IEA Heat Pump CENTRE NEWSLETTER

Volume 22
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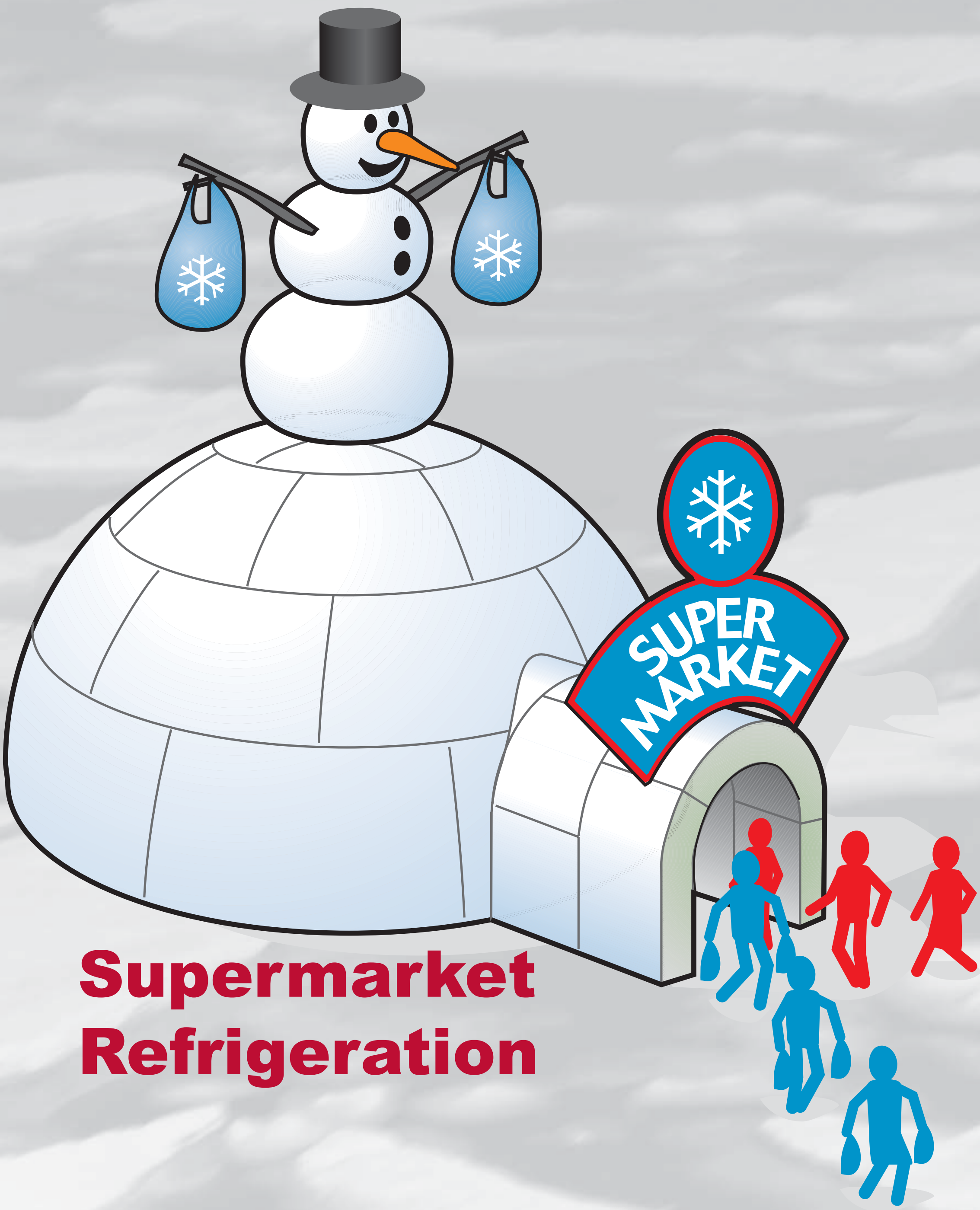
Energy-efficient super-market display cases

Energy Efficiency in Canadian Supermarkets

Optimal Control of Vapour Compression Cycles



Supermarket Refrigeration

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IEA Heat Pump CENTRE
NEWSLETTER
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In this issue

Supermarket Refrigeration

Supermarkets are very energy-intensive and the energy supply system can get quite complex, as there are needs for cooling at different temperature levels, yet there can also be a simultaneous need for heating. Supermarket refrigeration systems received considerable attention during the 21st IIR Conference in Washington in 2003, where the Heat Pump Centre took part in a workshop on this topic. Points of particular interest in this field are the question about direct or indirect systems, energy-efficient components such as display cases, integration of systems, and also how to reduce refrigerant leakage which, according to several of the authors in this issue of the HPC Newsletter, is large.

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Supermarket refrigeration systems

Van D. Baxter
Oak Ridge National Laboratory
USA

Supermarkets are among the most energy-intensive commercial buildings. Significant energy is used to maintain chilled and frozen food in both product display cases and storage rooms. The refrigeration systems also produce a large amount of rejected heat that can be recovered and used by heat pumps or other equipment to provide space and water heating for store requirements. Supermarkets in IEA/HPP countries range widely in size from about 500 m2 to 6000 m2 or more. Similarly, plant capacities range from 30-60 kW for small markets to over 400 kW for the largest stores. Annual energy use ranges from about 100,000 kWh/y for the smaller stores to 1.5 million kWh/y or more for the largest.

Most supermarkets today use the multiplex direct expansion (DX) refrigeration system, characterized by centrally located compressors with long connecting lines to display cases and storage rooms and large refrigerant charge - typically 4-5 kg/kW of refrigeration capacity. These systems must be field-assembled and have many individual connection joints between compressor racks, condenser units, cases, rooms and connecting lines. Each joint is a potential source of refrigerant loss and loss rates for older systems can be over 30% of total charge annually. As a result the total equivalent warming impact (TEWI; a measure of equivalent CO2 emissions from the combined impacts of energy consumption and refrigerant losses) for a single large system can be over 1.6 million kg of CO2 annually. For comparison, this is approximately equal to the annual CO2 emissions of 300 automobiles. Manufacturers have expended much effort to improve the integrity of muliplex DX systems and annual loss rates for new systems are about 15% of charge.

New system designs with lower initial charge and lower loss rates are beginning to be implemented – multiplex DX with improved charge management controls, systems with compressors located closer to cases (shorter lines, fewer joints), self-contained units for cases & rooms, and secondary loop systems. These show potential to achieve about the same energy efficiency as multiplex DX and to reduce TEWI by 60% or more. Researchers and industry are also working to develop display cases with smaller refrigeration loads which would enable down sizing supermarket refrigeration plants and further reducing annual energy use.

This issue provides a snapshot of the considerable efforts underway to improve the energy efficiency and environmental impacts of supermarket refrigeration systems.

With best regards,

Van D. Baxter
Oak Ridge National Laboratory, USA

Columnist

Development of new heat pump technology harmonized with global environment

HIHARA Eiji
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The development of new heat pump refrigerants and high-efficiency heat pumps is closely connected with solving global environmental problems, such as stratospheric ozone layer protection and the prevention of global warming. Meanwhile, the meteoric economic rise in Asian countries is encouraging the raising of living standards in terms of both comfort and efficiency. With rapidly increasing market demand, the production of air conditioners in the Asian region has been growing at the fastest rate in the world. Heat pump air conditioners are an essential appliance affecting our life quality, with the heat pump industry playing an increasingly important role in daily life.

Since the 1973 world oil crisis, Japan's lack of indigenous energy sources has resulted in the country's national energy policy being concentrated on conservation aimed at energy security. As part of this, strict COP regulations have been imposed on air conditioners and other appliances. Taking the residential split type air conditioners with a cooling capacity of 2.5 kW or less as an example, the average COP for cooling and heating needs to be 5.27 or more. In addition, air conditioners, refrigerators and other appliances are required to be recycled in order to conserve resources, with the refrigerants in refrigerators and air conditioners also being recovered and destroyed in order to prevent the emission of greenhouse gases. However, some Japanese economists point out that these environmental regulations will have the counter-economic effect of requiring manufacturers to make substantial environmental investments, barring the market entry of overseas companies and reducing the competitiveness of the Japanese heat pump industry in the international market. On the other hand, environmental investment in the heat pump industry will continue in the future.

The following products have been developed as part of new heat pump technology in Japan: hot water heat pumps using carbon dioxide as the refrigerant, gas engine-driven heat pumps, multi-air-conditioners for commercial buildings using R410A as the refrigerant and triple-effect absorption chillers/heaters. To support this technology, the Japanese Government pays a certain amount of subsidies for the development and promotion of those new products that contribute to the reduction of energy consumption and greenhouse gas emission.

However, minimisation of the global environmental effects of heat pump technology requires well-established methods of appraisal of heat pump operation and performance. Life cycle assessment of heat pumps indicates that the in-use power cost of heat pumps accounts for 90 % of their entire impact, and so corresponding appraisal methods for energy consumption are needed. However, there are some problem areas in the present methods. For example, although the variable-speed compressor controlled by an inverter shows outstanding partial-load performance, the present industrial standard is unable to take account of this characteristic. Further, no suitable method has been worked out to predict the partial-load energy consumption of direct-expansion multi-air-conditioners connecting two or more indoor units. Meanwhile, Annex 28 of the IEA heat pump program is examining the performance appraisal method of heat pumps used for hot-water supply and space heating. In Japan, a heat pump for combined hot water supply and space heating, using carbon dioxide as the refrigerant, has been successfully developed, and is considered as a key technology for reducing domestic energy consumption. However, without a suitable appraisal method available at present, the comparison with conventional oil- and gas-fired water heaters is still under investigation.

In summary, for developing new heat pump technology with overall minimum environmental impact, it is essential to develop suitable performance appraisal methods and to re-examine existing international standards.

HIHARA Eiji
Professor
Institute of Environmental Studies
University of Tokyo, Japan

General

Denmark leaves the IIR

Denmark – The Danish government has decided to withdraw Denmark's membership of the International Institute of Refrigeration (IIR), starting from 2005, despite heavy protests from the refrigeration industry and the research community in Denmark. The withdrawal will isolate Denmark from a lot of research and development activities, and also reduce Denmark's ability to influence international development. This is because, if Denmark is not a member, companies and institutions in Denmark cannot participate in the work of IIR.

"In Denmark we have two of the world's largest companies within the refrigeration sector – Danfoss and York. Therefore it will be a great loss if these two large innovative corporations lose their impact on the global market – just because the government will not pay the DKK 120 000 membership fee", says Lau Vørs, head of secretariat for the Danish Refrigeration Association (Dansk Køleforening).

This issue will probably not end with this – the Danish Refrigeration Association, Danfoss, York and the Technical University of Denmark (DTU) will work for continued membership within the IIR.

Source: Scandinavian Refrigeration, no. 5, 2004

Effective deployment of renewable energy technology

A new Implementing Agreement focusing on renewable energy technology deployment has been launched within the International Energy Agency. Members are Denmark, France, Germany, Ireland, Italy and Norway. These countries, with input from the European Commission, will work on ways to overcome barriers, promote enhanced strategies and encourage investments.

Source: IEA Open Energy Technology Bulletin, no. 20, 2004

China regulates air conditioner efficiency

China – Three national standards for energy efficiency of air conditioners have been approved. The aim is to reduce power consumption of air conditioning equipment, which at present accounts for 15 % of national power consumption. The standards that will take effect in March 2005 categorise air conditioners into five levels, and any air conditioner falling below the lowest level will be banned from the market.

Source: ASHRAE e-Industry, 23 September, 2004

Cool change in USA

USA – The Environmental Protection Agency, EPA, has launched a campaign called "Cool Change", designed to encourage Americans to save energy, money and the environment by increasing energy efficiency of home cooling systems. EPA offers tips such as replacing air filters, checking and sealing duct systems and replacing old cooling equipment with high-efficiency Energy Star®-qualified equipment. This program helps businesses and individuals to protect the environment by using efficient equipment that will use less energy and thus contribute less to air pollution. EPA estimates that by using energy-efficient heating and cooling equipment homeowners can reduce their annual cost for heating and cooling by 20 %.

Source: the Air Conditioning, Heating and Refrigeration News, August 30, 2004

Greenhouse gas emissions decline in the EU

EU – Greenhouse gas emissions from the EU's 15 pre-2004 member states dropped by 0.5 % between 2001 and 2002. This reduction is a small step towards the target of 8 % reduction within the next eight years. Compared to the base year of the Kyoto Protocol, 1990, the reduction is almost 3 %. The main reasons for this decrease are shifts from coal to gas, reduced emissions from manufacturing industry and reduced emissions from heating due to warm weather in many European countries.

Despite these reductions, the EU still has a long way to go to reach the projected 8 % reduction by 2008-2012. If the reductions had followed a linear path, the overall reduction should have been 4.8 % by 2002. Only four countries (Sweden, France, Germany and the UK) are on track without use of the Kyoto Protocol's trading scheme.

However, since 2002, several EU and national initiatives have been taken to reduce greenhouse gas emissions, which should accelerate progress to reach the Kyoto Protocol target.

Source: Netinform Newsletter, July, 2004

Increased interest for heat pumps in the UK

UK – Energy Minister Stephen Timms launched Cornwall's county energy strategy that aims to reduce carbon dioxide emissions and promote sustainable energy, on 29th July. The wide reaching plan is signed by 80 organisations in the county that have agreed to implement the measures in the plan. Among renewable energy sources are heat pumps. Fourteen bungalows in Chy an Gweal were retrofitted with ground source heat pumps, replacing solid fuel heating systems.

Another project on implementing heat pumps is being carried out in West Lothian, where air source heat pumps will be installed in 34 homes in a first trial phase. The West Lothian Council has committed GBP 200 000 to the project.

Source: Roger Hitchin, BRE and Edinburgh News

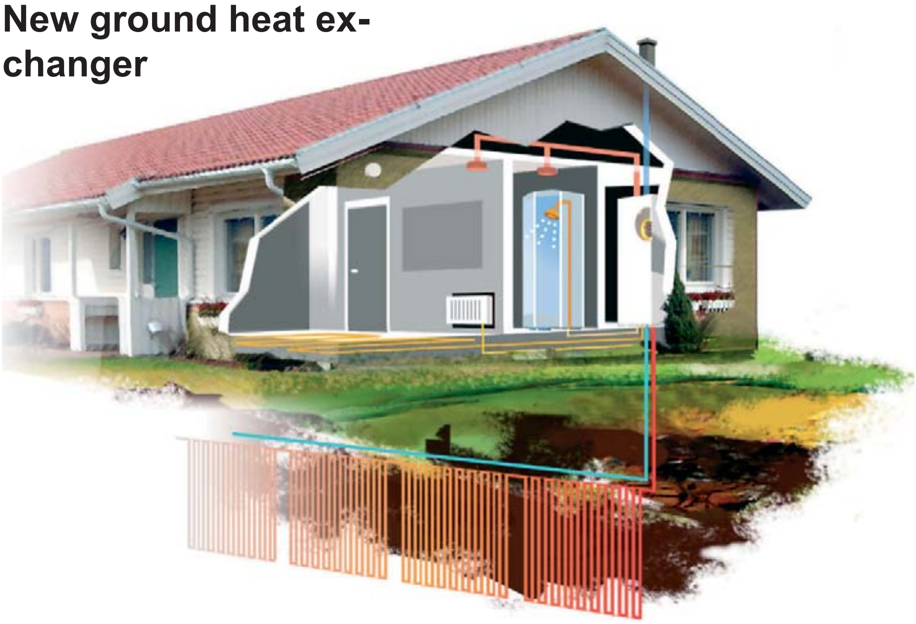
Near-zero-energy houses

USA – The US Department of Energy attempts to encourage the construction of near-zero-energy houses. These houses are air-tight, and use solar panels to generate part of the electricity needed. In addition, the houses have a heat pump water heater, geothermal systems, adaptive mechanical ventilation, cool roof and wall coatings with infrared reflective pigments and solar-integrated raised metal seam roofs. The first house built in this way has been occupied by a family of four since November 2002. The daily cost for heating and cooling with an air source heat pump was 45 cents, and the total daily cost for this all-electric house was 82 cents. As a comparison, a conventional house in the same area would use between 4 USD and 5 USD of electricity per day.

Source: ASHRAE e-Industry, 19 August, 2004

Technology & Applications

New ground heat exchanger



Sweden – Swedish heat pump manufacturer IVT has developed a new compact ground heat exchanger for use in small plots down to 40 m2, or when rock is deep below ground level. The patented compact heat exchanger is intended for use either with the company's IVT 495 TWIN unit (an exhaust air heat pump with an additional ground heat exchanger), or with the company's IVT Greenline unit (a ground source heat pump) with an additional exhaust air recovery module. The ground collector will be recharged with heat when there is no heat demand in the building, thus increasing the efficiency of the heat pump system.

Source: http://www.ivt.se

Geothermal heat pumps in German district heating system

Germany – 1700 meters under the city of Neuruppin is an aquifer layer with 60 °C salt water which, starting from next year, will be used for heating of a hotel and sports complex. The warm water will be pumped up, cooled in a heat exchanger and then returned to the aquifer again. The hotel and sports complex will use a low-temperature heating system. Gas engine driven heat pumps will be used to raise the temperature of the water supplied to the city's district heating system, which needs a higher temperature level. The geothermal heat pump system has been planned and constructed by GTH Geothermie Neubrandenburg GmbH.

Source: CCI Print no 10, 2004

Cooperation for improved efficiency

Norway – When discussing energy use in buildings, the focus tends to be on technical details or economics. However, for many applications, energy supply is very much influenced by two other factors: the design of the building, and responsibility for energy supply. Two examples from Norway show that energy use can be reduced if the same organisation is responsible for design, construction and operation of the buildings.

In these examples, the construction company Skanska Norway AS and Statoil Norway AS have cooperated from the beginning of the projects. Skanska has been responsible for construction, while Statoil has planned, operated and owned the installed energy plant. By cooperating from the start, optimum compatibility between heat distribution system and heat source could be ensured. In the first project, a new housing complex of 118 apartments with a total floor area of 8500 m2, heating was supplied by ground source heat pumps and an oil-fired boiler. The second project, which is also a housing project, consisted of 300 apartments, with heating being supplied by heat pumps and a propane-boiler.

In both of these housing complexes, each apartment has its own energy meter and is charged for its consumption. Making the residents aware of their energy use in this way creates incentives to reduce their energy use. This combination of individual energy metering, heat pumps and good insulation has reduced energy use for the second complex to 100 kWh/m2, which is 20-40 kWh/m2 lower than for the average apartment in this part of Norway today.

Source: EETIC Info Point, no. 2, 2004

Desiccant air conditioning systems

USA – Separating the cooling and dehumidification elements of air conditioning provides opportunities for both increased energy efficiency and comfort. These were some of the goals for a project where the Oak Ridge National Laboratories (ORNL) cooperated with several manufacturers in order to find high-efficiency technical solutions to independently controlled temperature and humidity levels in buildings.

Conventional air conditioners are not able to separate the cooling and dehumidification processes, with the result that users set the thermostat low in order to dehumidify the air. Compressors also tend to be oversized as far as cooling is concerned, in order to be able to dehumidify the incoming air. Air conditioners based on vapour compression cycles may even need partially to reheat the air in order not to deliver too cold air to the building. These effects, multiplied by the thousands of buildings in which they occur, waste a lot of energy and put a high load on the electricity system.

One solution to reduce this problem was found during the cooperative project at ORNL – desiccant air conditioning systems. There are different approaches in designing these systems, but the basics are the same in that the desiccant first dehumidifies the air, after which it is cooled by either evaporative cooling or a conventional air conditioner. The desiccant is continuously regenerated (i.e. the moisture is driven off from it) by some heat source, e.g. waste heat, an electric heater etc.

Two products based on this idea are already available on the market: one by SEMCO, and one by a partnership between Trane and Charles Cromer at the University of Central Florida.

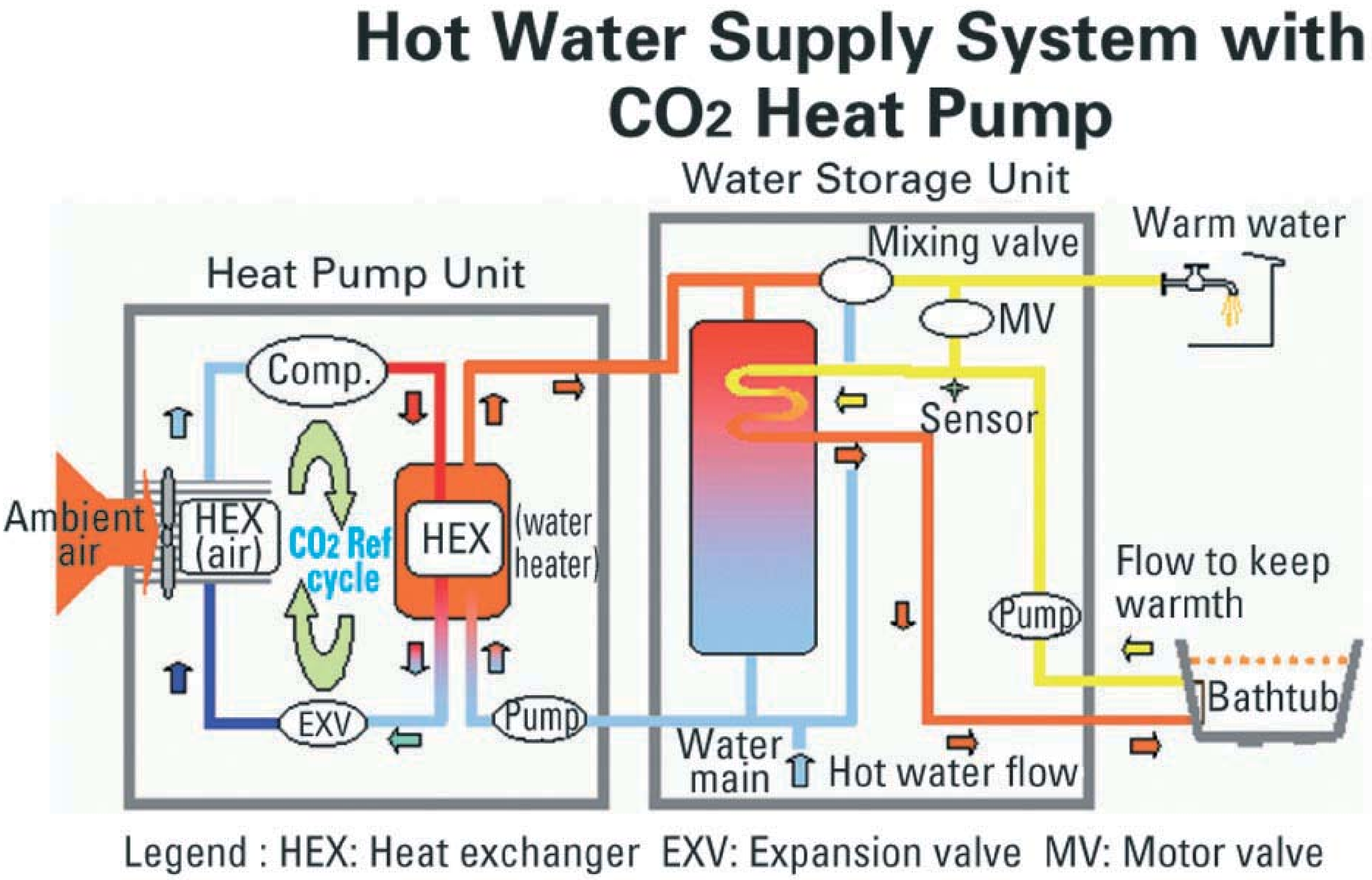
Source: http://www.newswise.com/articles/view/505686/

CO2 heat pump water heaters – ECO CUTE

Japan – The first air source CO2 heat pump water heater was developed in 2001, and the market has been steadily growing since then. 37 000 units were sold in 2002, and the estimate for 2004 is 100 000 - 110 000 units. The increased sales are due to growing environmental awareness and a government subsidy program.

The system consists of a heat pump unit extracting heat from the outside air and a storage tank for the hot water. The name ECO CUTE can be used by all electric power companies in Japan as a general name for heat pump water heaters using carbon dioxide as the refrigerant. The system is marketed by a number of companies, such as Mitsubishi Electric, Daikin, Sanyo, Hitachi AC Systems, Matsushita, Toshiba, Corona and Shofu. ECO CUTE is based on the CO2 technology developed by NTNU/SINTEF in Norway, and is licensed to the system manufacturers by the Norsk Hydro-SINTEF joint venture company Shecco Technology.

Source: JARN, no.5 & 8, 2004



Markets

Italy's air conditioning market in 2003

Italy – The Italian market for air conditioners is the largest in Europe, accounting for 25 % of the total European market. Italian production accounts for an even larger share, of approximately 30 % of total EU production. This is stated in the annual market survey by the Italian Association of HVAC Manufacturers, Anima-CoAer. The survey includes 70-75 % of the total residential split system market.

The Italian market has been increasing since 2002, for the following reasons:

- The very hot climate during the last two years.
- Comfort air conditioning is recognised by the general public, which is willing to pay for such equipment.
- Low market penetration of air conditioners in homes and small shops, only 9 %. This is a large, almost unexploited, market segment.

It should be noted that, as far as residential split systems are concerned, not many Chinese manufacturers took part in the survey for the sales statistics, which means that imports from China are not included in the figures. If they were included, it is estimated that the market approaches two million units. Further, in terms of numbers of units, there has been an increase of 46 %, but the increase in value is only 18 %. This is due to decreased prices, 15 % for single-split units and 27 % for multi-split units. Heat pumps account for more than 76 % of the units, and inverter-driven compressors are in 22 % of the units. The domestic Italian production of these systems is at its historic minimum of about 250 000 units.

However, in total, 2004 is expected to be another good year for residential systems, riding the wave from 2003 and also replacing systems installed during the late 1980s and 1990s.

Source: Eurovent/Cecomaf Review, August, 2004.

The table below shows the increase/decrease in sales for different market segments.

Market segment	*Transferable ACs*	*Residential split systems*	*Liquid chillers*
Number of units compared to 2002 (%)	*+ 47*	*+46*	*+ 3*
Value compared to 2002 (%)	*+ 48*	*+ 18*	*+ 7*
Total units in 2003	*> 220,000*	*> 1,325,000*	*?*

Chinese production of air conditioners sets new record

China – The production of air conditioners in China will hit a new record this year. For the refrigeration year starting on September 2003, the total volume of air conditioners sold by the end of May 2004 reached 36 million units. Sales during these nine months therefore already exceeded the total volume sold the previous year. Compared with the corresponding period during the previous years, sales for these nine months were 56 % higher. In addition, export sales of 19 million units exceeded domestic sales of 17 million units.

The market is now expanding so quickly that manufacturers have been unable to keep up with demand. One problem has been a shortage of compressors, and all major manufacturers have experienced difficulties in obtaining compressors. The export market has also become so large and important that the domestic supply (and particularly of 1 hp units) has suffered.

Source: JARN, no 6 & 7, 2004

Danfoss and Turbocor form joint venture

Denmark/Canada – Danfoss A/S, Denmark, and Turbocor Inc., Canada, have formed a 50/50 joint venture company called Danfoss Turbocor Compressors Inc. The new company has been formed with Turbocor's existing product line of oil-free centrifugal refrigerant compressors, its worldwide customer base and its manufacturing plant in Montreal. With this agreement, Danfoss expands its commercial compressor program with oil-free centrifugal compressors, and Turbocor can make use of Danfoss' powerful sales and service organisation. The market segments for Turbocor's compressors are the larger commercial and lighter industrial air conditioning. The compressors are oil-free with magnetic bearings, have direct-driven permanent magnet motors, variable-speed drive, two-stage centrifugal compression and fully integrated digital electronics.

Source: Scandinavian Refrigeration, no. 4, 2004

Variable-speed-controlled air conditioners increase in China

China – The use of inverter-controlled air conditioners is increasing in China. This seems to be caused mainly by the increasing problem of electricity shortage, which this summer was the most severe in 20 years. For example, in Guangzhou, the shortage reached 500-600 MW. Restricted electricity use is imposed in 24 provinces and cities in China. Consequently, in order to reduce the electricity used by air conditioners, the Chinese government is investigating the possibility of introducing a mandatory minimum energy efficiency for this equipment.

Another means of reducing electricity demand is to use inverter-controlled air conditioners. The awareness of electricity shortage among the public has increased the use of air conditioners. In addition, manufacturers have hitherto competed on price, but this is now about to change towards competition on technological development and high efficiency. This change is caused by the fierce price competition and the rising cost of raw materials.

Source: JARN, no 8, 2004

Working Fluids

Glasgow conference focuses on work on natural refrigerants

UK – 300 delegates from 35 different countries took part in the 6th IIR Gustav Lorentzen Natural Working Fluids Conference in Glasgow this August. The conference was organised by the UK Institute of Refrigeration on behalf of the International Institute of Refrigeration, and was successful in raising the profile of the UK's work to enhance the standing of refrigeration and air conditioning and in sharing the latest developments.

105 papers were presented over the four days of the conference, in addition to four short courses, four plenary addresses, three technical tours and a debate session. This was the leading international forum for the latest research and practical application of carbon dioxide, hydrocarbons, ammonia and other alternative processes. Nearly one-third of the papers dealt with carbon dioxide systems – and many of these covered a wide range of commercial applications which are already in place, as well as the progress of work on CO2-based car air conditioning.

In addition to the technical programme, delegates enjoyed a reception at the Glasgow Science Centre and Hunterian Museum, and a dinner in the magnificent Bute Hall at the University of Glasgow. Both events allowed plenty of opportunity for networking between the international delegates.

Robert Heap, Conference Chairman

For those who missed the conference, papers and presentations from the plenary and short courses are available on the CD-ROM of Conference Proceedings, priced at £35+VAT (see the Institute's web site for details).

A full report of the questions and discussion which followed the papers will be posted on the web site, www.ior.org.uk/gl2004.

The next Natural Working Fluids event will take place on 29-31st May 2006 in Trondheim, Norway.

Source: Press Release, Institute of Refrigeration, 13th September 2004

F-gas regulation good for controlling HFC use

UK – Eurammon, a trade body representing the interests producers of cooling systems using natural refrigerants, claims that the F-gas Directive issued by the EU marks a first step towards a total ban on HFC refrigerants. However, the main-stream industry considers the directive to be successful in containing and controlling the use of HFCs, thus reducing their environmental impact.

Malcolm Horlick, secretary of the Air Conditioning and Refrigeration Industry Board, considers the directive to have the same aim as the Kyoto Protocol – to minimise emissions. He further points out that refrigeration and air conditioning systems add to global warming both by direct emissions and by the much greater indirect emissions from electricity generation. "In some cases, natural refrigerants will be both safe to use and more efficient, and they should be used. In other cases, HFCs may provide the best overall solution for the environment".

"Systems using any refrigerant which leak will be less efficient as a result, and will add unnecessarily to global warming".

Source: RAC, August, 2004

Matsushita shifts to HC refrigerants

Japan - In 2002, Matsushita Electric Industrial Co. released its first refrigerators using hydrocarbon (HC) refrigerants, in response to growing environmental concerns. In 2004, Matsushita will switch all its domestic refrigerators, both for the Japanese market and for export markets, to HC refrigerants.

Source: JARN, no 6, 2004

Major end users plan to reduce HFC use

Belgium - Unilever, Coca-Cola and McDonalds announced or reiterated plans to reduce their use of HFCs during the Refrigerants Naturally conference held in Brussels in July. These plans were welcomed by Greenpeace, who also presented research results indicating that if the current trends in use of HFCs in the industry continues, HFCs' contribution to global warming will increase from 1.5 % today to between 6.2 and 8.6 % in 2050.

Unilever prefers to use hydrocarbons as the alternative to HFCs, and has committed to buying only HFC-free ice cream cabinets from 2005. McDonalds has converted one restaurant in

Rajendra Shende (UNEP), Gladys Terman (McDonald's), Gino Coronato (Unilever), Rt. Hon. John Gummer MP (Chairman), Pieter van Geel (Dutch State Secretary for the Environment), Jeff Seabright (Coca-Cola), Gerd Leipold (Greenpeace)"

Denmark from HFCs, and intends to continue developing and testing during 2004 and 2005. Coca-Cola will convert to HFC-free refrigerants where cost-efficient alternatives are commercially available. In addition, by 2010, Coca-Cola's new equipment will be 40-50 % more energy-efficient than equipment was in 2000.

It was not only hydrocarbons that were discussed during the conference. Helium-driven Stirling cycle systems, thermoacoustics, carbon dioxide and solar-powered technologies were also proposed as alternatives to HFCs.

Source: RAC, August, 2004

New secondary refrigerant

A new secondary refrigerant, with the trade name of Thermera, is a solution of water and betaine. It is said to have advantages over glycol and other chemical fluids in being non-toxic, non-corrosive and environmentally safe. Thermera is a true aqueous solution, rather than a mixture, and thus does not separate out, which can be a problem with glycols, and so there is no risk of an elevated freezing point.

Source: JARN, no 6, 2004

IEA Heat Pump Programme

New publication policy for the HPC Newsletter

When the Newsletter was produced as a printed document, it was distributed free of charge within countries that participated in the Heat Pump Centre. Other customers had to pay for copies. With the move to electronic publication in 1997, there has been open access to the Newsletter on the Centre's website. However, this policy reduces the perceived value of participation in the programme and amounts to a subsidy for non-participants.

We are addressing this matter by making the long version of the newsletter only available by subscription. For customers in participating countries, this will be free – other customers will have to pay for their subscription. The short version of the Newsletter (and the website itself) will still be freely accessible to all customers, but only subscribers will be able to read the full articles in the Newsletter.

The details of how this policy is being implemented are posted on the Centre's website. Customers in participating countries will not experience any difference from how things work today. Customers in non-participating countries will purchase a subscription and access the Newsletter using a password. In case of doubt about how this policy applies in a particular case, please contact the Heat Pump Centre, which will work with the Executive Committee, if necessary, to decide eligibility.

As is already the case, Annex reports will be available to customers in non-participating countries when they are released for wide distribution, the price being higher than for customers in participating countries.

Fore more information:
Membership IEA Heat Pump Programme
Subscription Newsletter
Contact Heat Pump Centre
www.heatpumpcentre.org

All reports from Annex 27 now available

Annex 27 "Selected issues on CO2 as a working fluid in compression systems" is now finalised and the results are available from two publications, which can be ordered from the Heat Pump Centre web site, www.heatpumpcentre.org.

Selected issues on CO2 as a working fluid in compression systems - workshop Norway.
Order No. HPP-AN27-1; Published February 2001. This report contains the proceedings of a workshop (held in Trondheim, Norway, 18-19 September 2000) on CO2 as a working fluid in compression systems. The proceedings are a useful information source for all those involved in CO2 technology for heating, cooling, refrigeration and air-conditioning. The report is available as a CD-ROM only.

Selected issues on CO2 in compression systems
This is the final report from the work within the Annex, and contains results from twelve different research projects together with an extensive literature survey. The projects were carried out as independent research projects, and the findings and the results are the sole responsibility of the authors. The following projects are presented:

- Feasibility of transcritical CO2 systems for mobile space conditioning applications
- Use of CO2 and propane thermosyphons in combination with a compact cooler in a domestic freezer
- Heat transfer of carbon dioxide in an evaporator
- Correlating the heat transfer coefficient during in-tube cooling of turbulent supercritical CO2
- Heat transfer and pressure drop characteristics of super-critical CO2 in microchannel tubes during cooling
- Flow vaporization of CO2 in microchannel tubes
- Two-phase flow patterns during microchannel vaporization of CO2 at near-critical pressures
- Small oil-free piston type compressors
- Some safety aspects of CO2 vapor compression systems
- Boiling liquid expanding vapor explosions (BLEVE) in CO2 vessels: initial experiments
- Experimental study on boiling liquid expansion in a CO2 vessel
- CO2 as a secondary refrigerant (Sweden)

Norway, Japan, Sweden, Switzerland and the USA participated in this annex and this report is available to these countries only, until 11th of May 2006.

Source: Heat Pump Centre

Workshop added to the agenda of the Las Vegas Conference

In conjunction with the 8th IEA Heat Pump Conference in Las Vegas, there will be a one-day workshop presenting the results from the ongoing Annexes 28, "Test procedure and seasonal performance calculation for residential heat pumps with combined space and domestic hot water heating", and 29 "Ground-source heat pumps overcoming market and technical barriers". The workshop will be held on the 30th of May 2005. More information about the workshop and the conference will be published in a second announcement and on the Heat Pump Centre web site, www.heatpumpcentre.org.

Source: Heat Pump Centre

New chairman of the Executive Committee

At the last meeting of the Executive Committee, which took place on 9-10th November in Paris, Sophie Hosatte from Canada was elected as the new Chairman, replacing Roger Hitchin from the UK. Sophie is currently working for Natural Resources Canada at the CANMET Energy Technology Centre - Varennes (Québec), where she now manages research, development and deployment programs of the Buildings Group including refrigeration and Intelligent Buildings. She is originally from France, where she performed her PhD work in physico-chemistry at the Université de Valenciennes.

Source: Heat Pump Centre and Sophie Hosatte

Sophie Hosatte, Canada

Third Working Meeting of IEA HPP Annex 28 in Yokohama

The third working meeting of IEA HPP Annex 28 took place at the Tokyo Electric Power Company (TEPCO) R&D Centre in Yokohama, Japan, in June 2004. The principal topics were the presentation and discussion of interim results of the national projects on Task 2, the development of test procedures, and Task 3, the calculation methods.

The meeting was embedded in a three-day program, which included a technical visit to the Japanese manufacturer, SANYO, and a workshop. The workshop provided an opportunity for the members of Annex 28 to meet the numerous members of the Japanese national team and more Japanese manufacturers. The delegates and the Japanese manufacturers described their work in connection with that of the Annex. Papers from the workshop are available for download under "Publications" on the Annex website at http://www.annex28.net.

The results of the work of Annex 28, the test procedure and the calculation methods, are intended as an input for international standardisation committees. The calculation method worked out in Annex 28 has, for example, been implemented by CEN in the draft prEN14335 standard. The draft has been accepted for circulation (a six-month period for technical and editorial comments), and will soon be sent out together with other revised standards in the framework of the new Directive on the Energy Performance of Buildings (EPBD). The EPB Directive comprises a set of new standards both for buildings and for building services (heating, cooling, ventilation, domestic hot water, lighting and control), and is to be implemented in January 2006. The work of Annex 28 in connection with European standardisation was presented at a workshop of the IEA HPP ExCo in November 2004 in Paris.

The time schedule of Annex 28 has been changed to suit the actual state of the national projects. Country reports on Task 2 and Task 3 are to be delivered in mid-November 2004, and the final report is due in May 2005. Final results will also be presented at a workshop, which will probably be held in connection with the 8th IEA Heat Pump Conference in Las Vegas at the beginning of June 2005.

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Ongoing Annexes

Bold text indicates Operating Agent.

Annex 25 Year-round residential space conditioning and comfort control using heat pumps	25	**FR**, NL, UK, SE, US
Annex 28 Test Procedure and seasonal performance calculation for residential heat pumps with combined space heating and domestic water heating	28	AT, CA, **CH**, DE, FR, JP, NO, SE, US, UK
Annex 29 Ground-Source Heat Pumps - Overcoming Market and Technical Barriers	29	**AT**, CA, JP, NL, NO, ES, SE, CH, UK, US

IEA Heat Pump Programme participating countries: Austria (AT), Canada (CA), France (FR), Germany (DE), Japan (JP), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US). All countries are member of the IEA Heat Pump Centre (HPC). Sweden is Operating Agent of the HPC.

Energy-efficient supermarket display cases

Van Baxter, USA

The cooling load requirements of supermarket display cases significantly impact the refrigeration system energy use. A research project is underway in the United States to develop advanced display cases with lower refrigeration loads. Project goals are to demonstrate a prototype advanced case with 10-20% lower refrigeration load and 20-25% lower energy consumption.

Introduction

Supermarkets are very energy-intensive requiring significant energy for maintenance of perishable food products in both display cases and storage refrigerators. Typical supermarkets with approximately 3700 - 5600 m^2 of sales area consume on the order of 1 – 1.5 million kWh annually for refrigeration [1]. Compressors and condensers account for 60-70% of refrigeration energy consumption. Display case and storage cooler fans and lighting, evaporator defrosting, and anti-sweat heaters (used to prevent condensate from forming on outside surfaces of display cases) account for the remainder. The display cases and coolers are the source of the refrigeration load on the system with the cases responsible for 75-80% [2].

Display cases are maintained at temperatures ranging from -32 to +2 °C, depending upon the type of product being displayed. The most common types of display cases used in the US are:

- coffin, island, or tub - often used for the storage and display of frozen or chilled meats, ice cream, and other food products in US markets;
- open vertical, single-deck (or single-shelf) - often used for display of fresh meat products in US markets;
- open vertical multi-deck (or multi-shelf) - usually used for display of medium temperature (chilled) meat, dairy, and deli products in US markets;
- vertical glass door reach-in - usually used for display of low temperature (frozen) foods and ice cream in US markets; and
- service - equipped with sliding doors in the back for access by serving people and a glass front to show product to customers.

Figure 1 illustrates the typical load components for open vertical cases. The open vertical medium temperature case type is typically the most common found in US supermarkets, constituting about 60% of the total case inventory and generating about half of the total refrigeration load.

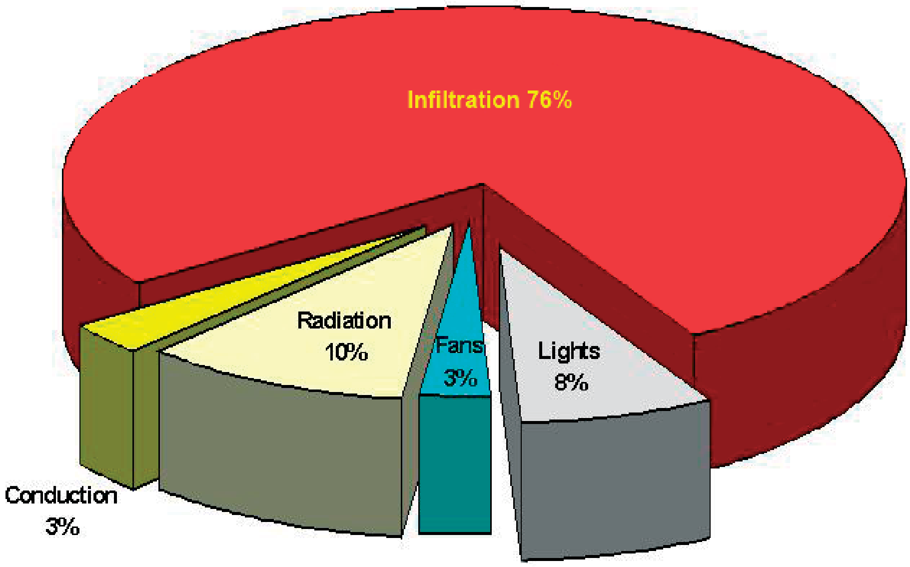

Figure 1. Typical refrigeration load percentage breakdown for medium temperature open vertical cases

Since mid-2001, the US Department of Energy, Oak Ridge National Laboratory, Foster-Miller, Southern California Edison, and a supermarket industry advisory group have collaborated on a research project to investigate the potential for energy savings through improved efficiency display cases [1]. The goals are to develop and demonstrate advanced display case(s) with 10-20% lower load and 20-25% lower parasitic energy consumption while continuing to meet maximum food temperature limits (5 °C for chilled foods). The approach has been to: establish the baseline performance of existing display cases; identify available and near-term technologies that can reduce display case load and direct energy use; evaluate energy savings potential through analysis and testing; and demonstrate these savings in a prototype high-efficiency display case. Since open vertical medium temperature cases are the most widely used, the project work to-date has been focused on that type.

Evaluation of energy saving potential

Figure 2 gives a schematic view of a typical open, vertical case showing the major components and illustrating the airflow pattern within the case. The infiltration load is caused by entrainment of store ambient air into the air curtain flow across the front of the case. In collaboration with supermarket industry advisors, energy efficiency measures (EEMs) pertaining to the air curtain (and air distribution system), the evaporator, and lighting system were selected for evaluation.

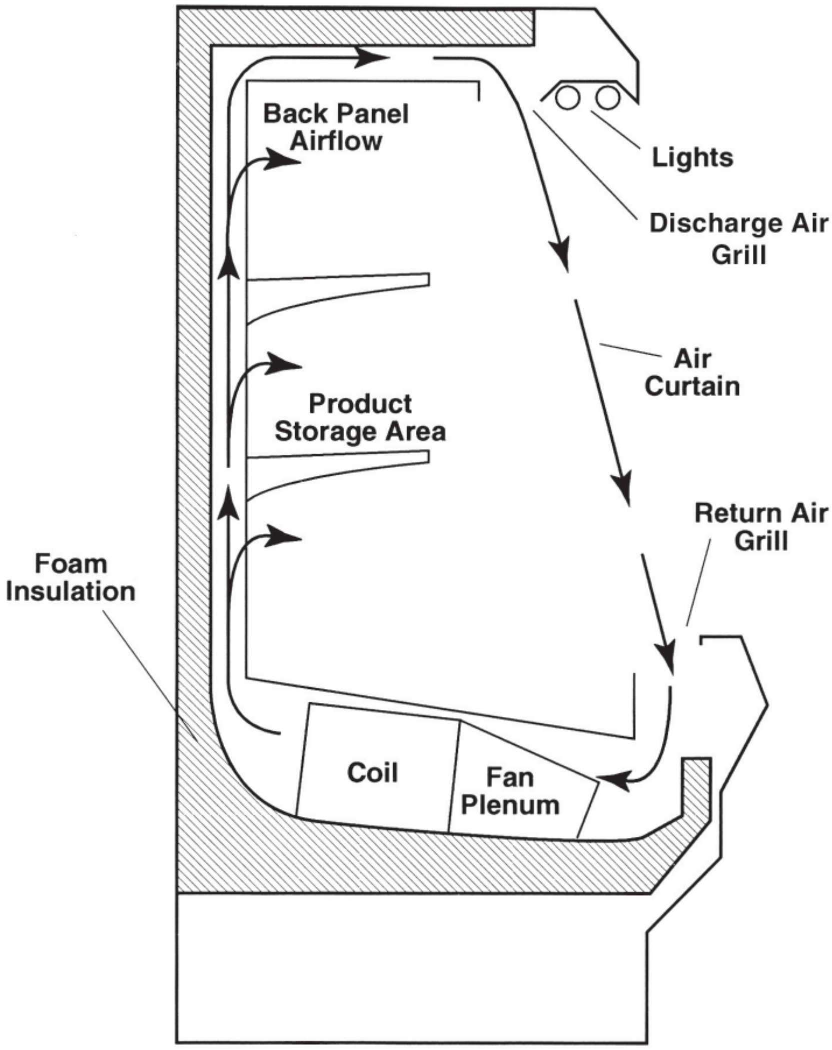

Figure 2. Typical open, vertical display case cross section and air flow pattern

The potential energy impact of employing high-efficiency display cases using these EEMs on total supermarket refrigeration energy use was evaluated using the DOE-2.3 model calibrated with field-monitored data from a single story 4740 m^2 supermarket located in Temecula, California [1]. After the calibration, baseline simulations were run at six different locations within the US. Then the display case inputs were changed to incorporate the EEMs, and the model was run to determine the impact of improved cases on refrigeration and store energy consumption.

Two combinations of EEMs were examined. The first combination consisted of:

- Improved air curtains on all open vertical display cases (assumed 20% load reduction)
- Advanced evaporators and controls (all cases)
- Scroll cage fan assembly with ECM fan motors (all cases)
- T-8 fluorescent lights with interior reflective film (all cases)
- Modular defrost

The second combination involved the same EEMs except instead of using an air curtain, glass doors were implemented on all open vertical cases. Prior research by one of the project team members has shown that adding doors can reduce refrigeration load on such cases by about 70% [3].

Table 1 summarizes the potential refrigeration energy savings for each location. As might be expected, adding doors to all open cases has a much greater impact than improving air curtains (almost a factor of 2 greater savings projected at all locations). There are however institutional barriers to adding doors. Our industry advisors indicated that there is a significant body of anecdotal evidence that shows shoppers react negatively to doors on meat, deli, and other medium temperature cases. Store merchandizing executives are reluctant to accept doors for these applications for this reason. Therefore we elected in this project to investigate improvements to air curtain technologies to offer a compromise choice and gain at least some of the load reduction potential.

Location	Baseline refrigeration energy use (kWh/y)	Savings with improved air curtain EEM package (%)	Savings with door EEM package (%)
Chicago, IL	1,387,000	14.6	27.3
Houston, TX	1,614,000	12.6	25.0
Knoxville, TN	1,497,000	14.0	27.0
Los Angeles, CA	1,519,000	14.4	27.5
Seattle, WA	1,426,000	15.7	28.4
Washington, DC	1,445,000	14.3	27.1

Table 1 - Summary of Supermarket Refrigeration Energy Savings Estimates

Case testing

A 2.4 m long, four-deck (four shelf) open vertical display case was obtained from one of our industry advisory group members for use as a laboratory baseline case. Baseline tests were performed on this case in accordance with the ASHRAE Standard 72-1998 test procedure. A small refrigeration compressor rack with three parallel scroll compressors was used to provide the necessary R404A refrigerant flow to the test case. Performance of the air curtain was evaluated to determine the baseline entrainment rate of ambient air and to identify curtain design parameter changes necessary to reduce this load. Digital particle image velocimetry (DPIV) techniques were used to determine the velocity streamlines for the air curtain flow field and boundary conditions at the discharge and return air grills to calibrate a CFD model of the display case. Parametric analyses of the flow field were then conducted using the CFD model. The primary factors affecting amount of ambient air entrainment into the air curtain were determined to be the Reynolds number (Re) and turbulence intensity (i), both evaluated at the discharge air grill (DAG). The turbulence intensity (defined as the ratio of velocity fluctuations and the mean air velocity) and Re are dependent on geometrical and airflow characteristics at the DAG.

The DPIV measurements and CFD modelling results showed that the total airflow through the case evaporator was approximately 22.1 m^3/min, with 7.9 m^3/min going through the DAG and the remainder passing through the back panel of the case into the display area to maintain the product at desired temperature. The total ambient airflow entrained in the air curtain was determined to be about 9.2 m^3/min, or 42% of the total fixture airflow; however, the net infiltrated flow that reaches the case evaporator was only about 2.8 m3/min, or 13% of the total fixture airflow. The entrained air mixed with the curtain air, but a large portion of the mixed air spilled out of the case into the test room. This phenomenon is responsible for the cold aisle effect seen in stores. The baseline case air curtain Reynolds number was determined to be approximately 4200 and its turbulence intensity about 18%. In order to achieve the desired case load reduction goal it was determined that a 30% reduction in ambient air entrainment would be required. A reduction of the Reynolds number to 3200 and the turbulence intensity to 2% were concluded to be the preferred means to reduce ambient air entrainment.

An initial redesign of the case DAG was developed from the baseline air curtain evaluation and incorporated into a prototype advanced case. Also included in the prototype were an improved evaporator, higher efficiency fan and fan motor, and an improved lighting system. Test results for both the baseline and first prototype case are compared in Table 2

The case energy use reduction results were encouraging. However, the load reduction is less than expected and the maximum food temperature was 0.3 °C higher than acceptable. Work is ongoing to evaluate the first prototype test results and develop a second DAG redesign to achieve the load reduction. A second prototype case with the new DAG will be built and tested. Future tests will be controlled to ensure that product temperature is maintained as nearly as possible to the same value as for the baseline case.

Conclusions

Analytical modelling results suggest that implementation of display cases with 20% reduced load and similar reduction in parasitic energy use could reduce supermarket refrigeration energy consumption by about 14%. An effort to develop technology for advanced cases has shown good progress in energy reduction but work still remains to achieve the load reduction goal. Success will enable future supermarkets to install significantly smaller refrigeration plants with reduced peak electric kW demand, annual energy use, and investment cost.

References

[1] D. H. Walker, R. T. Faramarzi, and V. D. Baxter. "Investigation Of Energy-Efficient Supermarket Display Cases," paper #ICR0507, Proceedings of the 21st IIR International Congress of Refrigeration; Washington, DC August 17-22, 2003.

[2] D. Westphalen, et al, Energy Savings Potential for Commercial Refrigeration Equipment, prepared for US Department of Energy, June, 1996.

[3] Faramarzi, R., B. Coburn, and R. Sarhadian, "Performance and Energy Impact of Installing Glass Doors on an Open Vertical Deli/Dairy Display Case," ASHRAE Transactions 2002, V. 108, Pt. 1, 673-679

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Case	Refrigeration load	Fan power	Lighting power	Compressor power	Total energy use	Maximum product temperature
Baseline	3.53 kW	0.115 kW	0.112 kW	1.46 kW	37.6 kWh/d	4.2 °C
First prototype	3.47 kW	0.093 kW	0.089 kW	1.05 kW	26.9 kWh/d	5.3 °C
% change	2% reduction	19% reduction	21% reduction	28% reduction	28% reduction	1.1°C increase

Table 2. Comparison of baseline display case and first prototype advanced case

Comparative analysis of direct and indirect systems in commercial refrigeration - A case study

Denis Clodic, France

Introduction

Commercial refrigeration systems for large and medium size supermarkets are recognised as highly emissive systems: typically, emissions range from 15 % to 30 % of the refrigerant charge per year. Progress is being made, but long refrigerant lines between the machinery room and the sales area introduce a number of factors that lead to these significant emission levels.

In order to limit refrigerant emissions, indirect systems are seen as a key means of reducing the refrigerant charge and avoiding any emissions in the sales area. Indirect systems also allow a wider choice of refrigerant, but one significant issue remains: are these systems as efficient as direct expansion systems?

Measurements on one direct and one indirect systems in a hypermarket

In France, several retail chains have developed the concept of very large supermarkets, under the name of hypermarkets. The sales areas vary from 5,000 up to 25,000 m². Usually, the food section represents from 25 to 40 % of the total sales area. In the machinery room, several racks of compressors are used for two different temperature levels:

- a medium temperature for preserving fresh food; the evaporating temperature in the machinery room varies between –10 and –15 °C, and
- a low temperature for frozen food and ice creams, with an evaporating temperature in the machinery room varying between –35 and 40 °C.

A measurement campaign has been launched for a precise comparison between indirect and direct systems. The first comparison is being performed on an open medium-temperature (MT) display case, in which the product temperature has to be precisely maintained between 0 and +2°C, and on a large ice cream 'island' with a temperature around –20 °C.

Dummy instrumented products (made of Tylose) have been installed into these display cases in order to monitor the temperature level of the products. Temperatures in the liquid line (before the expansion valve), and at the evaporator outlet are continuously measured. In the machinery room, low and high pressures are measured on the suction and discharge lines respectively of compressors, as well as the respective temperatures. The electric power required by the compressors is also measured. The outdoor and ambient temperatures, as well as the temperature in the sales area near the display cases, are also recorded.

Indirect system design

As shown on Figure 1, the LT compressor of the indirect system releases its heat of condensation to the MT heat transfer loop. This design permits low compressor ratios for the LT compressors, and also allows the heat released by the LT system to be used for defrosting the MT display cases.

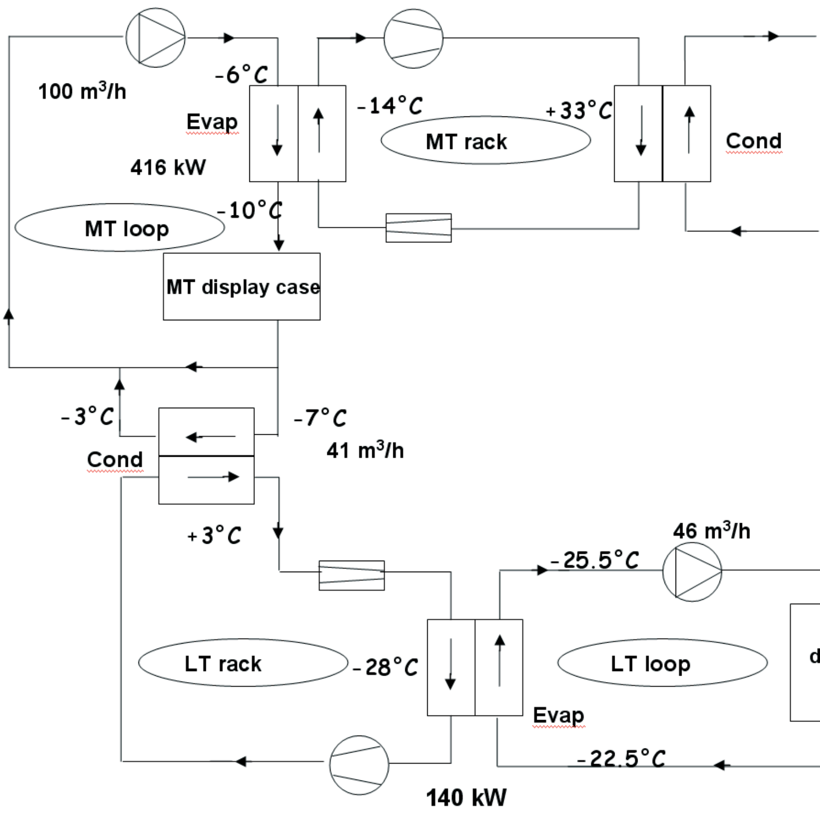

Figure 1 - Arrangement of the indirect system.

Comparison of the temperatures and energy performances of the MT display cases

The direct system has been installed recently (less than a year ago), and uses R-404A. It is up-to-date technology. As indicated in Figure 2, the outdoor temperature of a day in April varied from 7 to 11 °C, with the high pressure of the system varying from 11 to 12.5 bar because of the low ambient temperature. The evaporating temperature varied from 13.8 °C (3.8 bar) up to 11 °C (4.2 bar).

The temperatures registered in the MT display cases (see Figure 3) show that the average temperature of the product was +3 °C (varying from +2 to +4 °C). It can also be seen that there were three defrosts of approximately 15 minutes each per 24 hours, with the average temperature of the products rising by about 1 K after each defrost. When comparing the inlet and the outlet air temperatures (yellow line and pink line respectively), the air temperature differences vary from 2 to 4 K. The temperature difference is greater when the expansion valve is opened.

For the indirect system, the average temperature of the products varied from 0 to +3 °C (see Figure 4). The temperature of the blowing air varied between –6 and –2.5 °C, with a 3 K temperature difference between the air inlet and outlet. Globally, the temperatures of the products were 1.5 K lower than with the direct system.

The primary refrigerant is ammonia and the HTF is Tyfoxit 1.125. As can be seen in Figure 5, the evaporating temperature is more or less constant, at around 2.4 bar, corresponding to –14 °C. The condensing temperature is about 3 °C, corresponding to 12 bar.

Figure 2 - Suction and discharge pressures of the R-404A system.

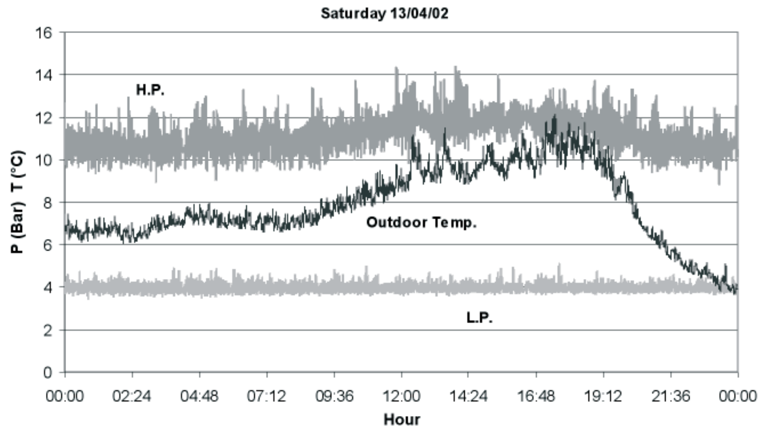

Figure 3 - Temperatures measured in the MT display-cases.

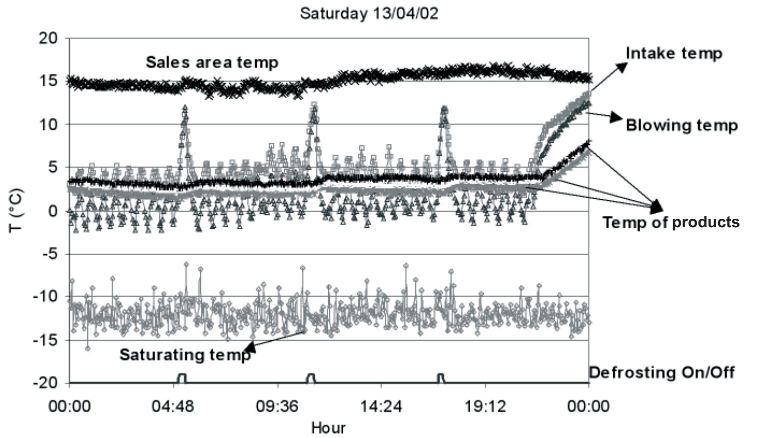

Figure 4 - Temperatures in the MT display using a heat transfer fluid (HTF).

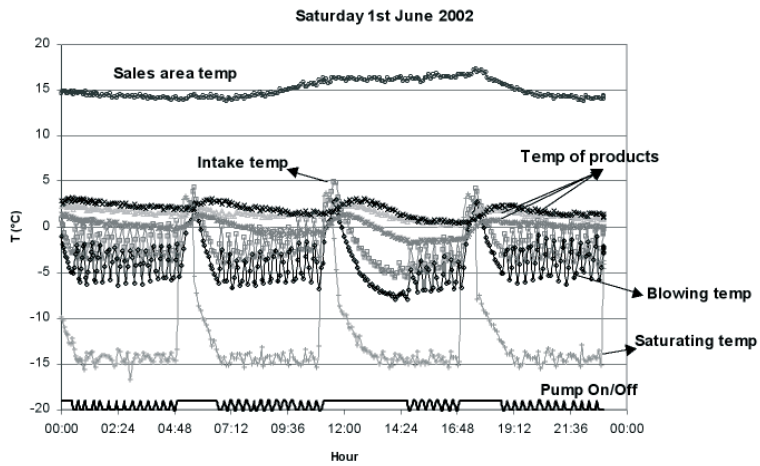

Figure 5 – Suction and discharge pressures of the ammonia system.

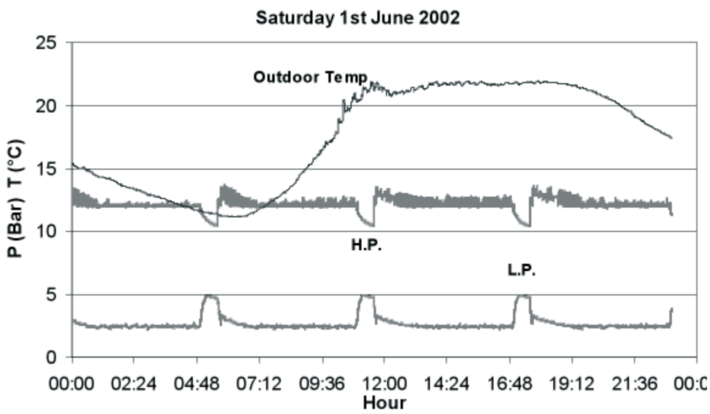

Table 1 indicates that the average temperature of the products in the MT indirect system display cases is 1.5 K lower than the temperatures of the products in the MT direct system display cases. The blowing temperatures of the MT indirect system are nearly 4 K lower than the temperature in the MT direct system.

When comparing the cooling capacities and the heat exchange surfaces, it can be clearly seen that the heat exchanger surface of the heat exchanger in the MT indirect system display case is 70 % larger than the one in the MT direct system. It can also be seen that the heat exchange coefficient of the heat exchanger using Tyfoxit is 2.5 times higher than that of the R-404A evaporator.

All these differences lead to an approximately 1.5 K lower evaporating temperature with the MT indirect system. However, taking into account the same difference of 1.5 K between the temperature of the products, the higher heat exchange efficiency and the larger surface may lead to the same evaporating temperature for the direct and indirect MT systems.

Based on the energy efficiency measurements (see Table 2), the COP of the MT direct system is significantly higher compared than that of the MT indirect system, but the condensing temperatures are different due to the difference in the outdoor air temperature. A correction can be made for the condensing temperature, assuming that the ratio of the COPsystem to COPCarnot is constant. This reduces the COP of the MT direct system from 3.23 to 2.57 when the condensing temperature increases from 22.5 to 31.5 °C. This shows that the COPs of the two systems are in the same range, but an additional energy consumption for the HTF pumps has to be taken into account, representing approximately 5 % of the compressor input power.

System	$T_{product}$ °C	Tr_{blow} °C	Tr_{intake} °C	$T_{in/out\ HTF}$ °C	$T_{evap\ comp\ rack}$ °C	P_{surf} W/m^2	$K_{average}$ W/m^2.K
Direct	+ 3	- 2	+ 2	--	- 12.5	48	3.8
Indirect	+ 1.5	- 6	- 3	- 9.5 / - 7.5	- 14	28.5	9.5

Table 1 - Comparison of the MT display cases with direct and indirect systems.

System	$T_{outdoor}$ (°C)	T_{cond} (°C)	T_{ev} (°C)	$T_{products}$ (°C)	$COP_{comp\ rack}$
Direct	8	22.5	- 12.5	3	3.23
Indirect	18	31.5	- 14	1.5	2.65

Table 2 - Temperatures and COPs of direct and indirect systems of the MT display cases.

System	$T_{product}$ °C	Tr_{blow} °C	Tr_{intake} °C	$T_{in/out\ HTF}$ °C	$T_{evap\ comp\ rack}$ °C	P_{surf} W/m^2	$K_{average}$ W/m^2.K
Direct	- 18	- 27.5	- 25	--	- 36.5	43.8	2.7
Indirect	- 20	- 22.5	- 19.5	- 25.5 / - 24	- 28	32.4	8.5

Table 3 –Comparison of direct and indirect system of LT display cases.

System	$T_{outdoor}$ (°C)	T_{cond} (°C)	T_{ev} (°C)	$T_{products}$ (°C)	$COP_{comp\ rack}$
Direct	8	30	- 36,5	- 18	1,36
Indirect	18	3	- 28	- 20	1,13

Table 4 - Temperatures and COPs of direct and indirect systems of the LT display cases.

Comparison of the temperatures and energy performances of the LT display cases

Based on the same methodology, Table 3 shows that the average temperature of the products in the indirect LT display case is lower than the measured temperature in the direct system LT display case
(20 °C compared to -18 °C).

The heat transfer efficiency is much higher for the LT indirect system than for the LT direct system. The temperatures have been measured at the same points, but the HTF heat exchanger has a heat exchange coefficient which is approximately three times higher, leading to much better heat exchange between air and the surface. The average temperature of the HTF is approximately –25 °C in the display case, and so the evaporating temperature of the ammonia in the machinery room is only 28 °C, as against an evaporating temperature of –36.5 °C for the direct system. The heat transfer efficiency and the larger heat exchange surface of the LT indirect system heat exchanger result in a difference of more than 8 K in the evaporating temperature, in favour of the LT indirect system, which is contradictory to what might be expected if no measurements had been made.

Analysing the compressor COPs, although the condensing temperature of the ammonia system is significantly lower, the COP is approximately 17 % lower. An additional energy consumption of 8 % for the HTF pumps must also be taken into account, giving a global COP of approximately 1.05, representing an energy penalty of approximately 23 % for the LT indirect system. The chosen design, where the condensing heat is released to the MT heat transfer loop, does not seems so efficient because it results in successive differences of temperatures in the successive loops.

Conclusions

Most of the heat exchangers used in LT and MT direct-expansion systems show a very poor efficiency in terms of heat transfer. Global heat exchange coefficients vary between 2.7 and 3.8 W/m².K. These very low heat exchange coefficients are due to the large fin pitch and the very low air velocity over the fins. Moreover, the average evaporating temperature is low due to inefficient control of the refrigerant mass flow rate in each display case. The variation in the surface temperature of the heat exchanger exceeds 10 K for the LT evaporator, and 6 K for the MT evaporator, due to the opening and closing of the expansion valves.

Compared with these very poor efficiencies in terms of heat transfer, the use of HTF in better designed heat exchangers leads to significant improvement of the heat transfer coefficient, in the range of 8.5 to 9.5 W/m².K, and a much lower temperature variation of the heat exchange surface, although further progress can still be made.

The designers of indirect systems have made progress in the design of heat exchangers, leading to evaporating temperatures for MT systems in the same range as those of direct systems, and higher evaporating temperatures for LT systems. Designs can still be improved, and the use of CO2 as a HTF will certainly lead to much higher heat transfer coefficients for the heat exchanger in display cases using indirect systems.

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Energy Efficiency in Canadian Supermarkets Secondary loop refrigeration pilot project in a Loblaws supermarket

Georgi Pajani, Daniel Giguère, Sophie Hosatte, Canada

Loblaws, a major chain of supermarkets in Canada, has taken the initiative to install innovative technologies at its new supermarket in Repentigny, a suburb of Montreal (Quebec). The technologies are designed to reduce energy consumption as well as greenhouse gas (GHG) emissions, while improving product quality and customer comfort. Undertaken in partnership with Natural Resources Canada's CANMET Energy Technology Centre - Varennes (CETC-Varennes), the project enabled the company to create an environmentally friendly supermarket by installing an efficient refrigeration system, integrated with the building's heating, ventilation and air conditioning (HVAC) system. This project is the first of its kind in Canada

Background

A supermarket consumes enormous amounts of energy (over 800 kWh per square metre per year) because, although it is heated, ventilated and air-conditioned like any other building, it also has a refrigeration system that keeps food cool or frozen–and that accounts for about half of the building's total energy consumption. The refrigeration systems of most supermarkets use large quantities of synthetic refrigerant (roughly 1,000 to 2,000 kg of HCFC or HFC per store), which circulate under pressure, from the refrigeration plant to the refrigerated display cases, through kilometres of jointed piping that is the source of significant leakage, estimated at 10 to 30 % a year. Although, since the Montreal Protocol, these refrigerants are now harmless to the ozone layer, they are nevertheless powerful GHGs that are 1,500 to 3,000 times more damaging than an equivalent mass of CO_2.

The refrigeration system in a supermarket is generally designed as an isolated process intended to produce cold. While most of the heat extracted from refrigerated display cases is released into the environment, the quantity involved is much greater than the energy needs of the store and could easily meet its heating and hot water requirements, even on the coldest winter days. Another operational feature of the refrigeration system is that it releases its heat at temperatures above 30 °C, a level adapted to the climate in the southern U.S., but not designed to take advantage of the Canadian climate.

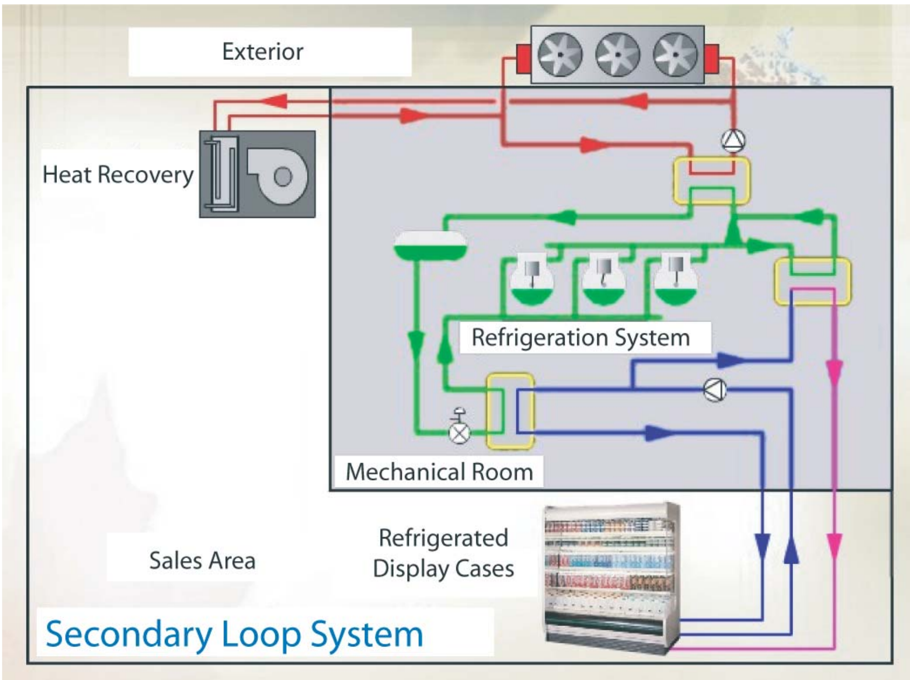

Figure 1: Secondary-loop system

Demonstration project

CETC-Varennes and Provigo/Loblaws cooperated closely on this demonstration project to implement the following strategies at Repentigny: refrigeration system and synthetic refrigerants confined to the refrigeration plant; cold distribution via two secondary loops; integration of the refrigeration system with the HVAC system (integrated HVAC&R) and heat recovery via a secondary loop; variable condensation pressure (floating head pressure).

As shown in Figure 1, two secondary fluids – potassium formate for low temperatures (around 28 °C), and propylene glycol for moderate temperatures (around –6 °C) – which have no environmental impact, are cooled by the refrigerant through a heat exchanger. They then circulate through pipes from the refrigera-

Figure 2: Suction by low-temperature compressors

tion plant to the refrigerated display cases at low pressure, thus reducing the possibility of leaks. The use of another secondary fluid (ethylene glycol), on the heat rejection side of the refrigeration system, makes it easier to recover the superheat energy from the compressor as well as the condensation heat to be used to meet the heating and hot water needs of the building. Finally, the HVAC-R system is managed in such a way as to take advantage of the Canadian climate. This means that the system – specifically the condensing temperature – is optimised on the basis of two criteria: heat load (recovery) and outside temperature, thereby offering another means of improving energy performance.

The integrated secondary-loop HVAC&R system (see Figures 2 and 3) makes it possible to reduce the amount of synthetic refrigerant by about 80 % relative to quantities used by conventional supermarkets. As shown in Figure 4, the project is expected to reduce energy consumption by 18 % and GHGs by about 75 % relative to conventional supermarkets of equivalent size. This decrease in GHGs corresponds to emissions from 430 family-size cars per year. The system also has other benefits: ease of operation and maintenance, more stable food temperatures, resulting in improved product quality and longer conservation times, and added comfort for store customers.

Figure 3: Secondary fluid pumping system for heat recovery

	Units	Typical supermarket	Pilot supermarket	Reduction
Energy consumption				
Total	kWh eq./yr	9,450,000	7,750,000	18%
Refrigeration	kWh eq./yr	4,210,000	3,450,000	18%
Heating	kWh eq./yr	1,700,000	205,000	88%
Synthetic refrigerants – charge				
Charge	kg	1,500	300	80%
Leaks	kg/yr	250	10	96%
Energy saved	kWh/yr		2,255,000	24% of total consumption
				38% of HVAC-R
Reduction in GHG emissions	**kg eq. CO_2 /yr**		**2,000,000**	**73%**

Figure 4: Projected impacts

The 10,000-square-metre (102,000-square-foot) Loblaws supermarket in Repentigny opened for business on April 28, 2004, and the integrated HVAC&R system has been operating successfully. Using the installed instrumentation, CETC-Varennes will monitor and analyse system performance for at least a year.

Refrigeration Action Program for Buildings

The project is part of the CETC-Varennes Refrigeration Action Program for Buildings (RAPB). The RAPB is funded through the Climate Change Plan for Canada which, in keeping with the Government's commitment under the Kyoto Protocol, aims to reduce GHG emissions in Canada. The goals of the RAPB are to reduce GHG emissions by 1.6 Mt of CO_2 equivalents a year, and energy consumption by 1,700 GWh equivalents a year by 2012, in the supermarkets, ice and curling rinks of Canada. Information activities, capacity building and demonstrations, and the development of constructive partnerships, will make these goals a reality.

In conclusion, it is interesting to note that the substantial environmental benefits to be achieved through this new approach to designing refrigeration systems require no specific expenditures, because the energy savings finance the entire investment within a time frame acceptable to the owner.

Acknowledgements
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Development of Integrated "Convenience - Pack" System for Cooling, Freezing and Air Conditioning

Kenji Miyata, Kenji Tanimoto, Hiroto Nakajima, Japan

After investigating the conventional packaged systems used for freezing, cooling and air conditioning in convenience stores, we successfully integrated these three functions into a single unit and achieved a reduction of 50 % in annual energy consumption. The utilization of exhaust heat from freezing and cooling processes as a thermal source for space heating has greatly contributed to the energy saving. In addition, we confirmed that the newly developed system is effective in lessening ecological impact, and we are confident that this technology will reduce the environmental loads.

Background of development

Up to now, researchers and engineers have devoted themselves to the technological development of high performance and efficiency for freezing, cooling, and air-conditioning units. Emphasis has therefore been mainly on the components of refrigeration systems, such as compressors, heat exchangers and fans. However, with the advancement of science and technology, further substantial improvements in efficiency become increasingly difficult. We therefore restarted our work from scratch and investigated existing systems from the viewpoint of product customers. We also realised that the three functions coexisting in the three separate units could be integrated into a single unit. With further consideration of thermodynamic cycles, we were convinced that we could break the record for energy efficiency in such a newly developed system. It is not possible to achieve such a high efficiency in conventional package systems with three separate units.

However, even if it was theoretically practical, we needed to identify specific markets so that we could develop products with an appropriate balance of capacities. Of various possible markets, we targeted convenience stores for the product development, for the following reasons:

1. Freezing, cooling and air conditioning usually coexist in all seasons and in the same store. Regarding air conditioning, space cooling is required in summer and space heating in winter.

2. Most convenience stores are open around the clock throughout the year. With an average business area of approximately 100 m2, the energy consumption per day in both summer and winter is quite large, around 480 kWh.

3. Over 60 % of the energy in a store is consumed by the coolers, freezers and air conditioners.

4. Following the change in lifestyle of Japanese people, the number of convenience stores in Japan is increasing every year (about 37,000 stores at present in Japan), and it is urgent to cut down their energy consumption.

5. Since the design of a convenience store is standardised, it is technically feasible to balance the capacities of cooling, freezing and air conditioning.

Features

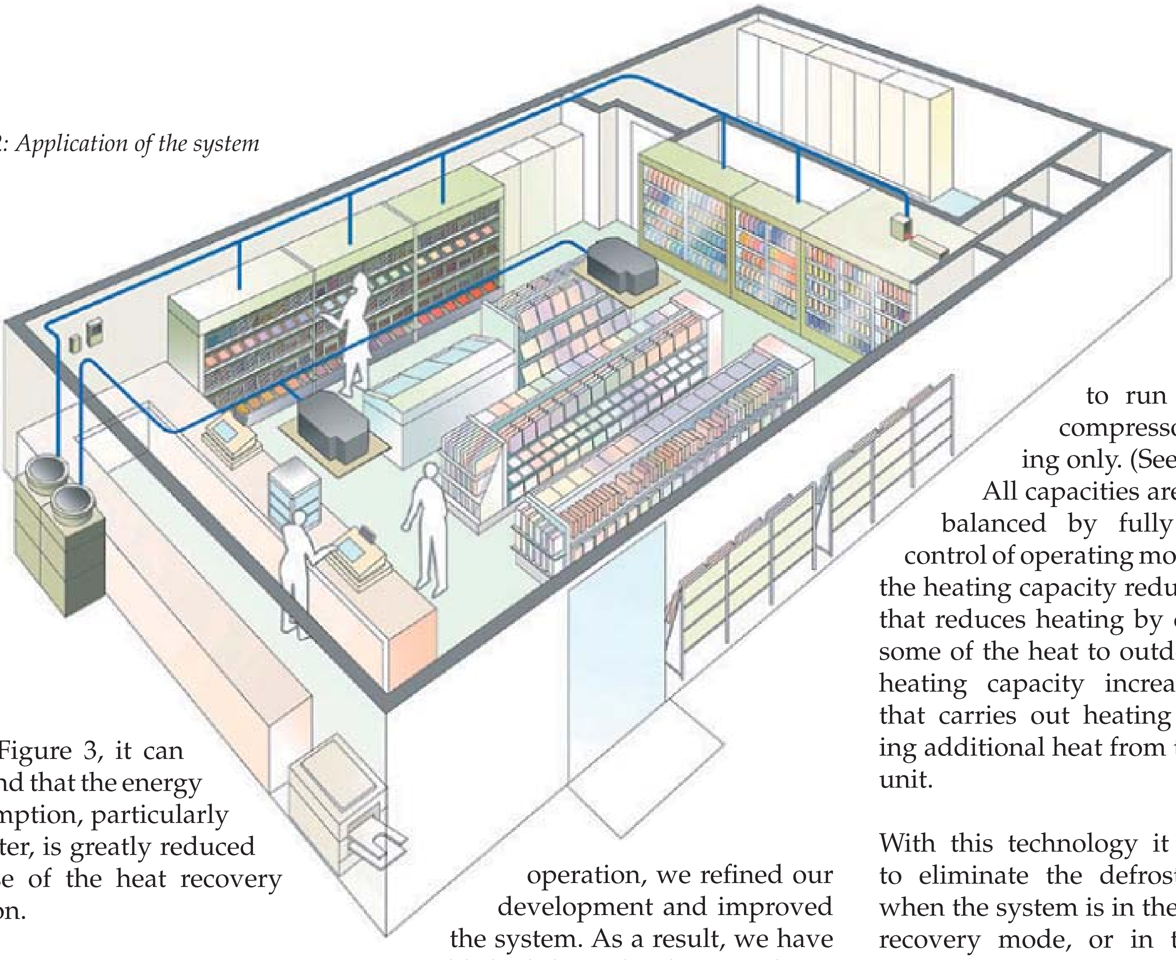
A reduction of 50 % in power consumption was mainly achieved by adopting the heat recovery function: the heat discharged from freezing and cooling processes is used for space heating in winter. The conventional system for a convenience store requires a total of four outdoor units: one for freezing, one for cooling and two for air conditioning: this newly developed system requires only one outdoor unit. Figure 1 shows the outdoor unit of the Convenience-Pack system, and Figure 2 shows the schematic of the system installed in a store. Its energy saving and ecological details are as follows:

Figure 1: Outdoor unit of the system

1. Energy-Saving Simulation

Calculations based on Japanese climate conditions, indicate that energy consumption should be cut by 20 % in summer, 60 % in winter, to produce an annual average of 50 % (see Figure 3).

Figure 2: Application of the system



From Figure 3, it can be found that the energy consumption, particularly in winter, is greatly reduced because of the heat recovery function.

2. Ecological aspect

CO_2 emissions can be reduced by half, according to the energy saving result. The amount of reduction of CO_2 emission per store was estimated to be 13.3 tonne per year (0.29 kg-CO_2/kWh assumed). In addition to the reduction of greenhouse gas emission, the improvement is also beneficial to the ecological aspects. The number of outdoor units is reduced from four to one, and the total weight of raw materials is reduced by 55 %. Of the peripheral materials, refrigerant piping is reduced by half, and the system installation space is reduced by 62 % (see details in Figure 4).

Technical Outline

Daikin Industries have successfully developed an integrated system for convenience stores. In developing this technology, we used two test methods: one being the normal measurement in a thermostatic test chamber, and the other being field tests in an actual convenience store. Based on the test data from the actual store in operation, we refined our development and improved the system. As a result, we have established the technology to obtain high efficiency and high reliability that can sustain around-the-clock operation with following features:

1. **Heat recovery**

The heat recovery is achieved by using the condensation heat from cooling and freezing processes. This provides space heating without the need to run a separate compressor for heating only. (See Figure 5.)

All capacities are constantly balanced by fully automatic control of operating modes, such as the heating capacity reduction mode that reduces heating by discharging some of the heat to outdoors, or the heating capacity increasing mode that carries out heating by collecting additional heat from the outdoor unit.

With this technology it is possible to eliminate the defrost operation when the system is in the 100 % heat recovery mode, or in the heating capacity saving mode. As a result, indoor comfort can be considerably improved. Normal defrosting procedures remove the frost formed on the outdoor heat exchangers by interrupting the heating operation, which means that the supply of heat to the indoor space is interrupted and so the indoor temperature drops. Even in the heating capacity increasing

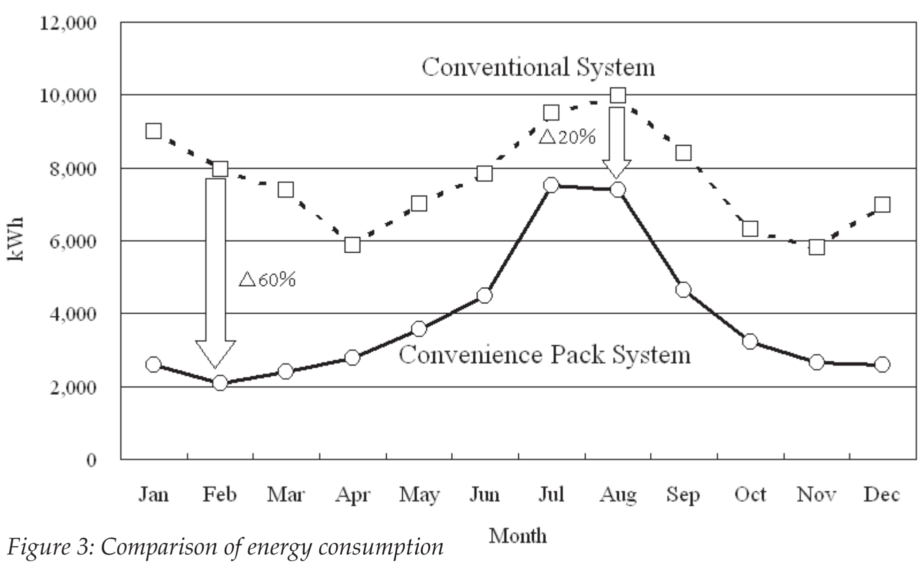


Figure 3: Comparison of energy consumption

	Convenience Pack Integrated System	Conventional System Freezing / Refrigeration / Air-conditioning
Number of Outdoor unit	1	4
Weight	Decrease 55% (330kg)	100(730kg)
Use of metal	Cu : decrease 63% Fe : decrease 43% Al : decrease 55%	100
Refrigerant charge	decrease 39%(26kg) R407C	100(43kg) R22
Manufacturing energy input	decrease 29%	100
Installation space	decrease 62%(2.20m2)	100(5.76m2)
Refrigerant piping (Between indoor and outdoor)	decrease 50%(4)	100(8)

Conventional system indicates the sum of four outdoor units.

Figure 4: Comparison viewed from ecological aspect

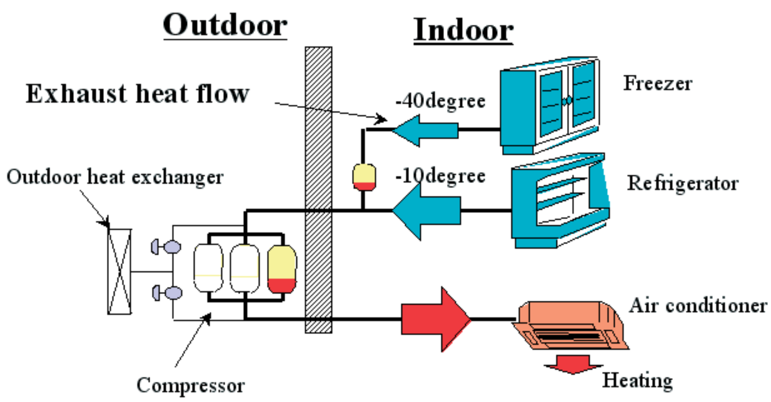


Figure 5: Exhaust heat recovery and two-stage compression

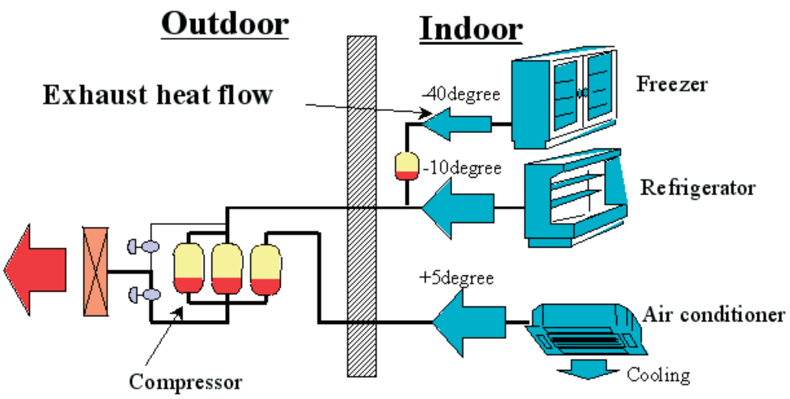


Figure 6: Three different evaporating temperatures and the integrated system

mode, the "Convenience Pack" system reduces the defrost operation of its outdoor unit by approximately 80 %. This system can perform cooling, freezing and heating operations with the outdoor temperature as low as –20 °C without any problem.

2. **Two-stage compression**
The compression ratio of a single-stage compressor for the purpose of freezing is as high as 18.8 in the conventional system. We use double stage compression, with the corresponding compression ratios being reduced to 2.7 for freezing and 7.1 for cooling. This improvement produces a very clear energy saving.

3. **DC inverter**
Operation of compressors and fans by DC inverters has realised significant energy saving.

4. **Three different evaporating temperatures and system integration**
We integrated three separate and independent refrigerant piping systems into one system, with three different evaporating temperatures for freezing, cooling and air conditioning in summer. (See Figure 6.)

Moreover, we improved the energy saving and the ecological aspect based on other technology aspects, such as the control of the outdoor unit fan for constantly maintaining the optimum head pressure.

Conclusion

We achieved both high efficiency and compactness of the system by integrating four conventional independent units into a single unit, designed particularly for use in convenience stores. In the future, we will continue our development work from the viewpoint of product customers. We must change our consideration from treating each unit in isolation to an integrated system approach. This complicates system control, so it becomes important that testing is based on actual field data, on system performance measurement and on analysis. We value such viewpoints.

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Optimal control of vapour compression cycles

Denis Leducq, France

A potential energy saving can be obtained by a global optimal setting of each actuator in a vapour compression cycle. This paper describes optimal control applying this strategy. Trials have been performed on scales ranging from laboratory-scale plant up to a multi-unit industrial-scale system. Energy benefits were significant. Integrated in a supervision-control package, this solution is particularly effective for large, multi-units plants

Introduction

Optimal control of a refrigerating plant implies determination of setpoints and modes of operation that minimise the total operating cost of the system. The concept of optimisation of a vapour compression cycle is usually reduced to a design optimisation based on predetermined steady-state operating conditions. However, in reality, few systems actually operate with permanent and predictable operating conditions. Most systems operate with conditions significantly different from the design cases, with varying working conditions being the usual way of operation for a system.

The development of dynamic optimisation has been made easier by recent advances in automation technology, electric motors and variable speed drives, making the refrigerating systems more “drivable”. Indeed, those additional degrees of freedom available to control the system and the computational capacity of computers or programmable logic controllers make it realistic to consider the possibility of searching “online” the best combination of compressor speed, the number of compressors, the number (speed) of fans on evaporators or condensers and various pumps to minimize the total power consumption of the system. In particular, the configuration of systems systematically equipped with programmable logic controller network-enabled and pressure and temperature measurements helps to develop such a plant-wide optimiser to determine optimal settings.

Performance of vapour compression cycles

Most vapour compression cycles have many operating variables (discrete or continuous) that can be controlled in order to minimize operating costs. However, the degree of freedom for controlling a vapour compression cycle may be very different between refrigerating plants. For instance, with only one on/off actuator, there is little scope for optimising the performance of a domestic refrigerator. At the other end of the scale, most industrial (or air conditioning) plants have a number of actuators, including in some cases variable-speed fans and variable-speed pumps that allow continuous control of variables. This means that it is possible to provide the refrigerating power for a desired temperature by various combinations of compressor speed, evaporator fans or pumps and condenser fans speed. However, only one maximizes the global performance of the refrigerating plant.

A good example is given by Jakobsen [1]. The system investigated (shown in Figure 1) is a single-stage vapour compression cycle consisting of an air-cooled evaporator and an air-cooled condenser, controlled by variable-speed motor drives and variable compressor speed.

In this study, an optimal setting of speed for each component has reduced the total power consumption from 1,592 kW to 1,482 kW, without changing the refrigerating capacity. This was achieved by reducing the capacities of the fans while increasing the capacity of the compressor. The author concludes that a general strategy implemented for dynamic optimisation based on a computer multi-input multi-output system could lead to a significant reduction in energy consumption.

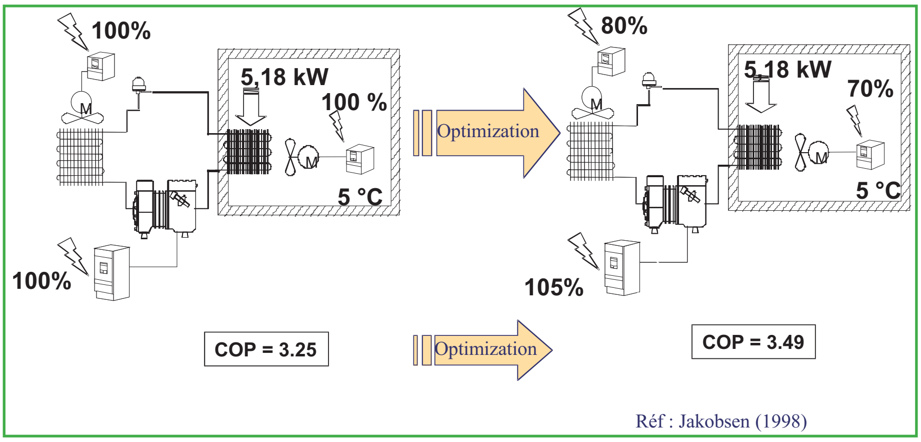

Figure 1 : Principle of energy optimisation

Non-linear predictive control

Plant optimisation has also been investigated by [2], [3], [4] and [5]. These studies primarily demonstrated the potential savings associated with the use of optimal control. The Cemagref laboratory, with the collaboration of the Matal company, has evaluated non-linear predictive control, as needed for dynamic optimisation strategy, based on algorithms already widely used in industrial processes in recent years.

Originally, the objectives of this algorithm were to drive future plant outputs y 'close' to the future set-point sequence w (Figure 2). This is done using a receding-horizon approach at each sample-instant t.

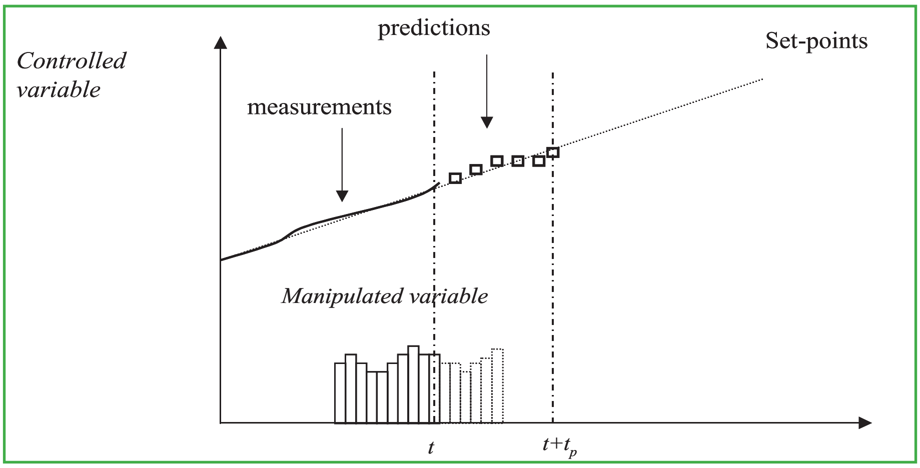

Figure 2 : Predictive control

Starting from available measurements, the behaviour of the system is predicted for different future command profiles using a model of the system. Selection of system performance parameters is based on an optimisation criterion that represents a compromise between the different user objectives. Only the first element of the profile is applied to the system, and the algorithm is reiterated at the next step.

Usually, in classical control, the model is locally linearised around a defined operating point. Under this condition, this principle leads to a simple and computationally efficient control law. In our case, vapour compression models are typically complex, nonlinear, constrained multivariable systems whose dynamic behaviour changes with operating pressures. Moreover, the objective function is subject to constraints on manipulated variables (actuator limitations) and very often to constraints on the controlled variables.

This environment led us to develop a more generally based control methodology, in which the dynamic optimisation problem is solved online at each step. Moreover, to take into account the energy cost of the various moves, the optimisation criterion includes an additional term for energy efficiency. The computational load is higher than in a traditional model-predictive control, but can be carried out with a standard PC computer and high-level software for an on-line control.

Results and discussion

A first implementation has been carried out on a laboratory-scale plant, and a second one on an industrial plant (dairy chiller) as a global supervisor. Since then, this control strategy has been proposed and installed in a supervision-control software package by the Matal company.

The experiments performed on the laboratory plant (chiller) showed that energy benefits of using optimal control were between 8 and 20 %, depending on the number of actuators available for optimisation. This order of magnitude has been confirmed on the industrial plant. In general, it can be observed that the setpoints obtained are mainly determined by the efficiency laws of the compressors. When several plants are available and can be freely chosen, the algorithm automatically favours the most efficient plants.

For real industrial applications, special care must to be taken to secure the system. A master-slave configuration (with the programmable controller as master) has been selected. In the event of a problem in the supervision software, the controller ignores information sent and uses predefined default setpoints. Minimum and maximum values are also defined for each actuator and setpoint, and the programmable logic controller filters data sent by the software if necessary.

Integrated in a network (Figure 3), the supervision computer can read any measurement on every programmable controller (even remote), and analyse the behaviour of the global plant. Its action is based on modifying setpoints or directly controlling the main actuators (for example, compressors), depending on the process. Indeed, the predictive control system was originally, and is essentially, a controller of dynamic processes, and this characteristic can be used to control processes when a classical PID algorithm is ineffective.

It must be noted that this approach is based on a model of the plant. Physical models can be used, but have to be kept simple enough to be computed thousand of times in a few seconds, since the software uses an iterative optimisation routine. At the same time, the efficiency of each component (and particularly of compressors) has to be described precisely in order to achieve significant energy optimisation results. A good compromise must be found, and is often specific to the plant.

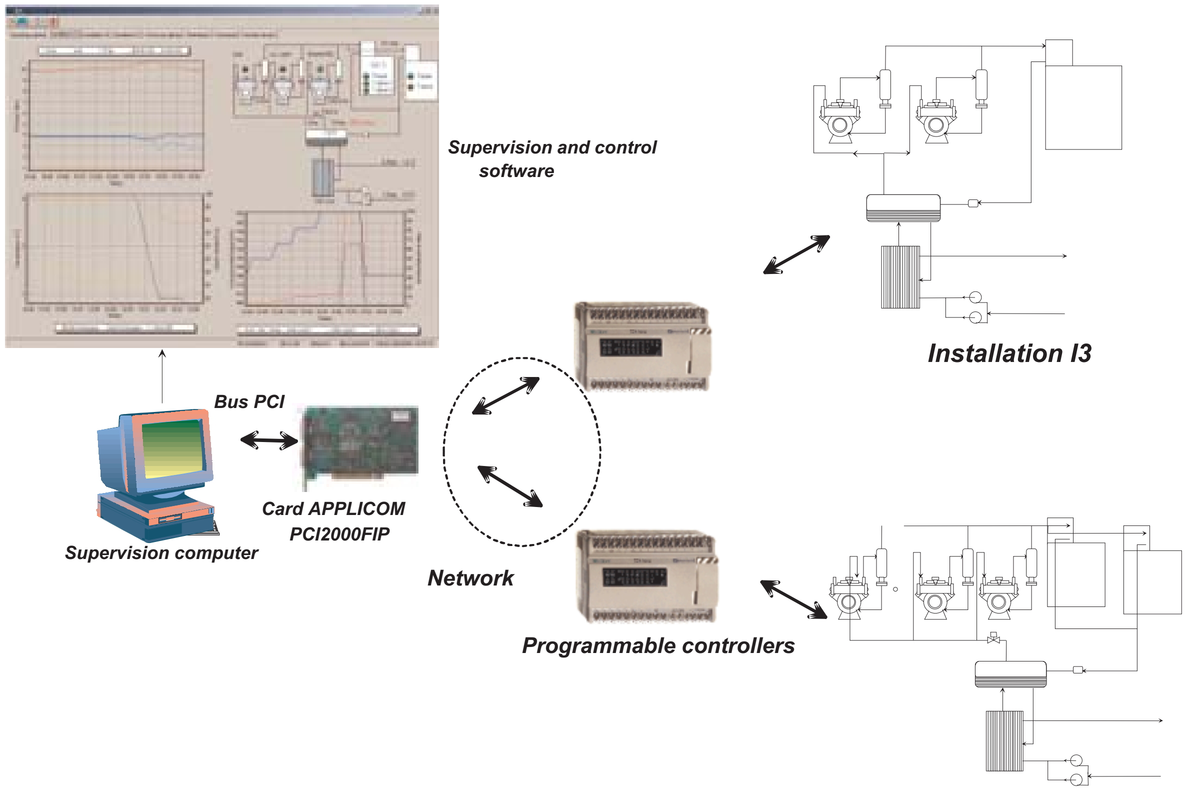

Figure 3: Configuration of the supervisor with a network of programmable logic controllers

Performance data are not always easily available, even in manufacturers' documentation. In this case, and when measurement devices are available, evaluation techniques (for example, recursive least-square identification) are used to determine missing parameters.

Conclusions

A potential energy saving can be obtained by a global optimal setting of each actuator in a vapour compression cycle. The use of presetting set-points, or a performance map generated by simulations over the range of operating conditions, is possible, but this procedure lacks generality and is not easily implemented.

An alternative approach is to use optimal control techniques. Non-linear predictive control, already widely used in industrial process control, is one of these techniques. When implemented to control a vapour compression cycle, measured energy benefits were significant.

Different levels of using such a controller exist. Generally, this kind of controller is seen as a part a multi-level hierarchy of control functions, optimal settings being sent to local controllers. But use as a dynamic controller for processes where PID is ineffective is also possible and is currently being evaluated. Further research would also be helpful in defining more generic but simple models[6], and techniques of reduction to transform a refined physical model into a low-computational one.

References

[1] A. Jakobsen and B. Rasmussen, "Energy-optimal speed control of fans and compressors in a refrigeration system," presented at Eurotherm 62, Grenoble, 1998.
[2] J. E. Braun, S. A. Klein, W. A. Beckman, and J. W. Mitchell, "Methodologies for optimal control of chilled water systems without storage," ASHRAE Transactions, vol. 90, pp. 652-662, 1989.
[3] Y. Yao, Z. Lian, Z. Hou, and X. Zhou, "Optimal operation of a large cooling system based on an empirical model," Applied Thermal Engineering, vol. 24, pp. 2303-2321, 2004.
[4] D. D. Massie, "Optimization of a building's cooling plant for operating cost and energy use," Int. J. Therm. Sci., vol. 41, pp. 1121-1129, 2002.
[5] D. Leducq, M. Nouhin, J. Guilpart, and G. Roger, "Contrôle optimal d'une installation frigorifique," Rev. gén. du froid, pp. 31-36, 2003.
[6] D. Leducq, J. Guilpart, and G. Trystram, "Low order dynamic model of a vapour compression cycle for food process control design," Journal of Food Process Engineering, vol. 26, 2003.

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Heat Pumping Technologies in New Markets

Volume 22 - No. 4/2004

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