedish manufacturer, became a partner. The Annex will focus on basic and pre-competitive challenges to bring CO_2 as a working fluid nearer to commercialisation. The following tasks will be included:

- Heat transfer characteristics of CO_2 (JP)
- Feasibility study on CO_2 compression systems (JP)
- Heat transfer and pressure drop characteristics (NO)
- Selected safety issues with CO_2 as a working fluid (NO)
- Lubrication issues in CO_2 systems (NO)
- Thermo-syphons with CO_2 for transferring heat in refrigerators and freezers (SE)
- Face seals for positive displacement compressor/expanders (UK)
- Evaporation heat transfer coefficient of CO_2 (US)
- Feasibility of transcritical CO_2 systems for mobile space conditioning applications (US)

Sweden will also contribute a second project.

The first Annex workshop is planned for 18-19 September 2000, at SINTEF Energy Research, Trondheim, Norway. The theme is *CO_2 technology in refrigeration, air-conditioning and heat pump systems.*

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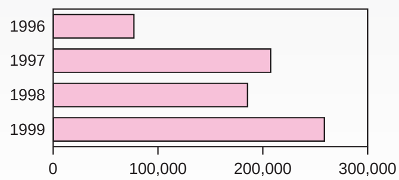
Pages requested from HPC website up 40%

The Netherlands – The number of pages requested from the HPC Internet site has increased by 40% compared to 1998. As a means of information dissemination, the Internet has become increasingly more important (see Figure 1).

With 13,500 requests in 1999, *More about heat pumps* is the most popular section of the website. The *News* sections enjoy an increasing popularity, with both news items listings and the items themselves recording 10,000 requests in 1999. The *Products and ordering* section was also well frequented. The number of requests for the search page (HPP Library) more than doubled (7,000) compared to 1998.

These requests were made by users from 89 countries around the world, although North America still dominates by far.

▼ *Figure 1: Annual page requests.*



Source: IEA Heat Pump Centre

RD&D Portal added to Internet site

The Netherlands – The Heat Pump RD&D Portal, the new section on the HPC Internet site saves you hours surfing time on the Net to find the specific information you need.

The Portal is a concentrated list of databases, mostly available on the Internet, containing specific information on heat pumps with thousands of references. Many of these databases cover research, development and demonstration of heat pumps, thus forming an additional information source, besides that maintained by the IEA Heat Pump Centre.

The Heat Pump Centre has categorised and analysed the various information sources, so that you can see exactly which database suits your needs best. The Portal includes over 30 databases with information on heat pumps, with links to the relevant Internet sites.

The HP Portal will be available on the HPC website from 1 April 2000 onwards.

Source: IEA Heat Pump Centre
http://www.heatpumpcentre.org

Ongoing Annexes

Red text indicates Operating Agent.

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

IEA Heat Pump Programme participating countries: Austria (AT), 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).

Commercial and industrial refrigeration - an international overview

Developments in commercial and industrial refrigeration are driven by the need to improve control of the cold chain, and to mitigate global warming by improving energy efficiency and reducing refrigerant emissions. The latter often makes good financial sense. This article discusses which technology trends are evolving in supermarkets, cold stores and industrial refrigeration applications.

Scope

Commercial and industrial refrigeration comprises various sectors and applications, from supermarket refrigeration to ice rinks and from industrial freezing to biomedical applications. The economic and societal impact of refrigeration is far more significant than generally believed. Electricity use for refrigeration, air conditioning and heat pumps amounts to 12-17% of the total in European countries, and 20-25% in Japan and the US. Mr Billiard, Director of the IIR (International Institute of Refrigeration), stated that 1,600 million tons of food alone annually need refrigeration. However, only 350 million tons are currently refrigerated per year. There is a significant potential for reducing post-harvest losses by more refrigeration, especially in developing countries.

Figure 1 [1] shows the world's refrigerant stock for various purposes. Commercial refrigeration, cold storage and food processing and industrial refrigeration together account for 402,000 tons (36% of total). Transport refrigeration adds another 59,000 tons (5%). The Japanese commercial refrigeration market is an example of the numbers involved: around 630,000 units of commercial refrigeration equipment were sold in 1998 (70% refrigerated cabinets and 30% commercial refrigerators).

Commercial refrigeration

Commercial refrigeration includes a wide range of equipment:

- *self-contained equipment* where all functions are integrated. These systems traditionally used R-12, but most new equipment uses R-134a. Several manufacturers in the UK, Denmark and Sweden have introduced small commercial equipment using hydrocarbons;
- *separate condensing and evaporating units* (small cold rooms; refrigerated display cabinets);
- *central systems* with compressors located in a machine room. These can be direct (refrigerant circulates through the sales area) or indirect, also called secondary loop systems (heat transfer fluid circulates through the sales area). **Figure 2** shows potential measures to increase the energy efficiency of the systems mentioned;
- *distributed systems* with multiple cooling plants rather than one central plant. Each plant is located close to a group of display cabinets.

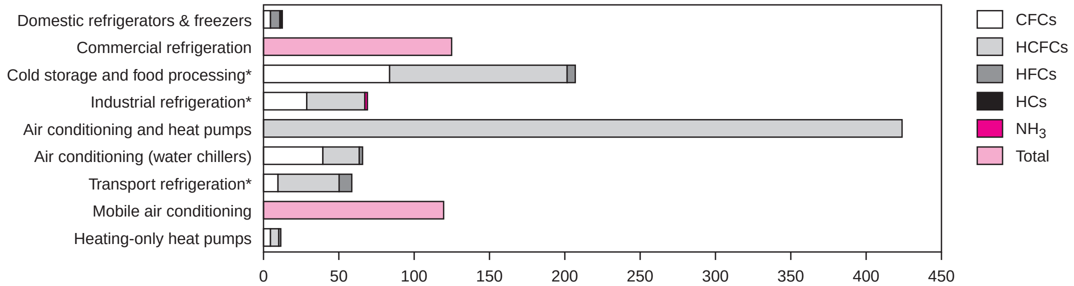
Distributed and central systems are discussed in detail in the article on page 13.

Annex 26

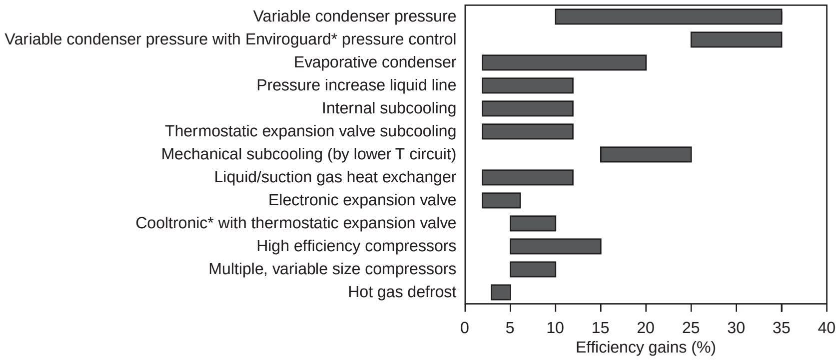
The IEA Heat Pump Programme's Annex 26: *Advanced supermarket refrigeration/heat recovery systems* aims to demonstrate and document the benefits of advanced system design for food refrigeration and space heating/ cooling for retail food stores (supermarkets). A specific goal is to identify advanced system design options to reduce the total equivalent warming impact (TEWI) of supermarkets.

Annex participants will provide case studies and life cycle cost analyses of distributed compressor systems (SE, UK, US), secondary loop systems (CA, SE, US) and energy storage systems (CA, SE). Further areas of interest include the use of natural refrigerants (UK), tools for supermarket planners (SE, US), water-loop heat rejection (UK), and desiccant dehumidification for store space conditioning (CA, UK).

▼ *Figure 1: World refrigerant stock by application.*



*CFCs, HCFCs and HFCs included only



*Enviroguard is a trademark of Tyler Refrigeration Corp, USA; Cooltronic is patented by CoolPro Products, NL

▲ *Figure 2: Efficiency gains through various measures, compared to baseline system [2].*

Supermarket refrigerants

Future supermarkets will probably choose HFC blends for direct expansion systems and as primary refrigerant, due to safety considerations and initial equipment cost. In Europe, R-404A and R-507A are currently used in new, central systems. In some European countries, manufacturers also offer units with ammonia or hydrocarbons, mostly with a secondary distribution system.

Emission reduction

Reducing refrigerant emission is a major issue in supermarkets. Governments regulate refrigerant handling in several ways. Leak rates are around 30% annually in the conventional central direct systems, and refrigerant charges are high. Better design, charge minimisation, better installation and better maintenance can reduce leakage significantly. After targeted measures in 56 US stores, the leak rate was reduced to 8% of the total charge per year.

Natural refrigerants

Annex 22 analysed innovative systems for supermarket refrigeration [3] with ammonia and hydrocarbons as primary refrigerants in supermarkets, and ice-slurry and CO_2 as secondary refrigerants.

CO_2 as a secondary refrigerant is used in large stores in Kilmarnock, UK, and Lund, Sweden. Compared to traditional brines and refrigerants, CO_2 offers a number of advantages (due to higher volumetric refrigerating capacity): reduced pumping power, smaller tubes, more efficient heat exchangers which enable smaller and cheaper units, and a smaller compressor volume.

An alternative for CO_2 in supermarkets is a cascade CO_2/NH_3 refrigeration plant with secondary loop, with CO_2 at the low temperature end. Cascaded CO_2 plants are used in around twenty supermarkets in Europe (1999). All-CO_2 systems (two-stage) are also possible. Suitable compressors are hard to find, though the number of manufacturers is increasing.

Energy-efficient display cabinets

A Swedish competition organised in 1997 shows that the energy efficiency of supermarket refrigeration systems can be improved significantly by careful design. The challenge of the competition was to design a brine-cooled refrigerated display cabinet with an annual electricity consumption lower than 2,600 kWh/m cabinet, 25% less than the best conventional systems. The competition focused on indirectly cooled systems, as the Swedes prefer these in new installations. The winning display cabinet uses 1,745 kWh/m, half that of the best conventional system. This was achieved by:

- larger coil area and higher brine temperature (–1.5ºC to –1.7ºC, compared to –7.8ºC to –8.2ºC conventionally), which increases the COP of the winning refrigeration installation, reduces frost growth and decreases brine-side pressure drop. No defrost was necessary;
- control strategy that adapts to diverse cooling demands (day/night operation, changes in climate);
- improved night coverage with guides for the night covers, which reduces air infiltration at the edges and prevents unacceptably warm spots;
- reduced electric input to fans, lighting and frame heating, to less than half that of conventional systems. Nevertheless, the winner had the highest value of illumination.

In December 1999, Eurovent/Cecomaf started a certification programme for refrigerated display cabinets. Ten major manufacturers are participating. The first directory of certified products will be published in May 2000, and will help users to select energy-efficient appliances. A labelling scheme for refrigerated display cabinets is also proposed, but it is not yet clear how the European Commission will implement this.

Secondary loop systems

There are only around 60 secondary loop supermarket refrigeration systems in the US, while Europe has thousands, mostly in Northern Europe. The popularity of these installations increases in Austria, the UK and other European countries. The article on page 18 describes such an installation. Their refrigerant charge is much lower than in direct expansion systems and they offer the additional advantage that prefabricated units can be applied, which can be leak-tested in the factory.

Oak Ridge National Laboratory (ORNL) in the USA is comparing a number of low refrigerant charge options to the conventional direct expansion central systems. A field test of a distributed compressor system (70% charge reduction) is on its way, and the secondary loop approach (more than 90% charge reduction) is also being evaluated.

Heat recovery in supermarkets

Recovering heat from refrigeration systems is common practice in several countries. In Austria, heat recovery from refrigeration systems is state of the art, either using a desuperheater ($COP_{heating}$ about 20) or an increased condensing temperature plus a desuperheater ($COP_{heating}$ about 10). In the food processing industry an additional heat pump is sometimes installed that uses the condenser heat of the refrigeration system as a heat source ($COP_{heating}$ about 5). A large cold store company supplies heat to the district heating network by increasing the return temperature.

Cold stores

Cold and frozen storage facilities form an growing market in countries such as the Netherlands and Germany, where the demand for frozen and pre-prepared food grows. To comply with the Kyoto Protocol, energy efficiency has become a priority. A breakdown of the heat load in cold stores is shown in **Figure 3** (UK data).

In the Netherlands, cold and frozen storage of products requires 0.3% of the total industrial energy consumption. The Dutch cold stores trade association has signed a long-term agreement with the government that an overall 28% energy efficiency improvement will be achieved in 2000 compared to 1989 levels. Measures (some also applicable to freezing) for improved energy efficiency during storage include:

- adequate maintenance of refrigeration plant and the building, particularly the building shell;
- minimising open doors and unnecessary lighting;
- maximising full-load operation when multiple compressors are used (up to 35% savings);
- avoiding coupled operation of ventilators and refrigeration plant. Ventilation along cold products is often sufficient to equalise temperatures in the store. Avoid bypassing;
- using condenser heat for defrosting, space heating in offices and underfloor heating (to avoid frost damage);
- using automated systems for stock control. Goods are transported into the store on pallets via a conveyor belt. This allows smaller doors and fewer passages through them.

Industrial refrigeration

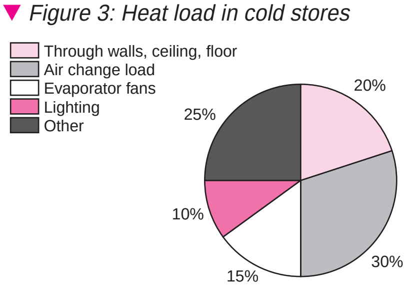
Industrial refrigeration covers a wide range of cooling and freezing applications, including the chemical and pharmaceutical industries, the petrochemical and the oil and gas industries, the metallurgical industry, plastic moulding, civil engineering, industrial ice making and other uses. This wide variety of applications is reflected in the wide range of demands and equipment choices. Techniques include mechanical cooling, free cooling, cooling towers, thermal storage in aquifers etc. The article on page 20 describes a cooling system being tested in a rubber and plastic mill in Japan.

Newsletter 99/4 discussed industrial heat pumps and process integration. Combinations of cooling and heating are often beneficial in the food and beverage industries. The article on page 16 presents such a combination.

CHP and absorption cooling

The UK is showing an increasing interest in combined heat and power (CHP) in combination with absorption refrigeration. However, the energy efficiency of this option must be considered carefully. Annex 24 (*Absorption machines for heating and cooling in future energy systems*) experts discussed this at their meeting in Turin, Italy, 1999. For cooling, gas engine CHP with H_2O-LiBr absorption cooling can be more efficient than compression cooling (COP=5) when the efficiency of the reference power plant falls below 42%. This shows a dilemma for policy makers. An important consideration is that power generation efficiency and absorption cooler efficiency are inversely linked when they are combined (bleed steam temperature), and that a 50-55% central electricity efficiency is attainable. More on this topic will be published in Newsletter 18/2 or 18/3.

▼ *Figure 3: Heat load in cold stores*



Conclusions and trends

Innovations in commercial and industrial refrigeration today are aimed at better control of the cold chain, higher energy efficiency and reducing emissions from refrigerants. At the same time, control of the product quality must remain at high standards or even improve. For supermarket refrigeration, interest in secondary systems has increased, but direct expansion systems will probably remain mainstream. In addition to HFCs, experience is being gained with NH_3, hydrocarbons, CO_2 (low temperatures) and ice slurry. Ammonia is being increasingly used in industry.

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Low-charge refrigeration for supermarkets

David H. Walker, USA

Current supermarket refrigeration systems require large refrigerant charges for their operation. Their energy consumption is also enormous: 1-1.5 million kWh annually. Various new system approaches are available that use significantly less refrigerant. This article discusses distributed and secondary loop system options and the integration of store HVAC systems with the refrigeration system.

Distributed compressor and secondary loop systems have been investigated in an analysis effort sponsored by the US Department of Energy through Oak Ridge National Laboratory (ORNL). With proper design and implementation, both these advanced systems can reduce annual energy consumption by 11-12%.

Integrating refrigeration and store HVAC (heating, ventilation and air conditioning) is also possible through water-source heat pumps. By incorporating the heat pumps in the heat rejection loop for the refrigeration, the rejected heat can be utilised for store space heating without increasing the condensing temperature of the refrigeration. This integrated method reduces operating costs by 12.6%.

Background: high energy and leakage

Supermarkets are the largest users of energy among US commercial buildings. A typical supermarket consumes around 2 million kWh per year. Many larger superstores can consume as much as 3-5 million kWh annually.

Refrigeration usually accounts for around half of a supermarket's energy use. Most products sold are perishable and must be kept refrigerated. Compressors and condensers account for 30-35%. The remainder is consumed by the cooler fans for display and storage, display case lighting and for anti-sweat heaters preventing condensation on doors and outside surfaces of display cases.

In a typical US supermarket all refrigerated fixtures employ direct-expansion air-refrigerant coils. To reduce noise and control heat rejection, compressors and condensers are kept in a machine room located in the back or on the roof of the building. Piping supplies and returns refrigerant to the case fixtures.

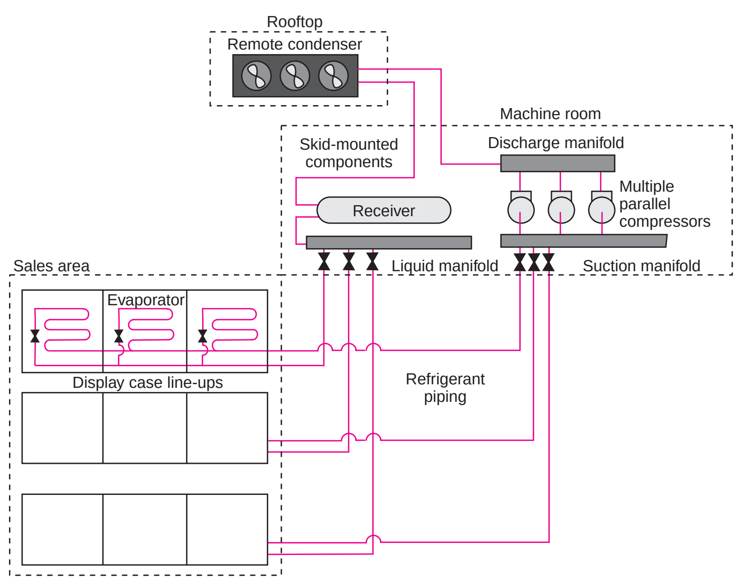
Figure 1 shows the major elements of a conventional *multiplex refrigeration system*, the most commonly used configuration in US supermarkets. Multiple compressors operate at the same saturated suction temperature. These are located in a remote machine room and piped with common suction and discharge. Using multiple parallel compressors provides a means of capacity control, since the compressors can be selected and cycled as needed to meet the refrigeration load. An air-cooled condenser is usually employed for heat rejection.

Using this layout means that a large amount of refrigerant is needed. A typical store will require 1,400-2,300 kg (3,000-5,000 lb) of refrigerant. The large amount of piping and pipe joints also provides many opportunities for refrigerant leakage. Losses can be 30-50% of the total annual charge.

Lower refrigerant charge

With increased concern about the impact of refrigerant leakage on global warming, new supermarket system configurations are being considered that require significantly less refrigerant charge. Advanced systems include new designs for multiplex systems that can reduce charge levels by 50% or more, distributed compressor systems, and secondary-loop refrigeration. These include small rooftop multiplex systems and several approaches that either minimise the amount of charge stored,

▼ *Figure 1: Multiplex refrigeration system.*



or reduce it by careful regulation and control of refrigerant inventory.

Heat rejection

The use of *glycol loops* for heat rejection can reduce refrigerant charge in multiplex systems by approximately one-third. Water-cooled condensers are mounted on each of the compressor racks and a water loop connects the condensers to a fluid cooler, normally located on the roof. Heat rejection using a glycol loop will involve added heat transfer resistance and will tend to raise the condensing temperature of the refrigeration. This is most significant during summer. During the winter, the ambient temperature is usually lower than the minimum condensing temperature of the refrigeration. The use of evaporative heat rejection or heat rejection to the ground can help eliminate the heat transfer penalty.

The latter method has been investigated for water-loop heat pumps. It showed that the ground rejection temperature can be lower than the ambient temperature, which would reduce the condensing temperature of the refrigeration without using evaporative heat rejection. Pumping power for the glycol loop must also be examined carefully to prevent excessive energy use.

Low-charge multiplex systems are being analysed to quantify the savings potential for energy and CO_2 emissions of these technologies. Results are expected late 2000.

Distributed refrigeration

In a distributed refrigeration system (**Figure 2**), multiple compressors are located in cabinets placed inside the building near the display cases (i.e. close-coupled). For heat rejection from the cabinets either air-cooled condensers located on the roof above the cabinets are used, or a glycol loop that connects the cabinets to a fluid cooler.

The system employs *scroll compressors* because of their low noise and vibration levels. These are necessary if the compressor cabinets are located near the sales area. Scroll compressors can produce significant energy savings:

- they have no valves, so they can operate at significantly lower condensing temperature;
- the lowest temperature possible is at a suction-to-discharge pressure ratio of 2 which, for supermarket systems, means that the lowest condensing temperature possible is between 12-16°C (55-60°F).

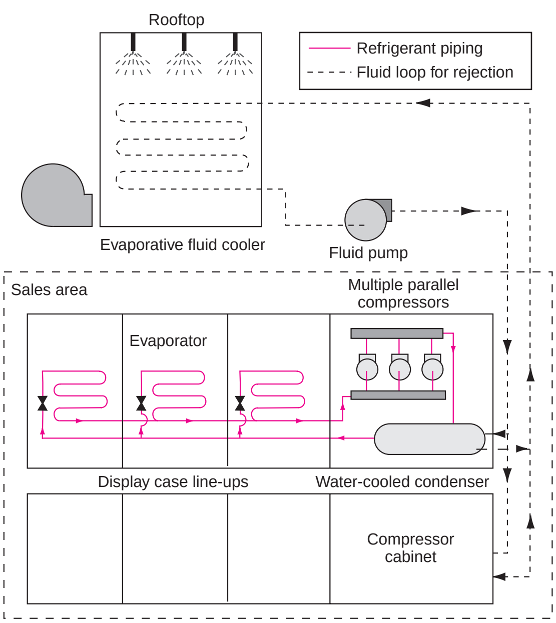
The *close coupling of the display cases* to the distributed refrigeration cabinets has other ramifications for energy consumption. The shorter suction lines mean that the pressure drop between the case evaporator and the compressor suction manifold is less than with multiplex systems, so the compressor saturated suction temperature (CSST) will be close to the display case evaporator temperature. Shorter suction lines also mean less heat gain to the return gas. The cooler return gas has a higher density that results in higher compressor mass flow rates, causing the compressor to work less.

The *refrigerant charge* required for a distributed refrigeration system will be 400-680 kg (900-1,500 lb). The exact charge depends on whether water- or air-cooled condensing is employed. Water-cooled condensers need the lowest refrigerant charge, as they reject their heat via a glycol loop and fluid cooler, usually located on the roof. Glycol loops can increase the energy consumption of the refrigeration as discussed above.

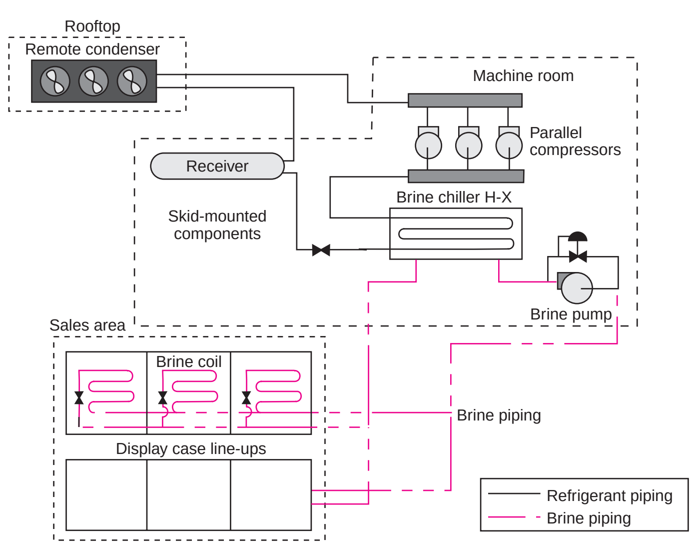
Secondary loop refrigeration

Cold brine loops between the display cases and central chiller systems replace the long refrigerant pipe runs of typical

▼ *Figure 2: Distributed refrigeration system.*



▼ *Figure 3: Secondary loop refrigeration system.*



multiplex systems. The brine is refrigerated at the chiller and then circulated through coils in the display cases, where it chills the air (**Figure 3**).

Lowest energy consumption for secondary loop systems is achieved when the display case evaporators are designed specifically for brine, so that the temperature difference between the brine and air is minimised. *Brine selection* is also important, because pumping requires high energy consumption. Using brines with high heat capacity and low viscosity at low temperatures is desirable, such as those based on potassium formate.

The central chiller systems are constructed similarly to the multiplex parallel racks, using *multiple parallel compressors* for capacity control. Using high-efficiency compressors, such as reciprocating or scroll units is desirable to offset some of the added energy consumption needed for brine pumping. Because the evaporator is located on the chiller skid, the compressors for the secondary loop system are considered *close-coupled to the evaporator*. The pressure-drop and return gas heat gain are therefore minimised. Both these factors help to reduce compressor energy consumption.

Heat rejection can be accomplished either with air-, water- or evaporator-cooled condensers. Lowest condensing temperatures are achieved with evaporative condensers. These help reduce energy consumption, particularly when the minimum condensing temperature is set as low as possible. The system refrigerant charge will be 230-320 kg (500-700 lb) with either air-cooled or evaporative condensers and 90 kg (200 lb) for water-cooled condensers and fluid loop. Like the distributed refrigeration, *evaporative heat rejection* for the fluid loop is recommended to reduce energy consumption.

Performance predictions

A model supermarket was formulated and *energy consumption estimates* were made for current multiplex refrigeration and the advanced, low-charge systems. The results are shown in **Table 1**. Both the distributed and secondary loop systems achieved similar results compared to the multiplex system, with annual energy savings around 11-12%.

An *environmental assessment* was also made using a total environmental warming impact (TEWI) analysis for operation over a 15-year lifespan (see **Table 2)**. The lowest TEWI was achieved by the secondary loop system with water-cooled condensing and evaporative heat rejection. The reduction in CO_2 emissions amounted to approximately 8.6 million kg or 43.4%. Similar emission reductions were seen for the distributed refrigeration system.

Supermarket HVAC

HVAC equipment represents about 10-20% of the energy used in a supermarket, depending upon geographic location. The large number of refrigerated fixtures has a major impact on the store HVAC. Because of the installed refrigeration, space heating is the dominant HVAC load.

Many US supermarkets now use a 'heat reduction' system to recover only a fraction of the refrigeration reject heat for space heating. Hot gas from the compressors is circulated through heat exchanger coils located in the HVAC air-distribution system. The use of *water-source heat pumps (WSHP)* using a *glycol loop* for refrigeration heat

▼ *Table 1: Refrigeration energy consumption comparison*

System	Annual energy consumption	Savings vs multiplex	% Savings vs multiplex
Multiplex air-cooled	976,800	–	–
Distributed air-cooled	859,200	117,600	12.0
Distributed, watercooled, evap.	866,100	110,700	11.3
Secondary loop, 4 brine loops, evap. condenser	867,400	109,400	11.2
Secondary loop, 4 brine loops, water-cooled, evap.	967,100	9,700	1.0

Results for site in Wahington, DC

▼ *Table 2: TEWI comparison of supermarket refrigeration systems.*

System	Charge (kg)	Leak (%)	Annual energy (kWh)	TEWI (million kg of CO_2) Direct	Indirect	Total
Multiplex air-cooled	1,360	15	976,800	10.00	9.82	19.82
Distributed air-cooled	680	10	859,200	7.34	8.63	15.97
Distributed, watercooled, evap.	410	5	866,100	2.20	8.70	10.90
Secondary loop evap. condenser	230	10	867,400	2.45	8.72	11.16
Secondary loop water-cooled, evap.	90	5	967,100	0.49	9.72	10.21

Results for site in Wahington, DC 15 year service life

▼ *Table 3: Operating cost results for combined refrigeration and HVAC.*

System Refrigeration	HVAC	Operating costs (USD) Electric	Gas	Water	Total	Savings
Multiplex	Convent.	85,565	17,653		103,218	
Multiplex	Reclaim	90,519	8,967		99,486	3,732
Distributed air-cooled	Convent.	77,218	17,653		94,871	8,346
Distributed, watercooled, evap.	WSHP	88,091	0	2,130	90,221	12,997
Secondary loop evap. condenser	Comvent.	77,804	17,653	1,784	97,241	5,977
Secondary loop water-cooled, evap.	WSHP	95,258	0	2,130	97,388	5,830

Results for Wahington, DC site

rejection as a heat source, represents a better way of space heating:

- a much larger portion of the reject heat can be recovered;
- the condensing temperature and head pressure of the refrigeration system do not have to be elevated.

Refrigeration energy savings achieved by *low head pressure* can be realised along with the energy benefits seen through heat recovery.

An analysis was performed for supermarket HVAC where conventional rooftop units, refrigeration heat recovery, and water-source heat pumps were compared. The results are shown in **Table 3**. Since both gas and electric energy are used, the comparison is given in terms of annual operating costs for both refrigeration and HVAC. Local utility rates for gas and electricity were used for these cost calculations. Operating costs include both the fuel energy cost and water consumption cost for evaporative condensing systems. The lowest operating cost was achieved with distributed refrigeration and water-source heat pumps, which saved USD 12,997, or 12.6% compared to multiplex refrigeration and conventional rooftop HVAC.

Conclusions

The best approach to reducing both refrigerant charge and energy use in supermarkets is to promote advanced, low-charge refrigeration systems together with water/glycol-cooled condensing and water-source heat pump systems. Proper system setup and operation are needed to obtain the cost savings estimated. Demonstration of these systems by field-testing is the best approach to providing supermarkets with the information needed to implement this technology.

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Integrated heating and cooling in the food and beverage industry

Frank Das, Novem, the Netherlands

A Dutch food company's demand for both heating and cooling encouraged it to integrate both functions into one overall system. By recovering the heat rejected from the cooling and freezing processes, this company realises energy savings that will pay back the extra investments within three years.

No pre-cooked solutions

The company (*Elite Salads and Snacks*) produces mainly pre-cooked foods for the catering industry. Three production lines produce 2,000 tons of finished products per year. Due to stricter hygienic demands and the company's need to expand production, the capacity of the cooling and hot water installations needed to be enlarged.

The management decided not to opt for an extra hot water boiler but searched for a better solution. One of its goals was to save energy. The existing utilities infrastructure had become less energy-efficient over the years, due to various modifications. The installation also needed to be adapted to meet national environmental legislation for cooling plants.

Natural gas was used to heat process water. In one section heat was required for the process, and in another section low-temperature heat was rejected by the cooling process. The obvious solution had to be found in combining measures: improving energy efficiency of the heating process, and recovering the heat rejected from the cooling process.

Heating and cooling the 'old way'

The production section is where fresh vegetables are cleaned, prepared and cooked. Meat, pasta and rice products are also prepared, cooked and finished. The fresh products are cooled or deep-frozen directly following the production processes. A conventional compression cooling installation is used for the cooling and frozen storage. In order to prevent condensation problems, the production areas are heated using underfloor and space heating.

Per day, 35 m^3 hot process water is needed for heating and cooking ingredients and for cleaning activities. Two steam boilers provide hot water. This energetically inefficient way of producing hot water became insufficient to meet demands during peak production periods, so hot water is stored in a buffer tank. The planned increase in production capacity also required a larger steam boiler capacity.

Integrated heating and cooling

The food and beverage industry has a large demand for heating and cooling. In conventional systems, gas- or oil-fired hot water boilers usually heat water to 60°C or more. Cooling and freezing is required to preserve and store the products. To recover the heat rejected in the cooling process, combining the heating and cooling processes seems obvious.

Combined heating and cooling by process integration is a well-known technique, but is not yet well established. This technique includes reusing reject heat from the cooling installations, connecting utilities and production processes and making both the heat and cold available for production purposes. This integrated technique can be applied in many cases in the food and beverage industry, but companies in other sectors that need useful heat at moderate temperatures and have access to reject heat, can also use this technology.

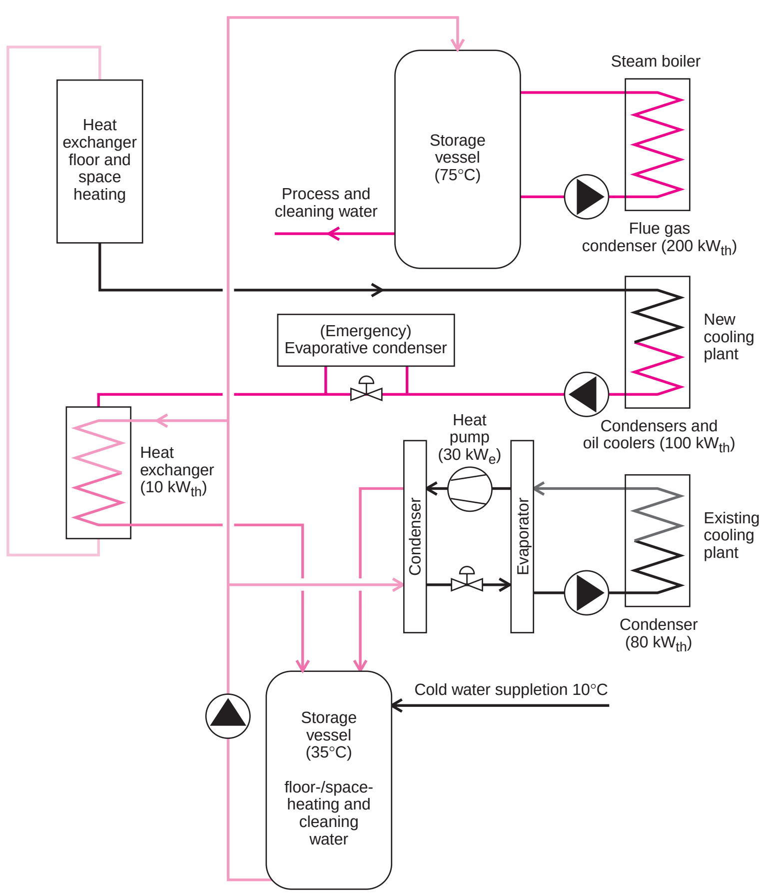
New situation *(see figure)*

Combined heating and cooling offered the solution, by using the cooling installation's reject heat to (pre)warm the process water, in combination with using a flue gas condenser on the steam boiler. The continuous heat flow from the cooling installation is upgraded to a higher temperature level. This heat is then made available to processes with a discontinuous heat demand.

The new cooling installation uses ammonia as a refrigerant. The water-cooled condensers transfer the heat from the cooling and freezing cells to the hydronic underfloor heating circuit. The heat from the compressors' oil coolers raises the water temperature to more than 35°C. A heat exchanger transfers part of this heat to a 5 m^3 buffer, containing 35°C water for cleaning purposes. The remainder is supplied to the underfloor/space heating circuit.

The rejected heat from the old cooling installation is raised to a higher level by a heat pump (lower part of the figure). A second heat pump (added later) is not depicted in the figure.
An important aspect of safety and hygiene is the risk of bacterial contamination in the water during the storage period. However, a temperature of 75°C offers sufficient protection against these risks. A flue gas condenser heats the water from 35°C to 75°C. A second buffer tank (40 m^3) stores this hot water, which is used for processing and heating purposes.

▼ *Figure 1: Integrated heating and cooling in the food and beverage industry.*



Efficiency improvements

The energy savings due to integrated heating and cooling amount to 120,000 m^3 natural gas per year. Savings from improved boiler efficiency account for 100,000 m^3 natural gas per year. Water heating with excess heat accounts for 60,000 m^3/year of savings. The extra electricity used for heat recovery amounts to 130,000 kWh per year (40,000 m^3 natural gas equivalent).

Economy

Calculating the payback period of the investment shows the economy of the new installation: the *extra* investment costs (NLG 140,000 / ± USD 70,000) are paid back by the annual energy cost savings of NLG 51,000 (USD 25,000) within 2.5 years.

The extra investment costs for integrating the heating and cooling equipment amount to NLG 260,000 (USD 130,000). Investment in a new second steam boiler (NLG 120,000, USD 60,000) has been avoided. The following tariffs have been used in the calculations: gas (NLG 0.366/m^3 / USD 0.18) and electricity (NLG 0.146/kWh / USD 0.07).

An extra benefit of the new system is that the boilers no longer have to produce hot water outside the normal production hours, which means that the boilers will last longer.

The total investments include two buffer tanks (5 and 40 m^3) plus extra cooling equipment (water-cooled condenser and the oil coolers), extra piping and control equipment, and a flue gas condenser for the steam boiler. Standard technology was used in the project.

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Unconventional secondary refrigeration in a UK supermarket

Nick Rivers, UK

Sainsbury's 'Millennium Store' at Greenwich has been designed to reduce energy usage by up to 50% compared to its traditionally built equivalent. With refrigeration in a supermarket accounting for almost half the energy consumption, system design obviously has a big part to play in achieving this goal.

Main features

Early in 1998 Sainsbury committed to building one of the most environmentally efficient supermarkets in the UK. The building and utilities incorporate the following features:

- wind and solar cell power generators;
- combined heat and power (CHP) for electricity and space (floor) heating;
- natural lighting to the sales area with north facing skylights and automatic lighting control;
- grassed earth walls provide thermal storage;
- natural ventilation: air enters through ducts in the earth banks, through side rooms and through supply ducts located within the 600 mm structural floor recess. The air leaves the building through louvers at the top of the skylights;
- cold air retrieval (spillage from display cabinets);
- groundwater for condenser cooling, and space cooling in summer, through fan-coil units in the offices and floor heat exchangers in the sales area. Water comes from two boreholes (75 m deep) with a temperature of 11.5ºC. Automatic back-flushing filters (100 micron) are used;
- an electronic control system is used for both the refrigeration plant and overall building control systems. This can optimise the setpoints according to the imposed load, ensuring continuous energy-efficient operation.

▼ *Figure 1: The store with roof lights and frozen food cabinets.*

The refrigeration system

The power used for refrigeration is typically 50% of the total power consumption. Therefore, the design of the refrigeration system plays a large part in the overall efficiency scheme.

The company wanted to use environmentally benign refrigerants. As primary refrigerant it chose the hydrocarbon 'Care 45'. However, due to the hydrocarbon's characteristics, a secondary refrigerant design was adopted using propylene glycol for the intermediate temperature (IT) system and potassium salt solution for the low temperature (LT) system. These combinations have zero ozone depletion potential and no direct global warming effect.

System layout

Five chillers (two LT and three IT) provide total store refrigeration. This configuration added capital costs but allowed flexibility with respect to design fluid conditions and load diversity. One chiller system comprises two parallel refrigeration units, each with a primary refrigerant charge of 4.5 kg (9 kg per chiller). The company opted for chillers from a Swedish manufacturer due to their expertise in secondary fluid solutions for supermarket and process cooling systems in Scandinavia and central Europe. The chillers are close-coupled to a dual-circuit evaporator and a condenser plate heat exchanger.

Secondary fluid off each packaged chiller passes through the distribution system to cabinets and cold rooms via two variable-speed pumps. A defrost circulation pump is used to distribute a warm fluid for defrosting.

Chillers and safety measures

The primary refrigerant used within each chiller can form an explosive mixture in specific circumstances. Therefore, each chiller is an integrated design within a self-contained housing.

The chiller housings are ventilated using an intrinsically safe extract system that maintains each chiller enclosure at a negative pressure. This negative pressure is protected by both interlock switches and by differential pressure switches monitoring the pressure difference between the chiller housing interior and the machine room area.

The machine room is mechanically ventilated by a two-fan extractor system with intrinsically safe motors. This system provides normal extraction and a boost extraction in the event of a refrigerant leakage. The machine room is located behind the back wall of the store and is partitioned into two sections. One section is classified as a zone-2 safe area. The remaining section is the pump station room.

A gas detection system monitors the chiller housing. High- and low-level sensor points are also installed inside the machine room. The detection system is linked to the BMS (building management system).

Access to the machine room is restricted to trained personnel only. The refrigeration and maintenance contractor is trained for specialist handling and application of hydrocarbon refrigerants.

Secondary system

Secondary fluids were selected according to materials compatibility, pumping power, capital costs and thermal performance. Pipework design considered both flow rates and system resistance, coupled with the specific requirement to remove any air entrained within the system. Full-flow three-way control valves were installed to provide minimal system resistance during both refrigeration and defrost operation.

Connections between display cabinets and between regulation valves were mostly positioned on top of the display cases to provide good installation and maintenance access. This configuration also reduced co-ordination of services underneath the cabinets (drains) and minimised airflow resistances through the kick plates and under the cabinets for cold air retrieval.

Energy-saving measures

The following measures were taken to reduce energy consumption.

- *Borehole water-cooled* condensers reduce the size of the main plant and corresponding energy consumption. Water is available all year round at 13°C (maximum), enabling a design condensing temperature of 25°C. In practice, condensing temperatures between 15°C and 20°C are anticipated.
- Liquid *subcooling* for the LT system using the IT system return fluid.
- High efficiency *plate heat exchangers* are used.
- *ABS piping* was used for diameters below 63 mm, as they are easy to install and have better thermal insulation characteristic than copper pipes. Pre-insulated ABS pipework was used for pipe diameters greater than 63 mm. All joints were ‘welded’ using propriety solvents. Connections between ABS and copper pipework use specialist composite unions.
- Reclaim heat from the CHP primary circuit heats the secondary fluid in the *defrost* loop through a plate heat exchanger mounted on the chiller pump stations. A four-pipe system distributes the fluid (20°C). Warm fluid defrost reduces power consumption and absorbed energy to the sales area and cold rooms.

▼ *Figure 2: Chiller pack.*

Energy monitoring

A full energy monitoring system monitors the installation every 15 minutes throughout the year and records the energy consumption of:

- each chiller;
- each pump station;
- borehole supply;
- sales area LT and IT cabinets;
- cold rooms and ancillaries, such as gas detection and controls;
- internal and external dry bulb temperature and relative humidity.

In addition to the equipment generated and monitored for Greenwich, a standard R-404A DX store, with similar profile and footprint, is to be fitted with a monitoring system and will be monitored for a minimum of one year.

Future work

The following aspects will require further attention in the future.

- The use of ABS pipework inside and on top of cabinets may be reconsidered as ABS fittings and valves are large when compared to standard refrigeration/plumbing components.
- Cabinet performances using secondary fluids should be considered and tested, as initial monitoring of the system performance suggests that optimisation of flow conditions could be achieved.

System performance, to be monitored for both Greenwich and the R-404A DX site over the next 12 months, will provide data for further system design enhancements for future installations.

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Cooling to -100°C with cascade system using natural refrigerants

Kazutoshi Ito, Japan

A Japanese company has developed a -100°C cooling system for milling rubber and plastics, as a cheap and environmentally friendly alternative to cooling with liquefied nitrogen. The refrigeration system, which is currently at the pilot stage, combines the natural refrigerants ammonia and ethane with brine in a cascade cooling system.

The search for environmentally friendly refrigerants has led to the introduction of HFCs and an increased use of natural refrigerants in the market. Japanese industry is now focusing on recycling resources as another way of preserving the environment. Mayekawa Manufacturing Co. has developed a cascade system using ammonia and ethane to cool used tires and plastics before milling them for reuse. This new method is expected to become an excellent replacement for conventional milling systems. Using secondary refrigeration is less expensive and has considerable environmental advantages over previous systems.

Cooling and milling: the 'old' way

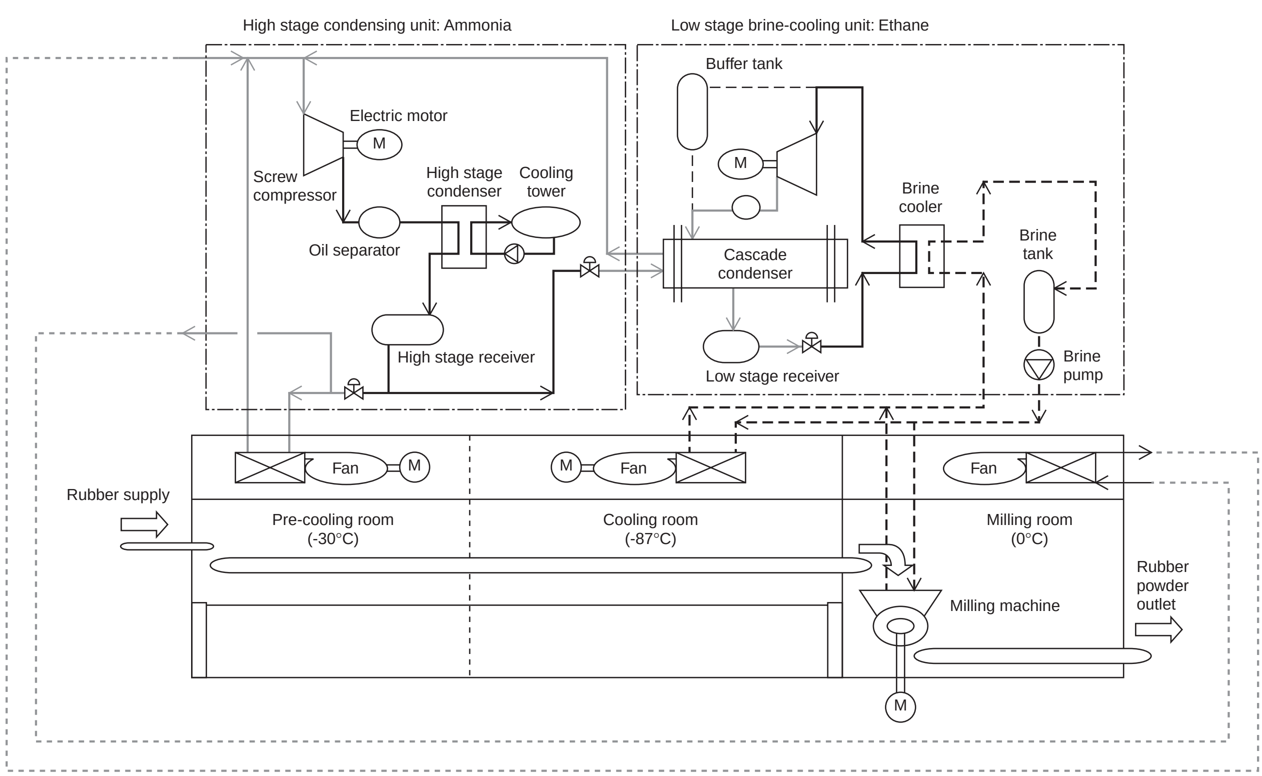
Worn tires and plastics can be recycled for use as a combustion additive.
To increase efficiency and improve recycling, the materials are milled into powder form. Cooling rubber and plastics to low temperatures increases their brittleness, which makes milling easier. This also makes fine milling a lot cheaper. Conventional milling systems use liquefied nitrogen for the cooling process but, because the nitrogen is released into the atmosphere, large amounts of this gas are needed, resulting in high running costs.

The new refrigerating system

The new system consists of a cascade refrigerating system working with two different refrigerants: ethane and brine (see figure) in the low stage and ammonia in the high stage. **Figure 1** shows a diagram of the system.

The system uses plate heat exchangers and a limited, optimized refrigerant charge to realize evaporation temperatures as low as –100°C. The pilot plant uses brine as a secondary refrigerant to cool the rubber.
A jet-flow-type freezer (cooling room at -87°C) cools the used tires and plastics

▼ *Figure 1: A cascade cooling system using natural refrigerants*



below the glass temperature. The brine also cools the milling machine in order to prevent the materials from melting during the milling process.

Cascade specifications

Table 1 shows the specifications of the cascade system in the new pilot plant. The system has a refrigerating capacity of 45.7 kW at an evaporation temperature of -100°C (low stage). Ammonia is the working fluid in the high stage of the plant. It cools the pre-cooling room, the milling room and removes heat from the low stage. The low stage uses ethane as working fluid and brine as secondary refrigerant. A plate heat exchanger cools the brine to -95°C. The brine is then supplied to the freezer and milling machine to remove the heat generated during the milling process. This heat has to be removed to prevent the materials from melting. Fans supply cold air to the milling machine.

	Low stage	High stage
Refrigerant	Ethane	Ammonia
Compressor	160VMD	FM160S
Evaporation temp. °C	-100.0	-38.4
Condensing temp. °C	-33.4	40.0
Refrigerating capacity, kW	45.7	71.1

▲ *Table 1: Specifications of the cascade system.*

Conclusion

This cascade cooling system with secondary refrigeration has developed into a strong replacement for the conventional liquefied nitrogen milling system, because it is both cheaper and friendlier to the environment. The system can also be used in other sectors that require very low temperatures, such as the medical, paint, food, and cosmetics industries.

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Cold climate can save you a fortune

Jeremy Tait, UK

For more than six months of the year, the ambient air temperature in the UK is below 5°C. Birds Eye Walls in Gloucester used this low temperature to their advantage – the ice cream manufacturer saves USD 250,000 (GBP 150,000) per year as a result. Owners of refrigeration plants should not complain about the British weather.

Low ambient temperatures: efficient cooling

In refrigeration systems, the condensers (heat exchangers) establish the so-called *head-pressure*, i.e. the pressure the compressor is required to generate. Since most UK refrigeration systems use ambient air as the coolant for their condensers, cool air could allow effective operation of the systems with very low head pressures for six months of the year. However, many plant operators ignore this potential for savings by artificially forcing their systems to be less efficient through head pressure control on their condensers. This causes the compressors to work far harder than necessary for most of the year (information frame, next page). By reducing head pressures, users could cut energy consumption, increase profits and reduce the global warming impact of their operations.

The principle of increasing profits by reducing head pressure is applicable to all refrigeration systems, regardless of size and type. Most refrigerating plants in the UK can benefit from the approach successfully demonstrated in Gloucester. Clearly, the magnitude of energy cost savings attained at Birds Eye Walls reflects the large size of the plant there.

Additional benefits

Lower head pressures have many additional benefits:

- lower discharge temperatures;
- less arduous plant operating conditions;
- more effective lubrication;
- lower levels of ‘machine stress’;
- lower bearing loads.

All this adds up to reduced maintenance costs and a longer life for the compressor.

The refrigeration plant

The company’s site in Gloucester covers over 300,000 m^2 and manufactures over 130 million litres of ice cream products per year. In 1985 the company invested USD 78 million (GBP 47 million) in a new manufacturing facility. Much of the site services were retained or extended and progressive reconfiguring of the refrigeration plant took place up to 1989.

The refrigeration plant uses an ammonia vapour compression cycle, which serves both the manufacturing processes and an extensive cold store complex. It operates at three low-temperature evaporating conditions: -45°C, -35°C and -10°C. The last of these acts as a common second stage to the two lowest temperatures, and carries some load as a single stage. There are two engine rooms with similar configurations and capacity: each 9,600 kW at the second stage. Condensing is by shell-and-tube plus cooling tower for the older plant, and evaporative condenser for the newer.

Successful reduction of head pressures

The refrigeration plant used 500,000 kWh each week, at a head pressure of 10 bar gauge. This was necessary to deliver liquid ammonia to the furthest evaporators on the site, and to ensure their satisfactory operation.

This meant that the older plant was running at up to 16 bar gauge on hot days. Engineers challenged the design specification to reduce this.

The first significant step towards changing this situation was to re-engineer the purging system away from localised manual to centralised multipoint systems. This ensured that for most of the year the newer plant would operate at up to 9 bar gauge. Very occasionally 12 bar gauge has been experienced. The indication to start this re-engineering was that the hot gas through the 18 shell-and-tube condensers of the older plant was unbalanced; some condensers received no hot gas at all. The pipework was re-engineered, the condensers overhauled and new multipoint purging installed. As a result, the more usual running conditions are 8-9 bar gauge, rather than 10.

How ambient temperature affects energy consumption

The rate at which a condenser can transfer heat depends on three factors:

a) the size of the heat-transfer-surface on the condenser: A m^2;
b) the rate at which the heat-transfer-surface can transfer heat per unit of surface area per unit of temperature difference between condensing gas and ambient air (for an air-cooled condenser). This is known as the heat transfer coefficient (U) measured in $W/m^2 °C$;
c) the temperature difference between the condensing gas and the mean ambient air temperature across condenser $\Delta T = T_{COND} - T_{A.M}$ (°C).

This relationship can be written in the form of a simple equation:

$$Q_c = A.U. (T_{COND} - T_{AM})$$

If the ambient temperature falls (i.e. T_{AM} gets smaller), the rate at which heat is extracted from the gas (Q_C) increases, thus resulting in a lower pressure in the condenser and less power absorbed by the compressor drive motor.

However, this cannot happen when some form of head pressure regulation or control is operating. Each type of control stops the head pressure from falling, even when ambient temperatures fall.

More measures

In 1991/2 the company applied Monitoring & Targeting methodology to analyse its energy consumption and reduce it by 3% per year. In 1994 the engine room control was changed to a SCADA-based system (System Control and Data Analysis, a software control package). The ensuing strategy since then has been to run as much of the condenser plant as possible to achieve the minimum operable head pressure at all times.

Continuous improvement

In 1996 the company was awarded the ISO 14001 Environmental Management standard. As the ISO standard demands continuous improvement, the objective to drive down head pressures continues. Engineers are now working on how to fulfil the minimum requirements for oil pressure differential on the high-stage machines and reduce running costs still further. A scheme is being designed to bring down head pressures to 5 bar gauge in cooler ambient conditions. Head pressures are now 3 bar gauge lower than 10 years ago. In the newer plant, savings on refrigeration energy costs have reached around USD 250,000 (GBP 150,000) per year, mostly due to head pressure reduction. The principal capital expenditure associated with this project was less than USD 50,000 (GBP 30,000).

Precautions

In recent years, advances in the design of ancillary equipment such as controls, purgers etc. have removed the necessity for costly year-round high head pressures. However, prior to embarking on a programme of lowering head pressure, a careful analysis of problems likely to arise should be carried out:

- thermostatically controlled expansion valves may need to be replaced with electronic types to facilitate effective operation at lower head pressure;
- for systems with evaporators at some distance from the receiver, which therefore require a fairly high pressure to drive liquid to them, a liquid pump could be used instead of relying on high head pressures to supply the liquid;
- plants employing hot-gas defrost often operate at high head pressures when much lower head pressures would achieve perfectly effective defrost. This is ensured by careful design of pipework to quickly clear the coils and hot-gas supply line of the condensed hot gas;
- air is a problem inside any system, but effective purging of air is particularly important for non-hermetically sealed systems operating with negative pressures.

ETSU is grateful for the cooperation of Birds Eye Walls in compiling this text.

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(Address on back cover.)

Developing a European market

Hermann Halozan, Austria

The first oil crisis in 1973 showed most industrialised countries the vulnerability of their trade and industry and their dependency on imported energy. Five years later - despite higher energy costs nothing happened - the second oil crisis occurred. This time it led to a more lasting reaction. Serious considerations were made both nationally and internationally on how to reduce the dependency on imported oil. This article attempts to answer the question: why European heat pump labels, certification and training programmes?

In 1980 the IEA published its 'Strategy Study', in which space conditioning was identified as having the greatest energy-saving potential that could be realised relatively quickly. Solar energy, district heating and heat pumps could save 600 million tons of oil annually by the year 2020. Heat pumps could account for around 80% of these savings.

The first oil crisis initiated the marked development of heat pumps in Japan and the US, due to their strong air-conditioning industry. Europe concentrated on introducing solar energy, mainly thermal systems for hot water production but also for space heating purposes. The second oil crisis also initiated the development of a heat pump market in Europe, though this was not as simple as in Japan and the US.

Developments in the US and Japan

When heat pumps for space heating were introduced in Japan and the US, this process was relatively simple. The main change from an air-air cooling-only unit to a heat pump was the introduction of a four-way valve to reverse the cycle. Additionally, due to different temperature levels required, the compressors, condensers and evaporators all had to be modified. However, a broad knowledge of the vapour compression cycles was available.

First heat pump developments in Europe

In Europe the situation was completely different, as air conditioning was only common in large commercial buildings. Heating was mainly via fossil-fuel-fired boilers connected to hydronic heat distribution systems. Most of these systems had been sized for design supply and return temperatures of 90°C and 70°C, which exceeded the levels supplied by heat pumps. Only new buildings had low-temperature underfloor heating systems that were suitable for highly efficient heat pump systems.

This meant that heat pumps had to be sized for heating-only operation and integrated into hydronic heat distribution systems. In other words, heat pumps were only one part of a complex system that needs to be designed carefully. The fact that the heat pump is just one part of the system caused a number of problems.

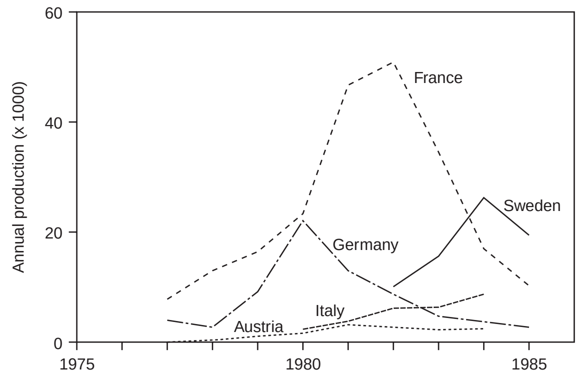
- Several companies started manufacturing heat pumps and initiating training programmes for installers. They were motivated by favourable governmental subsidies.
- Apart from the above, a number of refrigeration experts founded their own small companies. They knew how a refrigeration cycle (i.e. a heat pump unit) had to be designed, but often knew nothing about heating and hydronic heat distribution.
- Installers knew how a hydronic heating system worked, but knew nothing about the characteristics of heat pumps and how to size and integrate them into such a system.
- Electricity utilities were split into two groups:
- the larger group saw heat pumps as a competitor for direct electric heating, with the disadvantage of less electricity consumption, so they fought against this technology;
- the smaller, more farsighted group saw heat pumps as a new interesting potential market and started their own heat pump programmes. However, for many of these programmes, the main issue was not heat pumps, but improving the balance of their electricity grid.

This disastrous combination produced an initial rapid increase in heat pump sales, but ultimately resulted in a market breakdown. All parties involved failed in the introductory phase. Small companies produced unreliable products. Barely-skilled installers and salesmen offered fantastic reductions in heating costs. These factors undermined the efforts of the better companies (the majority). The most serious problem was not the market breakdown itself, but the fact that public confidence in heat pumps was totally destroyed, and will be very difficult to regain.

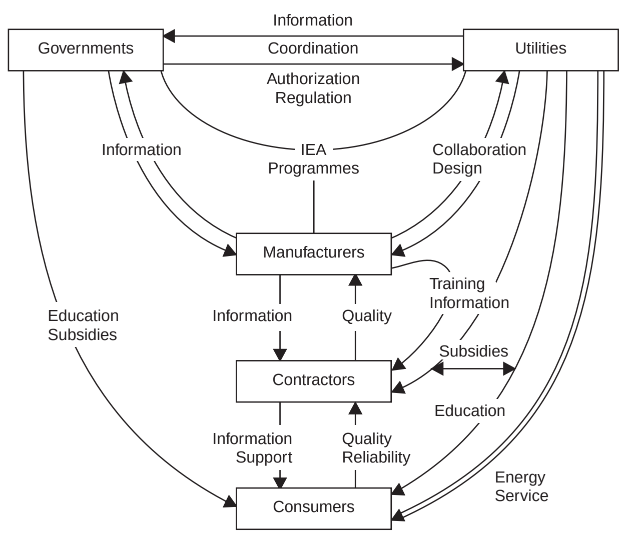
Certification initiatives

This situation is repeating itself today. The current drive to save energy is not due to the lack of energy carriers, but the environment – Kyoto. Some European countries have already started heat pump programmes. Everyone needs to work together to create a stable and lasting market.

The first goal should be to restore public confidence in heat pumps.
The first steps towards achieving this goal have been taken by D-A-CH, a collaboration between the heat pump associations of Germany, Austria and Switzerland. They have already introduced a quality label for heat pump units. This label, accepted by the utilities in the three member countries, guarantees that the customer receives a reliable product, and spare parts, maintenance and servicing are guaranteed for at least 10 years. The Austrian heat pump association (LGW) has also initiated a training programme for heat pump installers, to avoid another breakdown of the market such as at the beginning of the 1980s.
This training programme produces a pioneering certification label for installers. This should be extended under the D-A-CH umbrella or, maybe in the near future, under the auspices of a European heat pump association.
The Austrian utility association, some provincial utilities and LGW are cooperating to achieve a growing stable market. The member countries of D-A-CH have the same goal. One can only hope that these activities will be expanded over all of Europe and thus help to create a European heat pump market and industry.



▲ *Figure 1: First heat pump market development in Europe.*



▲ *Figure 2: Preconditions for a succesful heat pump market development.*

European heat pump industry

At that time (about 1980) there was no European heat pump industry comparable to that of Japan and the US. This is because the European countries all started their own heat pump programmes at various times, mainly to support the national industry (**Figure 1**). At that time the European Union was not in a position to act as a concerted group.

European countries did not realise that the domestic markets of the individual countries were too small. Even today, heat pump manufacturers are either small companies or a minor section of larger companies. Both need to be changed and, considering the market potential of the European Union (over 300 million inhabitants), this should be possible.
The first steps have already been taken. One is the European Heat Pump Network, which provides information. Further activities include the development of a European heat pump training programme and a European Heat Pump Association (EHPA). The first meeting took place in autumn 1999, with official establishment in February 2000 in Brussels. The EHPA can potentially become the starting point of a European heat pump market development.

Future steps

The consequences of increasing greenhouse gases such as CO_2 and CH_4 in the atmosphere (at least in the long term) are well known. Ice probes in Greenland show that higher CO_2 levels mean a significant increase in average temperature, resulting in climate change. The Kyoto Protocol demands less greenhouse gas emissions in order to reduce the consequences of the expected climate change. This means that we have to use our fossil fuels carefully and more efficiently. Heat pumps are one of the key technologies in achieving this goal.

If governments accept the importance of this technology, and if there is a real need to reduce CO_2 emissions according to international agreements, then heat pumps will also succeed in Europe and will contribute to a better future.

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Simulating the energetic and environmental impact of refrigeration and indoor climate control systems

Savvas Tassou and Yun-ting Ge, UK

The retail food industry faces considerable pressure from international agreements and environmental lobbies to reduce their impact on the environment. To achieve this, industries must improve energy efficiency and reduce the effect of refrigeration systems on ozone depletion. A simulation tool can be employed to assess alternative refrigeration and indoor climate control system designs, with respect to their environmental impact and life cycle cost.

The modern supermarket depends on electricity for lighting, ventilation, and above all, refrigeration for storing a vast selection of meats, dairy products, fruits and vegetables. Supermarkets are among the greatest single end-users of electricity. Their refrigeration systems account for over half the electricity used. Lighting uses about 25% and HVAC (heating, ventilation and air conditioning) equipment and other utilities take up the remainder. These systems not only contribute to global warming indirectly through CO_2 emissions at power stations. Refrigerant leakage from these systems also contributes directly to global warming. This leakage can be as high as 20% of the refrigerant charge per year.

The need for simulation

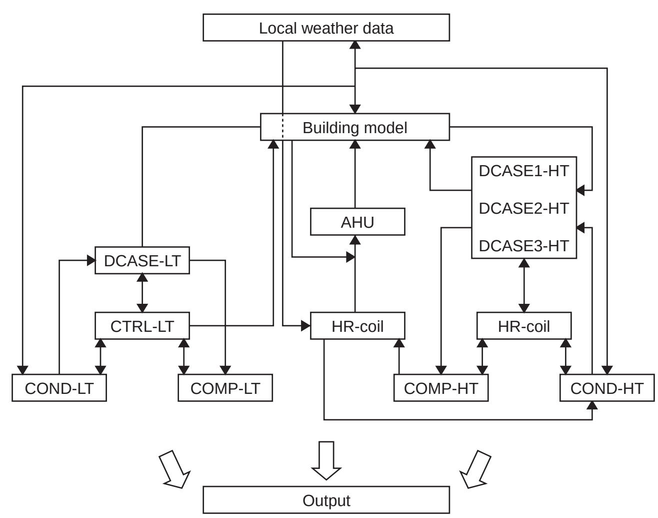
Supermarket owners are constantly urged to reduce their contribution to direct and indirect greenhouse gas emissions. Trying to satisfy legislation, the environmental lobbyists and considerations of capital and energy costs, consultants and supermarket managers are looking for more appropriate refrigerants and refrigeration systems. In deciding which is the most appropriate technology, they face the problem that no adequate simulation tools are available yet for energy analysis of retail food stores. Commercially available building simulation models can simulate the performance of the building fabric and HVAC equipment. However, in modern food retail stores there are considerable interactions between the display cabinets in the store and the space conditioning system. This interaction cannot be modelled with available building simulation tools without many additional subroutines.

The authors are currently developing a modular simulation model specific to the food retail industry. This will enable supermarket managers to make informed decisions on the design, selection and operation of cost-effective and environmentally friendly HVAC and refrigeration systems. The model will be capable of profiling the performance of alternative and innovative systems and simulating the effects of operating parameters and control strategies on the total equivalent warming impact (TEWI) and life cycle costs of these systems.

The model

The model being developed is based on the commercially available model TRNSYS. This is a modular thermal model for HVAC equipment and buildings. TRNSYS allows the user to add component models that are not included in the standard package. Because the package consists of component models, it is possible to simulate the dynamic performance of a system by collectively simulating the performance of the interconnected

▼ *Figure 1: System simulation flowchart for a high- and low-temperature supermarket refrigeration system with heat recovery.*



components. The user specifies the components that constitute the system being modelled and the manner in which they are connected.

To model a retail food store, a large number of additional subroutines need to be developed and integrated within the standard building and HVAC simulation subroutines. The model being developed consists of four major submodels.

Submodels

The four submodels are:
1. Building and HVAC system model
2. Display cabinet models
3. Refrigeration system model
4. Environmental impact and cost model (not discussed further here).

Most of the components comprising the *building and HVAC system model* (building fabric, ducts, fans, pumps, cooling coils, heating coils, boiler, heat exchangers etc.) are modelled using standard or slightly modified TRNSYS component models.

Display cabinet models include medium- and high-temperature vertical display cabinets and chest-type frozen food cabinets. These models account for the effects of both the heat and mass transfer across the air curtain and frosting on the evaporator coils.

Modelling of the centralised *refrigeration systems* such as the multi-compressor pack is based on a combination of standard component models to simulate both vapour compression and absorption refrigeration plant. A control submodel simulates the control processes in real supermarket refrigeration including indoor climate control systems. It enables alternative control strategies to be studied, including variable head and suction pressure control and PID control of the compressors and condenser fans.

The system model is also capable of modelling a wide range of primary and secondary working fluids likely to be found in supermarket refrigeration systems around the world. A flowchart is shown in Figure 1.

Current situation and future developments

In its present form the new model can simulate integral distributed and centralised direct expansion refrigeration systems and their integration with the HVAC equipment for space conditioning. The authors are currently developing and validating system models for indirect (secondary) refrigeration systems, and working on improving the user interface.

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Study on the potential for hydrocarbon replacements in existing domestic and small commercial refrigeration appliances
Available from: UNEP, Division of Technology, Industry and Economics, OzonAction Programme, 39-43 quai André Citroën, 75739 Paris Cedex 15, France. Fax: +33-1-44371459. E-mail: unep@unep.fr ISBN 92-807-1765-0. January 1999, 368 pages. Internet: http://www.unepie.org/ozonaction.html
This study helps decision makers in developing countries to weigh the positive and negative aspects of retrofitting existing domestic and commercial refrigerators and freezers currently using ozone-depleting CFCs with non-CFC refrigerants. It includes a synthesis report, the desk survey results, workshop conclusions and country-specific surveys on Indonesia, Costa Rica and Cuba.

Avoiding a double phase-out: alternative technologies to HCFCs in refrigeration and air conditioning
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This brochure contains several case studies of applications using non-HCFC refrigerants, including R-404A, R-407, R-410A, propane and other hydrocarbons.

Eliminating dependency on Halons: self-help guide for low volume consuming countries
Available from: UNEP, Division of Technology, Industry and Economics, see above. ISBN 92-807-1783-9. December 1999, 130 pages, USD 50. The publication can also be downloaded from http://194.51.235.137/ozat/tech/main.html#Selfhelp
A guidebook to assist countries using small volumes of halons to phase out unnecessary halon uses, and manage existing halon stocks to meet critical uses in a seven-step process. Annexes include key technical guidance from the UNEP Halons Technical Option Committee, sample brochures that can be adapted to a local situation, overhead presentations for workshops, and much more.

Ozone strategic information system (OASIS)
CD-ROM available from: UNEP, Division of Technology, Industry and Economics (TIE), see above. ISBN 92-807-1822-3. November 1999, USD 100.
OASIS is an easy-to-use CD-ROM-based reference system that provides essential resource material relating to the implementation of the Montreal Protocol, developed by the UNEP TIE OzonAction Programme. This release includes information on sources of assistance, alternative technologies, policies, procedures and guidelines, updated and significantly expanded.

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5th SDHK Conference 'Cold chain in food supply'
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ASHRAE Annual Meeting
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International Conference Sustainable Building 2000
22-25 October 2000 / Maastricht, the Netherlands
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IKK International Trade Fair for Refrigerating and Air Conditioning
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International Sorption Conference 2002
23-27 September 2002 / Shanghai, China
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E-mail: ISHPC@sjtu.edu.cn

IEA Heat Pump Programme events

CO_2 Technology in Refrigeration, Air Conditioning and Heat Pump Systems
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Annex 27 Workshop
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Next Issue

Heat Pump Programmes and International Heat Pump Organisations

Volume 18 - No. 2/2000

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

Novem

Netherlands agency for energy and the environment

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