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IEA HEAT PUMP CENTRE

NEWSLETTER

VOL. 28
NO. 4/2010

A key technology for the future

Supermarket refrigeration

Trends and perspectives

Using heat pumps for energy recovery

Glass doors on vertical display cases: lab and field studies

IEA **Heat Pump** CENTRE
NEWSLETTER

Volume 28 - No. 4/2010

In this issue

Heat Pump Centre Newsletter, 4/2010

Supermarket refrigeration, the topic of this issue, is an important and "hot" subject. This is evidenced by the large number and variety of the topical articles. The interaction of technology (from refrigerant and component to the system level) and customer and personnel behavior makes the subject very complex. This issue also contains a heat pump market report from the UK.
The Heat Pump Centre wishes you a Merry Christmas and a Happy New Year!
Enjoy your reading!

Johan Berg
Editor

Heat pump news

Regulars

Topical articles

COLOPHON

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Foreword

Supermarket refrigeration revisited

Judith Evans
Director, RD&T (Refrigeration Developments and Testing Ltd), and Research Reader, London South Bank University, UK

The last heat pump newsletter that dealt exclusively with supermarket refrigeration was published in 2004, and discussed issues such as energy efficiency and refrigeration leakage. It is clear that many of these issues are still pertinent today.

Refrigeration is the largest energy load in a supermarket. If the display cabinet refrigeration system cannot cope with the heat load, product temperatures may rise to unsafe levels. Recent work in France by Cemagref has confirmed that, apart from home storage, retail is the most poorly temperature-controlled area of the cold chain.

Supermarkets are a large user of refrigerants and play a major role in reducing greenhouse gas emissions. In the past, leakage of refrigerants - which often had high GWP (Global Warming Potentials) - have been high, often as much as 30% per year. Over the past 5-10 years, supermarkets have begun to favour 'natural' refrigerants such as CO_2 and hydrocarbons. Although numerous systems have been trialled, there is still a lack of really detailed and comprehensive comparative information on the performance of these new systems.

In the past, the primary concern when choosing a retail display cabinet has always been to maximise sales rather than to minimise energy consumption. However, with rapidly rising energy prices and the need for supermarkets to appear environmentally conscious, supermarkets are beginning to balance energy consumption with profit margins and are placing increasingly stringent demands on retail cabinet manufacturers to develop cabinets that are energy-efficient.

Savings to date have been achieved in a number of ways. Recent work in the UK compared 72 different technologies that could be used to reduce CO_2 emissions from supermarkets. Many of the technologies currently being implemented by supermarkets such as emc fans, cabinet doors and LED lights, showed good energy savings but had longer payback times than many technologies that could be applied quickly and simply. These included better maintenance of cabinets, better training of staff to install and use cabinets, recommissioning of cabinets, reducing store ambient temperatures and selecting the best cabinets in the first place.

Many of the challenges that were highlighted in the 2004 newsletter still remain. Supermarkets have made significant steps forward in applying low-GWP refrigerants, and leakage of refrigerants is now an issue that is no longer ignored. Supermarkets have been evaluating a number of technologies that can save them energy and have been experimenting with renewable energy technologies such as wind turbines and biomass, combined heat and power, and gasification to turn food waste into power. Although significant steps have been made, the traditional modular approach to supermarket design, where individual aspects of a supermarket (cabinets, air conditioning, refrigeration plant, building design) are still considered separately, is still almost universal. If carbon reduction targets set by Governments are to be achieved, there must be acceleration in the application of new technologies and a greater integration of heating and cooling in supermarkets. Ultimately, the dream must be a zero-carbon supermarket that efficiently and cost-effectively manages to maintain food at the correct storage temperature whilst also being able to ensure that consumers enjoy their shopping experience.

Refrigerants: towards new policy

Didier Coulomb,
IIR Director

Refrigeration (including air conditioning) is indispensable to life. Because of the need to preserve foods and to ensure human health, as well as the use of refrigeration in almost all technologies, use will continue to grow steadily in the future, particularly in developing countries. Most refrigeration equipment uses, and will continue to use, vapour-compression technology. Most systems use fluorinated gases. Chlorofluorocarbons (CFCs) are already banned, and hydrochlorofluorocarbons (HCFCs) will be banned in the near future under the terms of the Montreal Protocol on the stratospheric ozone layer. However, these refrigerants will have to be replaced. The easiest way to do so is to replace them with hydrofluorocarbons (HFCs) which, unfortunately, are also generally potent greenhouse gases.

F-gas (CFC, HCFC, HFC) emissions from the refrigeration and air-conditioning sectors currently represent 1-2 % of total greenhouse gas emissions (expressed as CO_2 equivalents). This percentage could be much higher in the future, if no additional measures are taken, due to an increase in the use of refrigeration and air-conditioning equipment (7-8 % in 2050 at least, probably). For this reason, North American (USA, Canada, Mexico) and island countries (Mauritius, Micronesia) presented amendment proposals last year for controlling HFC production and consumption through the Montreal Protocol, and for phasing down these refrigerants within about 30 years.

These proposals were put forward again this year, particularly during the discussions held during the latest United Nations Conference on Depletion of the Ozone Layer on November 8-12, 2010. However, opposition from some emerging countries prevented adoption of the proposals.

Discussions on this issue will continue. At UN level, the difficult issue of funding the Multilateral Fund for the Montreal Protocol will oblige the parties to find a compromise. Developed countries - at least, within the European Union - would like to set an example. The F-gas Regulation in Europe is due for review in 2011, when discussions on the future of HFCs will take place. Powerful campaigns led by non-governmental organizations will try to replace HFCs with natural refrigerants (ammonia, CO_2, hydrocarbons, water).

New policy is needed for the near future:
- Reducing leakage from existing equipment, reducing refrigerant charge and losses;
- Promoting non-ozone-depleting and low-global-warming refrigerants;
- Reducing the energy consumption of the systems;
- Improving technologies and developing new technologies.

There are two kinds of low global warming refrigerants: natural refrigerants, and HFCs with a low global warming potential, currently named HFOs. HFOs could easily replace HFCs, because of similar thermophysical properties (HCs could also replace HFCs, however), although they do have the drawback of being slightly flammable, whereas the most common HFCs are non-flammable. They are currently still under development for various uses; HFO-HFC blends with no flammability will probably appear in the near future.

However, solutions with natural refrigerants, such as CO_2, already exist in supermarkets and should be promoted, provided that we carefully examine the energy efficiency of systems. The International Institute of Refrigeration, through its databases, publications and conferences, is at your disposal to help you.

The 10th IEA Heat Pump Conference

Heat pumps-The Solution for a Low-Carbon World

Date: 16 May 2011 ~ 19 May 2011
Venue: Chinzan-so Tokyo, Japan

1. Registration:
   Online registration has started since Oct 1, 2010. We have 3 kinds of fee categories, general participants, students and accompanying persons.
   Technical and non-technical tours information, Accommodation booking have also been available.

2. Call for Exhibitions & Call for Sponsors have started.

3. Conference Program

•Monday 16 May 2011
AM/PM Workshops

•Tuesday 17 May 2011
AM: Opening plenary session
PM: Two parallel Sessions including poster presentation
EV: Welcome Reception

•Wednesday 18 May 2011
AM: Two parallel Sessions including poster presentation
PM: 8 Technical and 2 Non technical tours
EV: Banquet

•Thursday 19 May 2011
AM: Two parallel Sessions including poster presentation
PM: Two parallel Sessions including poster presentation
EV: Closing plenary session
*Exhibition: from May 16 through 19.

Web: For more information, please log on to the Conference website at: http://www.hpc2011.org

Regional Coordinators

For information on papers and workshops, conference program, etc., please contact the Regional Coordinator for your area:

- Asia and Oceania: Mr. Makoto Tono, tono.makoto@hptcj.or.jp
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2011 TOKYO
10th IEA Heat Pump Conference

General

3rd China-Japan Joint Meeting on Heat Pump and Thermal Energy Storage, 2010

The 3rd China-Japan Meeting on Heat Pump and Thermal Energy Storage was held from October 12 to October 13, 2010 in Beijing at Beijing New Century Hotel, and attended by about 120 delegates from China and over 40 delegates from Japan. The participants included policy-makers, researchers, engineers, university representatives and relevant industry experts from electrical utilities, industry, building and HVAC system design companies, contractors, equipment manufacturers of heat pump and thermal energy storage systems, and Chinese media. The meeting was co-sponsored by the China Academy of Building Research (CABR) and the Heat Pumps & Thermal Storage Technology Center of Japan (HPTCJ). This meeting is the third: previous meetings have been held in Beijing (2005) and Tokyo (2007).

Twenty presentations were given over the two days: nine from China and eleven from Japan. Both sides presented the energy policies of the two countries. Chinese representatives described a) Chinese energy trends, energy efficiency standards and the status and function of heat pump and thermal energy storage, b) the status and trends of ground-source heat pumps in China, c) utilization and management of refrigerants in China, d) development trends of residence construction in China and prospect of cooperation of China and Japan on the industrialization field of residence construction, e) district energy plans in China, f) energy efficiency – consulting and design, g) the current situation, features and energy efficiency solution of energy use in public buildings in China.
The Japanese representatives described a) Japanese energy trends, energy efficiency standards and the status and function of heat pumps in Japan, b) the status and trends of ground-source heat pump in Japan, c) the wider deployment of heat pump & refrigerant management in Japan, d) the background to the development and latest trends of highly efficient heat pump and thermal storage technology in Japan, e) waste water-source heat pump technology and application in Japan, f) application of river-source heat pump systems in Japan, g) application of Japanese district heating and cooling plans, h) ESCO (Energy Service Company or Energy Management Contracting) entrepreneur's current status and trend in Japan, i) heat pump technology in the cold parts in Japan, j) inverter-controlled turbo freezer technology in Japan, and k) inverter-controlled CO_2 heat pump water heaters in Japan.

After the presentations, a panel discussion was arranged to discuss the improvement of heat pump efficiency, refrigerants management, ground-source heat pump systems and thermal energy storage systems. In China, because energy consumption is increasing in parallel with the country's rapid economic growth, so expansion of energy conservation technology, such as heat pumps, is a pressing need. The market for both air heat source heat pumps and the ground-source heat pump will expand at an increasing rate. It is expected that this market will expand further as a result of Chinese energy policy: it is forecast that, by 2020, sales of air-source heat pumps in China will be three to five times higher than today. Similarly, ground-source heat pump numbers (and including river water heat source heat pumps etc.) are forecast to be five to eight times higher than today, as a result of expansion of greenhouse cultivation and industrial applications.
There was active discussion of the importance of heat pumps at the

meeting. It was also emphasised that China's role in refrigerant management was crucial. China expected to implement rigorous refrigerant management in order to achieve global brand competitiveness and a reputation for quality products. Joint future design and manufacture of heat pumps by the two countries was also discussed.

The meeting was a great success for both sides, reinforcing the deep and close co-operation in heat pumps and thermal energy storage. It was also expected that there will be increasing information exchange in the coming years.
Source: CABR (China) and HPTCJ (Japan)

Live monitoring of six air-water heat pump sites started. Sample data online!

Requests for real data on heat pump performance are increasing. The Belgian company, Thercon, has now put the results of an online monitoring of six units online. Fraunhofer is currently providing anonymised data for eight of its measurement sites.
http://www.ehpa.org/news/article/live-monitoring-of-6-air-water-heat-pump-sites-started/

Publication of report on EST heat pump field trial

Given the lack of data on heat pump performance in customers' homes, the Energy Saving Trust undertook the first large-scale heat pump field

trial in the UK to determine how heat pumps perform in real-life conditions. The year-long field trial monitored technical performance and customer behaviour at 83 sites across the UK. The findings provide valuable information about the factors that affect the success of a domestic heat pump installation. Instead of revealing outcomes along statistical grounds, or acting as a "brand-vs-brand" competition, the field trial findings provide a discussion of key points of interest to potential consumers.
Source: http://www.energysavingtrust.org.uk/Media/node_1422/Getting-warmer-a-field-trial-of-heat-pumps-PDF

Policy

ASHRAE 90.1-2010 Energy Standard published

The newly published ANSI/ASHRAE/IES Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings, provides minimum requirements for the energy-efficient design of buildings other than low-rise residential buildings. The standard contains 109 addenda approved since the 2007 standard was published.

Since being developed in response to the energy crisis in the 1970s, Standard 90.1 has become the basis for building codes and the standard for building design and construction throughout the United States.

"This year marks the 35th anniversary of our flagship energy conservation standard, and the 2010 version of 90.1 represents a milestone achievement in increased energy and cost savings," Lynn G. Bellenger, ASHRAE president, said. "Working within the constraints of strict economic justification and a prescriptive format, the project committee has achieved remarkable energy savings across all building types and U.S. climate zones. The standard is written in mandatory code language and offers code bodies the opportunity to make a significant improvement in the energy efficiency of new buildings, additions and major renovations. We congratulate the project team and our partners of 35 years, the Illuminating Engineering Society."

"The 2010 edition of Standard 90.1 represents a significant accomplishment by ASHRAE and IES to implement cost-effective measures for energy conservation in new buildings designed using the standard," Steve Skalko, 90.1 Committee Chair, said.
Source:http://www.ashrae.org/pressroom/detail/17644

Launch of the IEA Policy Pathway 'Energy Performance Certification of Buildings'

The second publication of the IEA's new "Policy Pathway" series, Energy Performance Certification of Buildings, has been published.
The Policy Pathway series helps countries to implement essential energy efficiency policies. It provides policymakers with practical "how-to" guidelines for designing, implementing and evaluating energy efficiency policies. In these times of austerity, governments can save money by learning from the experiences of other countries.
Source: http://www.iea.org/press/pressdetail.asp?PRESS_REL_ID=401
Source: http://www.iea.org/papers/pathways/buildings_certification.pdf

European Commission's 2020 energy plan presented

The European Commission recently presented its new energy strategy, calling for €1 trillion of investment over the next decade to integrate Europe's energy networks, while fending off criticism over a lack of concrete ideas.
The Energy 2020 strategy lays down priorities in five broad areas. It seeks to curb Europe's energy consumption with financial incentives to renovate Europe's energy-guzzling buildings and to integrate the European energy market.

Furthermore, it proposes to pursue an external EU energy policy, ensure Europe's leadership in innovative energy technologies and address consumer issues such as making billing more transparent or making it easier to switch suppliers
Source: http://euractiv.com/en/energy/commissions-2020-energy-plan-fails-impress-news-499634

ASHRAE 90.1-2007 Energy Standard Available as Free Download

In order to move the industry forward towards more energy-efficient design, ASHRAE is making its flagship energy standard, 90.1, 2007 version, available as a free download for a limited time.Through a funding contract with the Department of Energy, copies of the I-P edition of ANSI/ASHRAE/IES Standard 90.1-2007, Energy Standard for Buildings Except Low-Rise Residential Buildings, are being offered as a free downloadable PDF at http://www.ashrae.org/standard901-2007-free .
Source: http://www.ashrae.org/pressroom/detail/17639

EU agrees deal on using crisis funds for energy efficiency

EU lawmakers have agreed to free up €146 million from uncommitted funds from the European Energy Recovery Plan to finance energy efficiency and renewables projects, members of the European Parliament said.

The deal was reached between Parliament negotiators and the Belgian EU Presidency in October. It creates a fund managed by the European Investment Bank and German bank KFW, which can finance projects, including building renovations that include renewable or energy effi-

ciency solutions, grid-connected decentralised renewable energy generation, clean public transport, electricity storage solutions, smart metering and smart grids.
Source: http://euractiv.com/en/energy-efficiency/eu-cuts-deal-using-crisis-funds-energy-efficiency-news-499027

First phase of Smart Grid Technology Roadmap released

The IEA has released the first phase of its IEA Smart Grid Technology Roadmap at the Korea Smart Grid Week in South Korea. The IEA published its key findings and new regional CO_2 emission reductions and smart grid drivers analysis. This smart grid roadmap document also provides advice on required actions for stakeholders to support smart grid development and deployment, including advice for electricity generators, system operators, government and regulators, technology and solution providers, consumers and environmental groups. Further publications related to the IEA Smart Grid Roadmap will be forthcoming in the next few months.
http://www.iea.org/Papers/2010/SmartGrids_Roadmap_Foldout.pdf

Working Fluids

ASHRAE publishes 2010 editions of refrigerant safety standards

The 2010 editions of ASHRAE's major refrigerants-related standards have been published as a package, with 14 new refrigerant blends added.

Requirements in ANSI/ASHRAE Standard 34-2010, Designation and Safety Classification of Refrigerants, and ANSI/ASHRAE Standard 15-2010, Safety Standard for Refrigeration Systems, complement each other in that Standard 34 describes a shorthand way of naming refrigerants and assigns safety classifications based on toxicity and flammability data, while Standard 15 establishes procedures for operating equipment and systems when using those refrigerants. ASHRAE sells the standards as a set
Source: http://www.ashrae.org/pressroom/detail/17638

AREA calls for split systems to be brought within F-gas regulations

AREA, the European contractors' association, is calling for changes to the F-gas Regulations to require all non-monobloc air conditioning and refrigeration systems to be installed by a certified professional. It also wants to see the F-gas threshold lowered from its present 3 kg to just 100 g, and is backing a call for a mandatory register of ACR professionals.

The association argues that while refrigerants in cylinders can be sold only to certified professionals, non-monobloc split systems pre-charged with refrigerant can be purchased by anybody, and since installing this equipment necessitates interfering with the refrigerant circuit it should fall within the remit of the F-gas Regulation. AREA maintains that these systems are usually installed by non-professionals, and practically never checked, which invariably results in bad leakage rates.
Source: http://www.area-eur.be/_Rainbow/Documents/AREA%20PP%20F-Gas%20Review%20(100713).pdf
Source: http://www.acr-news.com/news/news.asp?id=2263&title=AREA+calls+for+split+systems+to+be+brought+within+F%2Dgas+regulations

Consultant study: Refrigerant differences may not be significant, long term

A comparison study of HFC and CO_2 refrigeration systems has shown that each need time to reach their best level of performance and minimise climate impact. The report suggests that the financial and environmental gap between the different refrigerant solutions can be closed, and the choice of refrigerant will then no longer make any significant difference.

This can be achieved either by improving HFC-based refrigeration systems in line with the requirements of the F-gas Regulations, or via the maturation of CO_2 based refrigeration systems.

The study was conducted by the British environmental consultants SKM Enviros, and commissioned by the industry expert organization EPEE.
Source: http://www.acr-news.com/news/news.asp?id=2238&title=Refrigerant+differences+may+not+be+significant%2C+long+term
Source: http://www2.epeeglobal.org/epeedocs/internet/docs/Excerpt_of_Eco-Efficiency_Study_on_Supermarket_Refrigeration_4472.pdf

Africa the preferred destination for illegal waste fridge exports

In a crackdown on the illegal trade by European authorities, customs officers in Germany have intercepted a shipment of CFC-containing waste refrigerators bound for Africa.
Source: http://www.acr-news.com/news/news.asp?id=2271&title=Africa+the+preferred+destination+for+illegal+waste+fridge+exports

Chemical producers reveal details of new HFO refrigerant blends

Just when it looked as if 'natural' refrigerants were to be the long-term answer in many applications, two of the world's leading chemical companies have revealed details of a potential new range of low-GWP blends. These are based on the technology behind the refrigerant HFO1234yf which is currently being adopted as a replacement for R134a in car air-conditioning systems. At Chillventa in October 2010, DuPont announced the development of Opteon XP10, a blend based on HFO1234yf and a number of other as yet unspecified gases, but thought to be readily-available HFCs. Meanwhile, Honeywell has revealed some of its work with five HFO blends that could eventually provide a low-GWP alternative to many of today's common refrigerants.

Source: http://www.acr-news.com/news/news.asp?id=2259&title=Chemical+producers+reveal+details+of+new+HFO+refrigerant+blends

Honeywell supermarket refrigerant receives R407F designation from ASHRAE

Honeywell recently announced that its new commercial supermarket refrigerant, Genetron Performax LT, has received the official designation of R407F by ASHRAE. ASHRAE designations assign safety classifications for refrigerants based on toxicity and flammability data. Genetron Performax LT is rated as 'A1' by ASHRAE, indicating it has low toxicity and is non-flammable.

Source: http://www.ejarn.jp/Type_news_inside.asp?id=13618&classid=10

Technology

Could the future lie in linear refrigeration compressors?

Linear technology could become the predominant energy-efficient refrigeration compressor design in the future, according to Brazilian manufacturer Embraco. The company, which last month announced the launch of an oil-less linear compressor for domestic refrigerators, has plans to launch a commercial range in the future. The new compressor is said to provide energy savings of up to 30 % in comparison with existing technology.

Source: http://www.acr-news.com/news/news.asp?id=2262&title=Could+the+future+lie+in+linear+refrigeration+compressors%3F

Virtual power plant launched

A virtual power plant began operation in Berlin at the end of October, uniting 15 combined heat and power plants (CHPs) and heat pumps into a single network. Vattenfall Europe Wärme AG, SenerTec Center Berlin-Brandenburg, SES Energiesysteme GmbH and heat pump manufacturer Stiebel Eltron are all partners in the endeavour. The goal of the project is to control the decentralised energy producers and their facilities from a central location in order more effectively to integrate renewable energy into the power grid. The project represents the first power plant that is able to produce heat while the CHPs produce power, and heat pumps utilize power during times of peak demand. By the end of the year, the virtual power plant's capacity is set to expand to over 50 power plants, producing a total of 10 MW of power.

Source: Energy-Server Newsletter, Issue 127

Markets

European HVAC&R market data published

Eurovent Market Intelligence (EMI), a European statistics bureau collecting data on the HVAC&R market, has published its results on HVAC&R activity in the Europe and Middle East zone (EMEA), based on the latest available sales data collected from manufacturers in the sector.

Source: http://www.ejarn.jp/Type_news_inside.asp?id=13637&classid=10

GSHP technology to provide heat for 65 million m^2 in Shenyang, China

Ground-source heat pump (GSHP) technology will provide heat for 65 million m^2 in the city of Shenyang, China, by the end of 2010, accounting for one-third of the city's total heat supply area. From January to July this year, GSHPs have been supplying heat to about 8.6 million m2 of floor area in Shenyang, with the whole GSHP-supplied area in the city reaching about 43.2 milllion m2, more than half of the floor space heated by GSHP technology in the whole country. By the end of 2010, the city will supply sewage-source heat pump heat to more than 10 million m^2.

Source: JARN Oct 25. 2010, p 38

Canadian GSHP industry report published

Canadian GeoExchange Coalition (CGC) has published a report on the state of the Canadian geothermal heat pump industry in 2010. This industry survey and market analysis is the first document ever published in Canada to present a comprehensive and credible picture of the Canadian geoexchange industry. Industrial use of, and government requirement for, the CGC's Global Quality GeoExchange Program have proven a key link in developing the depth of the information in this report.

Source: http://www.geo-exchange.ca/en/UserAttachments/news447_PR%20%2001-11-2010_E_%20State%20of%20the%20Industry.pdf

Full report: http://www.geo-exchange.ca/en/UserAttachments/news451_Industry%20Survey%202010_FINAL_E.pdf

The Market for Heat Pumps in the UK

Penny Dunbabin, Department of Energy & Climate Change , UK

Introduction

Heat pumps are widely used in the non-domestic sector in the UK, but remain rare in the domestic sector.

This article gives a résumé of the state of the market, the policies in place to encourage the development of the heat pump market in the UK, and some of the research that is currently being conducted.

Table 1 : Estimated number of heat pumps installed in the UK in 2009. Source: BSRIA and HPA

	2009	
Ground source	3980	Mixed commercial and residential
Air to water	8325	
Exhaust air	4350	
Air to air and reverse cycle	200,000	Commercial sector only
TOTAL	about 220,000	

Market for Heat Pumps in the Non-Domestic sector

The non-domestic market for air-to-air and reverse-cycle heat pumps is quite well developed, with BSRIA (Ref. 1) estimating that around 200,000 air-to-air heat pumps were installed in the non-domestic sector in 2009.

Other types of heat pumps (air-to-water and ground source) are much less well represented, with a few thousand ground source heat pumps installed in the same period. The financial value of the non-domestic heat pump market in the UK in 2009 was estimated at over €345 million. Most of these pumps are used for both space heating and cooling.

Heat pumps are being used in a wide range of applications in the non-domestic sector, including offices, businesses, schools, hospitals, supermarkets, hotels, children's residential homes, leisure centres, swimming pools and even in a state-of-the-art diving centre complete with shipwreck!

Market for Heat Pumps in the Domestic sector

In comparison, the market for heat pumps in the domestic sector is less developed. BSRIA estimates that just under 12,000 heat pumps were installed in the residential market in 2009.

In the UK, electricity is substantially more expensive than gas, and currently has a high carbon factor (although policies are in place to decarbonise the electricity grid). This means that heat pumps are currently most attractive to householders who use oil or electricity for heating. There are around 4 million such households in the UK.

Heat pumps are most likely to be installed in the new build sector, or when a house is undergoing major refurbishment. Heat pumps are installed in both the private and social housing sectors.

Manufacturers

There is a wide range of players in the UK heat pump market, from small companies to major international ones.
One Asian manufacturer based in the UK has recently switched a production line from air conditioning units to air-source heat pumps and hopes to produce 10,000 units per year for the UK and European markets.
Scandinavian manufacturers of both ground- and air-source systems are also active in the UK market.
Finally, several UK manufacturers produce innovative designs of ground- and air-source heat pumps.

Trade Bodies

There are three trade bodies for the heat pump industry in the UK:
The Ground Source Heat Pump Association (**GSHPA**) is a contractors' trade body, representing installers and consultants in the ground-source heat pump industry.
The Heat Pump Association (**HPA**) represents manufacturers and suppliers of both air- and ground-source heat pumps.
BEAMA covers the whole of the energy industry, and works closely with the HPA and GSHPA.

The three associations work together to influence legislation and other matters that affect the interests of either the industry in general, or its members in particular. In addition, the HPA co-ordinates technical and market research into areas of mutual interest, identified by members with the aim of improving market opportunities for members, at home and abroad.

Policies that affect heat pumps

Heat pumps have the potential to make a significant contribution to the UK's target of 15 % of all energy from renewables by 2020, which itself derives from the EU's 2020 renewables target.

There is a range of policy instruments that affect heat pumps.

The Renewable Heat Incentive

On 20th October 2010, the Government confirmed that it would put in place a renewable heat incentive. The proposal is to use money raised by taxation to subsidise the production of renewable heat (e.g. by heat pumps, solar thermal or biomass). This incentive would apply to both the non-domestic and the domestic sectors.

Code for Sustainable Homes and Zero Carbon Homes

In 2007, the Government announced its intention to ensure that building regulations would be successively tightened, to reach a "Zero Carbon" standard for new build by 2016 (for the residential sector) and 2019 (for the non-domestic sector). Part of the savings must be achieved by improving the thermal performance of the building envelope or by on-site renewable electricity or heat generation (e.g. from heat pumps).
The Government is currently considering the fine details of the proposals. The Welsh Assembly Government has indicated a preference for reaching the Zero Carbon standard for new build homes in Wales by 2011.

Carbon Emissions Reduction Target

The Carbon Emissions Reduction Target is a requirement on suppliers of electricity and gas to the domestic sector to install energy-saving measures (particularly insulation) in the household sector. Heat pumps are an allowable measure and, to date, around 2,100 ground source heat pumps have been installed in the residential sector via this programme since April 2008. This policy will continue until December 2012, although heat pumps will be eligible for installation only in a "super-priority group" of households on certain benefits from April 2011.

The Green Deal

The Government has proposed a new financing mechanism for improving the thermal properties of buildings in both the domestic and non-domestic sectors. The proposed mechanism would allow customers to purchase energy-saving apparatus, which would be paid back by the savings on their bills. This policy is currently under review.

Local Planning Policies

The so-called Merton Rule – named after the London Borough of Merton, in which it was first applied in 2003 – requires that new development beyond a certain size must obtain at least 10 % of its energy demand from on site renewable sources (which can include heat pumps). The Merton rule has been adopted by more than half of the local authorities in the UK. However, national standards such as Zero Carbon Homes and Zero Carbon Non-Domestic buildings will supersede these local requirements.

Low Carbon Buildings Programme: This programme provided grants to householders and to public sector, charitable and community organisations for the installation of low carbon renewables. The programme closed in May 2010.

Current Research

The Energy Saving Trust, a body part-funded by Government to provide advice to householders on energy efficiency, is currently conducting field trials of domestic heat pumps. Over 80 heat pumps have been monitored for one year, to establish the performance of heat pumps in situ, as opposed to in the laboratory. One important aspect of the trials is that the seasonal performance coefficient has been calculated for the heat pump and the entire heating system of the house. Figure 1 shows a generic monitoring diagram used in this study.

Figure 2 shows the heat pump SPFs measured from the first year of the trial and Figure 3 shows the system efficiency, which includes all auxiliary heating and water heating, plus the electricity used by the circulation pump. As can be seen from both figures, the first year of monitoring showed a range of performance from good to poor. A second year of trials is planned to investigate those sites where performance was poor, to see if installation practices and operational schedules can be modified to improve performance. The final report is expected at the end of 2011.

The field trials have demonstrated that correct sizing and good quality installation are key to achieving good performance. The three heat pump associations (HPA, GSHPA and

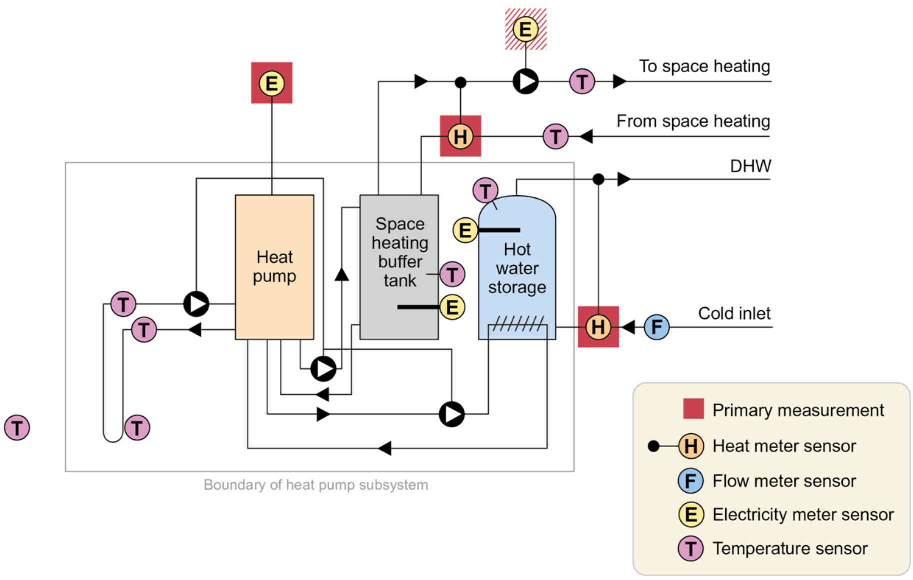

Figure 1 : Generic Monitoring Diagram

BEAMA) are all committed to working to improve training, and BEAMA is in the process of developing guidance on controls which will be published in April 2011.

There is a greater trend for manufacturers to train their own accredited installers. For example, a Scandinavian company recently opened a new training facility for installers in Scotland, and other manufacturers have teamed up with technical colleges to ensure good practice.

Other research includes work by Brunel University on modelling compressors in heat pumps used in supermarkets, and work by Warwick University into super-compact adsorption pumps and gas-fired heat pumps. Meanwhile, the University of St Andrews is carrying out a study into the diversity of geothermal energy sources in Scotland, including hot fractured rocks and the use of hot water from mines.

Finally, DECC is considering acoustic monitoring of air-source heat pumps.

Conclusions

The market for heat pumps in the non-domestic sector is beginning to be well established.

In the residential sector, the heat pump market is less developed in the UK than in some other European countries (for example, Sweden or Germany). However, the potential market is significant – 4 million homes off the gas grid, and increasing interest from householders who have access to gas.

The Government is currently considering two policies that could have a significantly beneficial impact on the heat pump industry: the Renewable Heat Incentive and the Zero Carbon Homes Policy. Ministers' decisions on these policies are expected before the end of 2010.

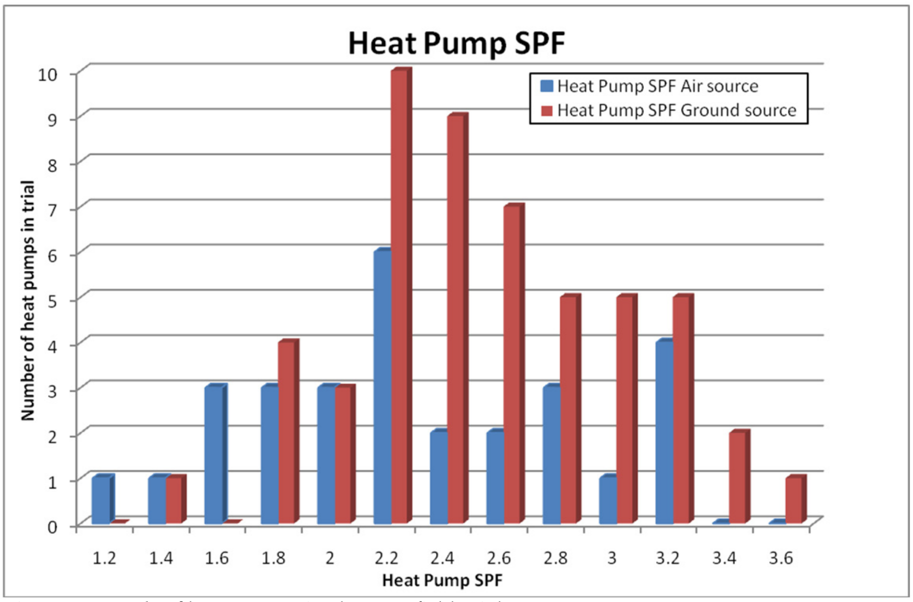

Figure 2 : SPF's of heat pumps in the EST field trial

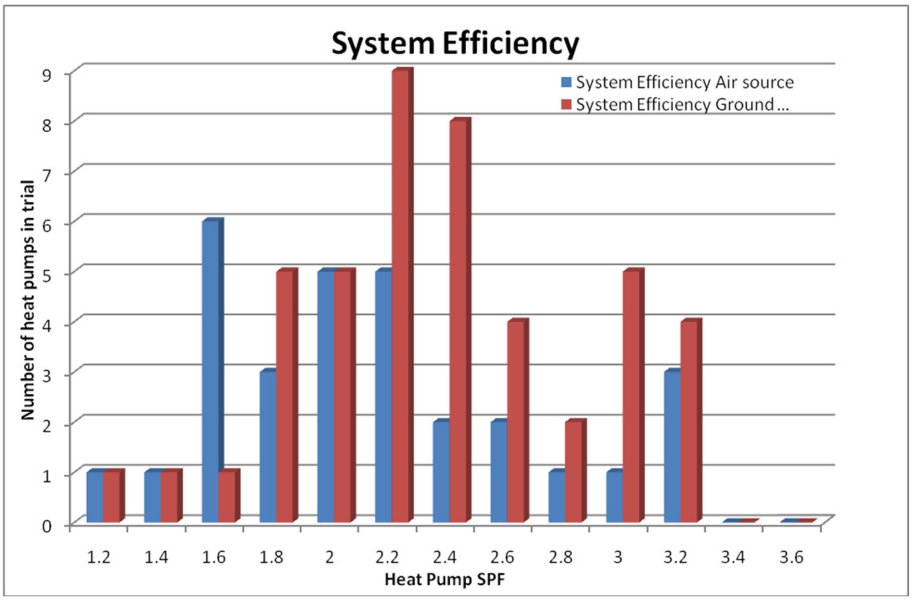

Figure 3 : System efficiency of heat pumps in the EST field trial

Finally, the heat pump industry itself is active in developing training programmes for installers and contractors.

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References

1 : BSRIA is a research consultancy, test, instruments and research organisation that provides specialist services for construction, building services and facilities management.

Annexes, ongoing

IEA Annex 34 "Thermally Driven Heat Pumps for Heating and Cooling"

The technologies within Annex 34, "Thermally Driven Heat Pumps", cover a wide range, from solar thermally driven cooling to gas-driven heat pumps. Even though solar cooling systems have already been on the market for several years – albeit still on a small scale with only a few hundred installations worldwide – more gas-driven heat pumps are currently entering the market. An example is a recently developed adsorption heat pump that has been available since spring 2010, although absorption heat pumps have been sold for some years.

Even though the technologies have been available for several years, there is still no common standard for determination of their performance figures, especially for gas-driven heat pumps. For this reason, a new German VDI guideline (VDI 4650 -2 Gasbetriebene Sorptionswärmepumpen), has been developed and published in November 2010, covering at least parts of the technologies. The experts in Annex 34 are working on a proposal for a standard measurement and performance evaluation protocol for thermally driven heat pumps for better com-parison of heat- and cold-producing technologies. The first draft of this standard is currently being circulated within Annex 34, and will be cross-checked with experimental data from a number of laboratories. These results will then be compared to other relevant standards from comparable technologies. Thus, CEN TC 299 has started reviewing EN 12309-2 "Gas-fired absorption and adsorption air-conditioning and/or heat pump appliances" with several members of Annex 34 on the committee in November 2010.

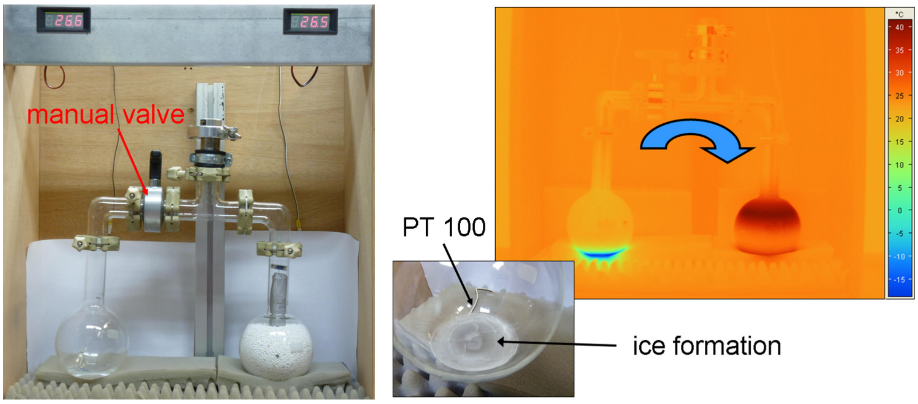

Figure 1: Experimental set-up to demonstrate sorptive heat pumping in a thermally driven adsorption chiller (left). The thermal image (right) shows the temperature distribution in the equipment after opening the valve between the flask containing water and the flask containing the zeolite (white spheres). The inset picture shows ice formation in the water from which water vapour is being evaporated.

Meanwhile, best case examples of existing installations are being collected, and will be presented on the Annex 34 web-page http://www.annex34.org. Other pages of the web site will present details of the test equipment used by the participating laboratories.

Some of the preliminary results of Annex 34 will be presented at a workshop at the HPC Conference 2011 in Tokyo.

Newsletter no. 1/2010 (Volume 28) described the cooling mode of a system-integrated thermally driven adsorption machine. The following briefly explains the underlying physical process, illustrated by an experiment.

The left hand photograph in Figure 1 shows the experimental set-up at starting conditions (steady state), i.e. ambient temperature (t_{amb} = 26,5°C, as can be seen on the temperature display at the top). The set-up consists of two vacuum-tight round-bottom flasks containing water (left) and dried zeolite (right). These two flasks are connected via an isolating valve, which is initially closed.

Opening the valve causes a number of effects. The zeolite is dry and highly hydrophilic (and thus has a large affinity for water). A mass transfer of water vapour (cf. blue arrow) therefore occurs from the left-hand flask (containing water) to the right-hand flask (containing zeolites). This adsorption process is exothermic (i.e. heat is released), and heats the zeolite up to approximately 50°C. The

water vapour pressure in the whole system is reduced, as water molecules are adsorbed at the zeolite's surface. Therefore, the zeolite acts as a vacuum pump, continuously sucking more and more water vapour from the water reservoir. This, in turn, causes continuous evaporation of water in the left-hand flask. As the process is quite fast, the necessary heat to evaporate the water (latent heat of evaporation for the phase change from liquid to vapour) is taken from the water reservoir itself, thus causing the temperature of the remaining water to drop. The overall effect is that heat (thermal energy) is pumped from the left-hand flask to the right-hand flask, so that the temperature on the left decreases while the temperature on the right increases. Heat and mass transport are shown in the right-hand picture by the blue arrow against the thermal image, with the temperature scale showing the temperatures of the various parts. As can be seen in the inset picture, the latent heat necessary for evaporation is very much larger than the sensible heat content of the water volume, with the result that the water reservoir freezes. The adsorption process stops either if there is no more liquid water available or, more importantly, if the zeolite is fully hydrated, i.e. unable to adsorb any more water.

In practice, heat exchangers would be used inside the flasks to supply heat for the evaporation (i.e. cooling of the heat exchanger's fluid circuit) and to remove the heat from the zeolite (e.g. heat rejection to a cooling tower, or useful heat for heating purposes as is the case for a heat pump). For continuous cooling or heating operation – i.e. in practical applications – first, the adsorption material must be regenerated, and then the water is to be refilled. The regeneration requires heat in order to drive off the water molecules from the surface of the zeolite (desorption process). Suitable sources of heat can be solar energy, waste heat or "gas heat", as is the case for a gas-driven heat pump.

Annotation: The driving force behind thermally driven absorption machines is similar (adsorption versus absorption affinity). However, in the absorption case, solid material is replaced by a liquid mixture "only", which necessitates significant considerations in constructing machines (e.g. a solvent pump is required) and in system management. More details will be available on http://www.annex34.org soon.

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IEA HPP / IETS Annex 35 / 13 Application of Industrial Heat Pumps

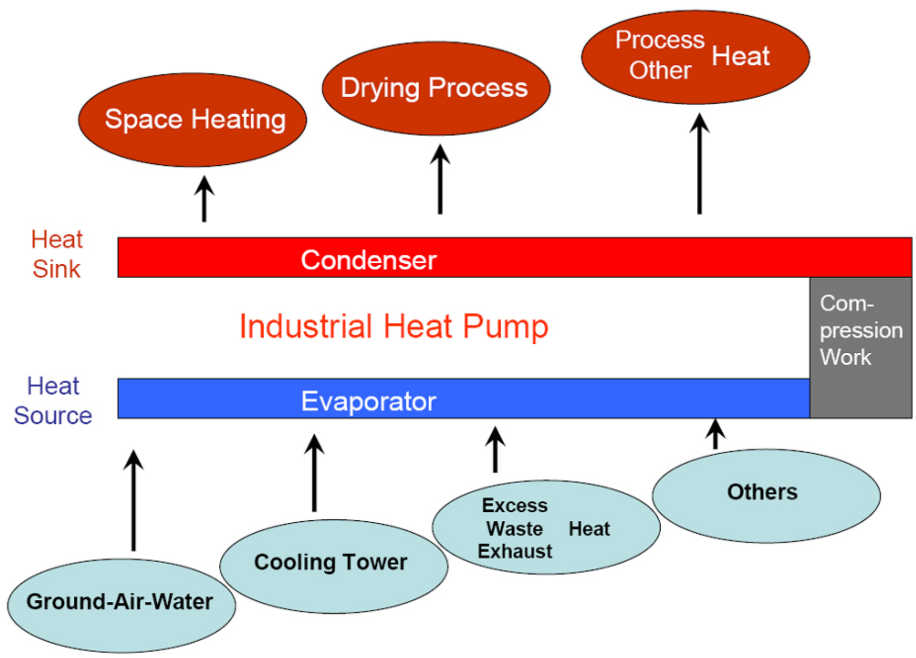
To achieve an excellent working heat pump system, the right type of heat pump must be chosen and installed with a matching heat distribution system. For this reason, it is important to have reliable information on both the heat pump itself, and how it is influenced by the surrounding system.

A common SPF method would be important for fair comparison between different types of heat pump systems as well as fair comparison with other competing technologies using fossil fuels. A common SPF method can then later be incorporated in different labelling, rating and certification schemes.

There is thus a need for an improved transparent and harmonised method for calculation of heat pump system SPF based on repeatability and reliable test data from laboratory measurements.

The main market barrier to the introduction of industrial heat pumps is the lack of experience, and thus lack of acceptance in the market by operators, industrial partners and their supply and consultancy chains.

It has therefore been agreed to start a new Annex entitled "Application of industrial Heat Pumps" as a joint venture between the IEA "Industrial Energy Technologies and Systems" (IETS) and "Heat Pump Programme" (HPP) Implementing Agreements. Annex 35/13 officially started on 1st April 2010, with 16 participating or-



ganisations from ten member countries of IETS and HPP.

The annex will focus on:
- reduction of energy costs, fossil energy consumption and CO_2 emissions in industrial and commercial heat generation,
- constraints related to medium- and high-temperature refrigerants (low GWP, ODP = 0)
- modification of compressors for high temperatures (80 – 200 °C)
- process methodology for integration of heat pumps.

A kick-off meeting took place on 26th April 2010 at the European Academy of Refrigeration and Air conditioning in Maintal/Germany, with 14 participants from eight countries. The meeting discussed and decided on the following topics:
- The role and objectives of the Annex
- Expected contributions from the participants
- A detailed work plan
- Main tasks and time schedule
- The number of meetings

It was agreed that the following tasks-
1. Market overview, barriers to application
2. Modelling calculation and economic models
3. Technology
4. Application and monitoring, and
5. Communication

- should form the framework of the programme, and that each task should have a task leader with specific expertise for the individual task.

It was also agreed that the annual fee of each contracting party should be € 5.500.

The first Annex meeting took place on 11th October 2010 in connection with Chillventa 2010, the international Refrigeration, Air Conditioning and Heat Pumps Trade Fair at the Exhibition Centre, Nürnberg/Germany and the "Industrial Heat Pumps" Forum Workshop of the 2010 Chillventa Congressing, jointly organised by the IZW e.V. and the IEA HPP, with five papers presented by Annex 35/13 participants.

The Annex meeting was attended by 19 participants from ten member countries. Annex Coordinator IZW e.V. presented the current status of
- Contracting parties / Participants
- Legal text: Specific obligations and responsibilities of the participants
- Status of work

The main topic of the meeting was the presentation related to Task 1:
- Overview of the energy situation
- Overview of energy use in industrial sectors

of the participating countries, and a detailed discussion of the work programme.

A problem area was the present lack of experience for Task 2, "Modelling Calculation and Economic Models", as no participant was able to take over the lead for this task. It was proposed that contributors and knowledge for this task should be provided by IETS partners and the IETS network.

In conclusion, the participants discussed options for presentation of the results

The next Annex meeting will take place in connection with the 10th IEA Heat Pump Conference in May 2011 in Tokyo/Japan.

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New IEA Annex 36: Quality Installation / Quality Maintenance Sensitivity Studies

(Avoiding Efficiency Degradation due to Poor Installations and Maintenance)

It is widely recognized that residential and commercial heat pump equipment suffer significant performance loss (i.e., capacity and efficiency) depending on how the components are sized, matched, installed, and subsequently field-maintained. Annex 36 will evaluate how installation and/or maintenance deficiencies cause heat pumps to perform inefficiently and waste energy. Specifically to be investigated is the extent that operational deviations are significant, whether the deviations (when combined) have an additive effect on heat pump performance, and whether some deviations (among various country-specific equipment types and locations) have larger impacts than others.

Objectives

- Develop information for use by industry stakeholders, policy makers, and owners/operators
- Each Participant to evaluate heat pump equipment types and applications that are:
    - o germane to their country's general equipment applications
    - o for residential and commercial buildings
- Lead to more efficient heat pump operation
    - o Reduced energy utilization
    - o Reduced greenhouse gas emissions
    - o Provide for enhanced penetration of heat pumps

In undertaking the sensitivity analyses, each individual Annex partner will be seeking to quantify impacts on system performance (e.g., capacity, energy utilization, etc.) related to varying QI and QM practices / attributes for their varied equipment applications of interest.

Target Audience
- HVAC practitioners responsible for designing, selecting, installing,

Confirmed / Pending Participants for Annex 36	
Confirmed Parties	France Sweden United Kingdom United States *(Annex Operating Agent)*
Interested / Pending Parties	Canada Germany Japan South Korea Switzerland

Co-Operating Agents for IEA Annex 36
Glenn C. Hourahan, P.E. Air Conditioning Contractors of America (ACCA)
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Van D. Baxter, P.E. Oak Ridge National Laboratory (ORNL)

Annex Time Schedule

Start Date	End Date	Activity
November 2010	April 2011	Task 1 – Critical literature survey
May 2011	October 2011	Task 2 – Identify sensitivity parameters
November 2011	July 2012	Task 3 – Modelling and/or lab-controlled measurements
August 2012	April 2012	Task 4 – Simulations on seasonal impacts
May 2013	November 2013	Task 5 – Report and information dissemination

and maintaining heat pump systems in varied applications.
- Building owner/operators interested in achieving improved comfort conditioning and efficiency performance from their HVACR equipment.
- Entities charged with minimizing energy utilization (i.e., utilities, utility commissions, energy agencies, legislative bodies, etc.) in varied heat pump applications and geographic conditions.

Anticipated Meetings

May 2011: 1st meeting (in conjunction with 10th IEA HPC in Japan)
Jun 2012: 2nd meeting (in conjunction with ASHRAE or Purdue Conferences) in the U.S.
mid-2013: 3rd face-to-face meeting at a venue still to be confirmed
Web Conferences to be scheduled on an as-needed basis.

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New IEA HPP Annex 37

Demonstration of field measurements of heat pump systems in buildings – Good examples with modern technology

There is a need to demonstrate the potential for energy savings and CO_2 reduction through heat pump technology. There is also a need for increased knowledge of the efficiency of heat pumps in real installations, and particularly for heat pump systems for combined operation, i.e. providing heating, cooling and domestic hot water.

Demonstration of heat pump systems would be an efficient way to communicate the potential of the technology, promote top-of-the-line [state-of-the-art] heat pump systems, and also to improve existing guidelines for selection, design and installation of the systems. Demonstration of best

available heat pump technology is a way to achieve further acceptance for the technology and expand into new markets. It is important that information on different heat pump systems is accessible, analysed and presented in a harmonised manner.

The operational performance of heat pumps (COP) is often given only for single-mode operation conditions and at full capacity. These conditions do not always reflect the performance of heat pumps operating in real heating systems. The efficiency of a heat pump system is affected by how the heat pump is connected to the system, by the system design, and by the temperature level of the heating system.

The aim of this project is to demonstrate and disseminate the economic, energy and environmental potential of heat pumping technology. The focus will be on best available technology, and results from existing field measurements will be used to calculate energy savings and CO_2 reductions. It should be possible to predict the most suitable heat source and heat pump system for particular applications. In order to reach the right results, it is most important that the quality of the measurements is assured. The criteria for good and assured quality will be defined in the project.

A kick-off meeting is planned to be held in Borås in January 2011, and all member countries are free to participate in the Annex. So far, Austria, UK, Switzerland and Sweden (OA) have committed to join the Annex. Other countries have expressed interest in making a contribution by providing results from existing or ongoing field measurements.

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IEA HPP Annex 38: Solar and Heat Pump Systems

The combined SHC Task 44 and HPP Annex 38, "Solar and heat pump systems", started in 2010, and will run from 2010 to 2013. It is a joint effort of SHC and HPP, and will be led by a single operating agent (JC Hadorn of Switzerland). For SHC, the project carries the designation of Task 44, while for HPP it has Annex Number 38, and was approved in November 2010.

The scope of the task covers solar thermal systems in combination with heat pumps for domestic hot water production and space heating in detached houses. The objectives of the task are assessment of performance and relevance of combined systems using solar thermal and heat pumps; development of a common definition of performance of such systems; and contribution to successful market penetration of these new systems.
The first meetings in Bolzano, Italy (April 29-30, 2010) and Vienna (October 27-28, 2010) were attended by more than 50 experts from 14 countries, from both technical backgrounds (solar and heat pumps).

Subtask A (leader, S. Herkel from ISE, Germany), dealing with real projects, has received more than 20 presentations of projects combining solar collectors and a heat pump. These combinations will be evaluated and compared as part of the work of the task. A "map" of system configurations has been produced, and a new way to describe system configurations has been proposed.
Subtask B (leader: I. Malenkovic from AIT Austria), discussed a common seasonal performance factor definition and laboratory testing procedures.

Subtask C (leader: M. Haller from SPF Switzerland) reviewed existing solar collector types, including condensation effects, and started a review of transient heat pump models. A reference case was also discussed, and will form an extension of IEA SHC Task 32, which is a well-documented case for TRNSYS simulations and comparisons.

Subtask D (leader: W. Sparber from EURAC Italy), discussed the newsletters to be issued, the final handbook, the web site and the new logo, which was finally issued in July 2010.
Participating countries are Austria, Belgium, Canada, Denmark, France, Germany, Italy, Spain and Switzerland from SHC, and Finland, Germany, UK and Switzerland from HPP.

Link to Annex 38 website
http://www.iea-shc.org/task44
For further information on this work, please contact the Operating Agent, Jean-Christophe Hadorn, jchadorn@baseconsultants.com from Switzerland.

Note: at the recent meeting of the Executive Committee of the Heat Pump Programme, held in Vienna in November 2010, four new Annexes were approved. These are Annexes 36, 37 and 38, all of which are presented above, and Annex 39, "A common method for testing and rating of residential HP and AC annual/seasonal performance", which was presented in HPC Newsletter 3/2010, p 16.

Ongoing Annexes

Bold text indicates Operating Agent. * Participation not finally confirmed, ** Participant of IEA IETS or IEA SHC

Annex 34 Thermally Driven Heat Pumps for Heating and Cooling	34	AT, CA, CH, **DE**, FR, IT, NL, NO, US
Annex 35 Application of Industrial Heat Pumps (together with Task XIII of "Industrial Energy-Related Technologies and Systems" (IEA IETS))	35	AT, CA, DK**, FR, **DE**, JP, NL, KR, SE, CH*
Annex 36 Quality installation and maintenance	36	CA*, CH*, DE*, FR, JP*, KR*, SE, UK, **US**
Annex 37 Demonstration of field measurements of heat pump systems in buildings – Good examples with modern technology	37	AT, CH, **SE**, UK
Annex 38 Systems using solar thermal energy in combination with heat pumps	38	AT**, BE**, CA**, **CH**, DE, DK**, ES**, FI, FR**, IT**, UK
Annex 39 A common method for testing and rating of residential HP and AC annual/ seasonal performance	39	AT, CH, DE, FI*, FR, JP, KR, **SE**, US

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

Trends and perspectives in supermarket refrigeration

Michael Kauffeld, Karlsruhe University of Applied Sciences, Germany

This paper describes the latest trends and perspectives in supermarket refrigeration, with the focus on improving energy efficiency, reducing refrigerant charge and using natural refrigerants. Several alternative systems, such as indirect, distributed, cascade and two-stage, are described, and measures for refrigerant charge reduction and energy consumption reduction are presented.

Introduction

Refrigeration used to be very straightforward: our forefathers simply used natural ice to cool their foodstuffs. Starting in the mid 19th century, mechanical equipment was used to produce the ice needed for cooling food. Soon, cooling was applied directly to the food without the intermediate matter of ice. Until the 1930s, all refrigerants used in refrigeration systems were naturally occurring substances, such as ammonia, carbon dioxide, propane and sulphur dioxide. Due to the safety concerns related to these substances, refrigeration was mainly limited to large refrigeration plants. It was thanks to the benefits of what were known as "safety refrigerants" – CFCs, introduced in the 1930s - that refrigeration systems became very popular. Supermarket refrigeration was very simple with these fluids. Most central systems operated on R22 or, for medium temperature, R12. Plug-in units and many condensing units were running on R12. Due to their ozone-depleting potential, these refrigerants are now being replaced by a new class of synthetic fluids: HFCs, with R134a and R404A being the most popular HFC fluids for commercial refrigeration systems. Although safe to the local environment (non-flammable and non-toxic), they do have one big drawback: they have global warming potentials (GWP) up to several thousand times higher than carbon dioxide, and are therefore included in the Kyoto Protocol, i.e. their emissions must be reduced as far as possible.

Anthropogenous contributions to global warming are the major challenge for our society today. Refrigeration systems usually contribute in two ways:

- direct emissions of greenhouse gases, such as CFCs, HCFCs and HFCs
- indirect emissions due to energy consumption.

The contribution of commercial refrigeration to global warming can therefore be reduced by:

- reducing direct emissions of greenhouse gases, which can be achieved by:
    - o leaktight refrigeration systems
    - o reduced refrigerant charge
    - o refrigerants with no, or only very low, GWP
- reducing energy consumption of operation and manufacture
- using renewable energy.

This paper will describe different ways of implementing these measures.

Reducing direct emissions of greenhouse gases

Gastight refrigeration systems

Typical German supermarket refrigeration systems have leakage rates between 5 and 10 %, i.e. 5 to 10 % of the total system charge is lost to the atmosphere every year. Over 30 % of all leaks stem from mechanical joints. One way of attempting to reduce leakage rates is therefore to avoid mechanical joints as far as possible, and use welding or brazing instead, especially in hidden or inaccessible pipes. Another major leak source is failures of pipes due to vibration. Decoupling of compressor vibrations from the rest of the plant is therefore very important.

Many larger leaks start as very small leaks which grow over time. Regular maintenance with leak testing is therefore of key importance for gastight systems. European Regulation (EC) No. 842/2006 on certain F-Gases (e.g. HFCs) requires stationary refrigeration and air conditioning systems to be checked regularly, depending on the systems' amount of refrigerant:

- At least annually for systems containing 3 kg or more of F-gases (unless the equipment is hermetically sealed, in which case this goes up to 6 kg)
- At least once every six months for systems containing 30 kg or more of F-gases
- At least once every three months for systems containing 300 kg or more of F-gases
- Leakage detection systems must be installed on applications with 300 kg or more of F-gases and, when these are in place, checking requirements are halved
- If a leak is detected and repaired, a further check must be carried out within one month to ensure that the repair has been effective.

Time will show whether this F-Gas Regulation will have an impact on leakage from stationary refrigeration systems.

Another approach is used by the Danish and Norwegian governments, which impose a high greenhouse gas tax on all refrigerants. The tax rate for R404A in Denmark is approximately EUR 50/kg, and in Norway approximately EUR 80/kg. Consequently, these high prices encourage all users to maintain gastight systems, especially if the charge is of the order of several hundred kg as for multiplex systems in larger supermarkets.

Reduced refrigerant charge

In many refrigeration systems, most of the refrigerant is contained in the heat exchangers, especially in the condenser. Most central multiplex supermarket refrigeration systems use round-tube-and-fin heat exchangers as evaporators and condensers, with a typical tube diameter of 15 mm. The refrigerant content inside the heat exchangers can be reduced by up to 80 % by using mini-channel heat exchangers, which are well known in the automotive air conditioning industry. The automotive air conditioning industry has developed from large round-tube condensers (ø 12 mm) in the 1970s via small round tubes (ø 7 mm) to Multi-Port-Extruded (MPE) all-aluminium brazed heat exchangers, with a fourfold increase in heat transfer coefficient on the refrigerant side and a very substantial decrease in refrigerant charge. This development has yet to reach stationary refrigeration and air conditioning equipment. At least one major American air conditioning manufacturer already offers its chillers with mini-channel condensers, with noticeably reduced refrigerant charge. It is just a matter of time until the commercial refrigeration market follows.

Another possibility for reducing refrigerant charge is the use of indirect refrigeration systems, which are very common in Sweden where refrigerant charge per system has been limited to some 30 or 40 kg for many years. Typically, propylene glycol is used as a liquid secondary heat transfer medium in the medium-temperature (MT) loop. Glycol becomes too viscous for the low-temperature (LT) loop. Attempts have been made using different potassium formate and potassium acetate solutions for LT applications.

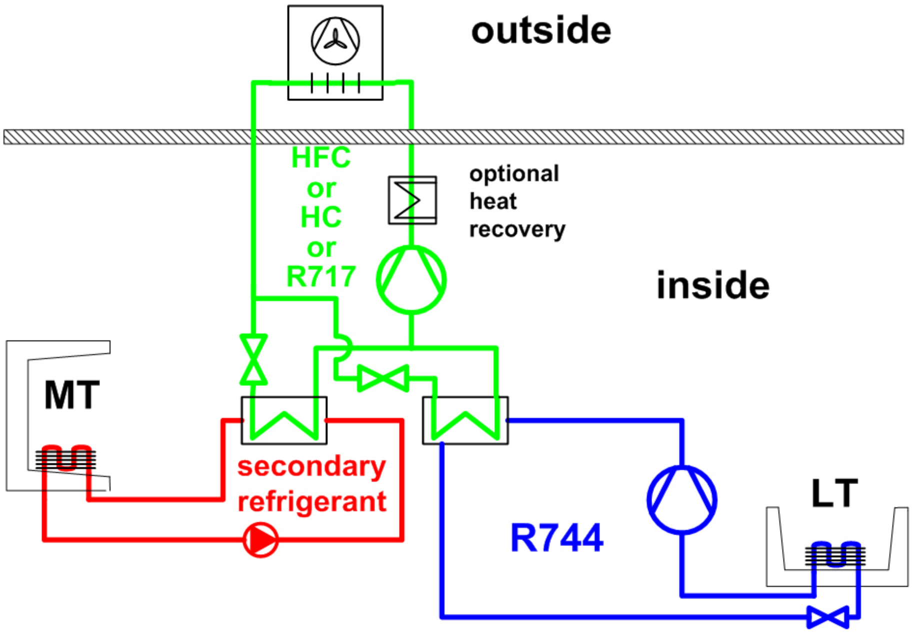

Figure 1: Secondary loop MT refrigeration system, also called indirect refrigeration system. The low-temperature loop is built as a cascade system to the MT system.

Although MT secondary loop systems can achieve energy efficiencies quite similar to direct expansion systems, using a liquid secondary heat transfer fluid in a low-temperature application usually increases the energy consumption. Systems have therefore been developed using carbon dioxide as a volatile secondary refrigerant. These systems show good energy performance. Recently, attempts have been made to use the carbon dioxide loop as a fully integrated refrigeration system, i.e. to build it as a cascade below the MT system, see Figure 1. Although the MT primary refrigeration system is confined to the machine room, the LT system uses conventional direct-expansion technology. Due to the potentially high system pressure of the carbon dioxide loop at standstill, special precautions have to be taken to avoid excessive pressures. In a typical supermarket system, which operates 24 hours a day, seven days a week, CO_2 is simply blown off to atmosphere if pressures exceed the maximum allowable pressure during standstill.

Employing a propylene glycol system for MT cooling has a few advantages over direct expansion systems:

- First of all, reduced primary refrigerant charge: reductions up to 80-90 % are possible.
- Factory assembly of the primary refrigeration system, with higher quality and lower risk of leaks.
- Reduction in oil charge of the much smaller internal volume primary refrigeration system.
- Possibility of using flammable or toxic refrigerants as the primary refrigerant, safely confined to the machine room. Air-cooled rooftop condensers are legally permitted in some countries, e.g. Denmark, even with flammable or toxic refrigerants.
- Easy utilization of heat recovery when using a water cooling loop for the condenser, as is often the case in Denmark or Sweden, in order to reduce the primary refrigerant charge as much as possible.
- More stable air temperature and air humidity in display cases, due to lower temperature fluctuations of the glycol loop and higher surface temperatures of the heat exchangers inside the cabinets. Higher air humidity results in less shrinkage of the food stuff.
- Fewer defrost cycles.
- Possibility of constructing the secondary loop in plastic piping and fittings which can be cheaper than copper piping traditionally used with direct expansion systems.

Especially in the USA, the use of distributed systems is gaining a considerable market share, see Figure 2. In 2006, 15 % of all new supermarket refrigeration systems in the USA were of the distributed type [Garry 2007]. Losses in suction pipes can be greatly reduced due to the compact design of the individual compressor racks, which are installed in noise-reducing enclosures and placed inside the store. Experience from American supermarkets therefore shows 5-8 % lower energy consumption [Walker 1999] and about 30-50 % lower refrigerant charge [Baxter 2007] than for comparable R404A direct-expansion systems.

Some countries try to force charge reduction in refrigeration systems. Denmark has prohibited the use of HFC in quantities greater than 10 kg in a single system since 1 January 2007. In Sweden, the "Köldmediekungörelsen" stipulated minimum charge systems, which led to a large market penetration of indirect systems. However, today, with the F-gas regulation in place, no demands on minimum charge exist in Sweden; only the leakage control demands as described in the F-gas regulation.

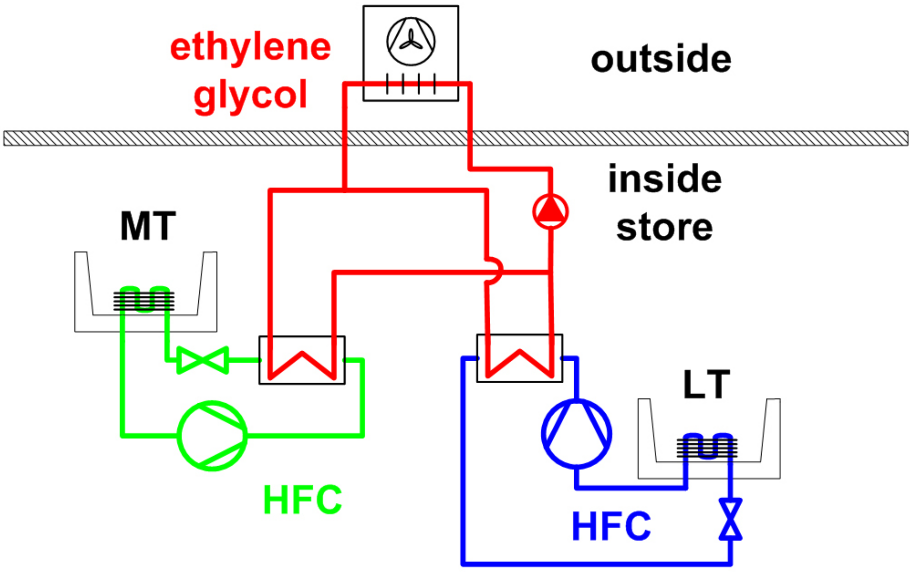

Figure 2: Distributed system – compact multiple-compressor arrangements are housed in noise-reducing enclosures and placed close to the refrigerated cabinet inside the store. Condenser heat is rejected to a water/glycol loop, which rejects its heat via a cooler to the outside air unless used for heating the building.

Table 1: Properties of various refrigerants for commercial refrigeration systems.

	GWP	Flammability	Toxicity	Price of refrigerant	Price of system	Theoretical system efficiency
HFCs	High	No	No	Moderate	Low	Good
Hydrocarbons	Low	Yes	No	Low	Low to medium	Good
Carbon dioxide	Low	No	Only at high concentr.	Low	Medium	Medium
Ammonia	Low	Can be ignited	Yes	Low	Medium to high	Good

Refrigerants without, or with very low, GWP

Another possibility for reducing direct emissions of greenhouse gases is to use refrigerants with low GWP. But GWP is not the only criterion when selecting a suitable refrigerant. Among others, the following items are of interest:

- Zero ODP
- Good thermodynamic and other properties
- Good heat transfer
- Low pressure ratio
- High volumetric refrigeration capacity
- Non-corrosive
- Oil compatibility
- Stable
- Non-toxic
- Non-flammable
- Available
- Cheap

Table 1 shows the properties of several refrigerant candidates suitable for commercial refrigeration systems.

From a technical point of view, the vapour pressure curve is an important characteristic. Figure 3 shows the vapour pressure curves for several refrigerants for commercial refrigeration systems, from which it can be seen that one refrigerant (R744 – carbon dioxide) is quite different from all the others. System pressures are much higher with R744 than with any other refrigerant shown. In addition, the critical temperature of R744 is only 31 °C, which means that, during hot summer days, an air-cooled R744 system will not be able to condense the refrigerant in the condenser/gas cooler. Without system modifications, the system COP of such a transcritical system will be lower than that of a conventional system that is capable of condensation at all times.

A possibility for using carbon dioxide whilst ensuring it always operates well below its critical temperature is its application in a cascade system, as described above. The maximum operating pressure of such systems is typically limited to 40 bar. During the last couple of years, many components have been developed suitable for that pressure range, e.g. expansion valves, control valves, filter/driers, heat exchangers and compressors. Such R744 cascade systems are now seen as state-of-the-art by many European supermarket refrigeration equipment manufacturers [Sienel 2007].

But systems condensing CO_2 at ambient air temperatures are also gaining popularity in Europe, and slowly in the rest of the world. The typical direct-expansion system for MT and LT applications uses two-stage compression for the LT side, as shown in Figure 4. Pressure inside the store is usually limited to 40 bar, and the higher pressures (up to 120 bar during the summer) are restricted to the machine room and the outdoor heat exchanger. To date, over 400 such stores have been built in Europe by several companies. Energy efficiency is usually better than for a comparable R404A system when outdoor temperatures are below about 12 °C, equal to R404A between 12 and 26 °C, and slightly lower at higher ambient temperatures [Sienel 2007].

Flammable (hydrocarbons) and toxic (ammonia) refrigerants can be used as primary refrigerants in indirect systems – see above. But hydrocarbons can also be used directly in the store if certain safety precautions are taken. The usual standard considered is IEC 60335-2-89, which calls for a maximum charge of 150 g of a flammable refrigerant. Taking the system's internal volume and the volume-pressure product for the hermetic compressor into account, hermetic refrigeration systems up to about 1 kW refrigeration capacity are being built using propane (R290). Such systems have approximately 10 to 15 % lower energy consumption than comparable HFC-products [Jürgensen 2004]. New developments also include variable-speed compressors for these plug-in units, which save an additional 10-15 % [Jürgensen 2004]

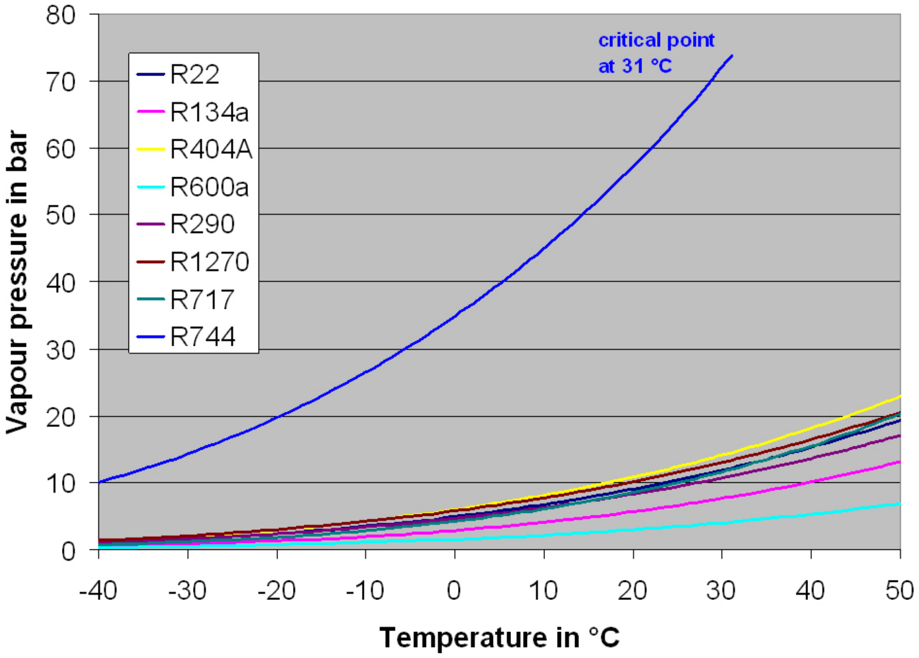

Figure 3: Vapour pressure curve of some common commercial refrigerants. The graph shows the vapour pressure as a function of temperature, e.g. R744 (carbon dioxide) boils (evaporates) at –20 °C at a pressure of 20 bar, or condenses at a pressure of 60 bar at a temperature of 22 °C.

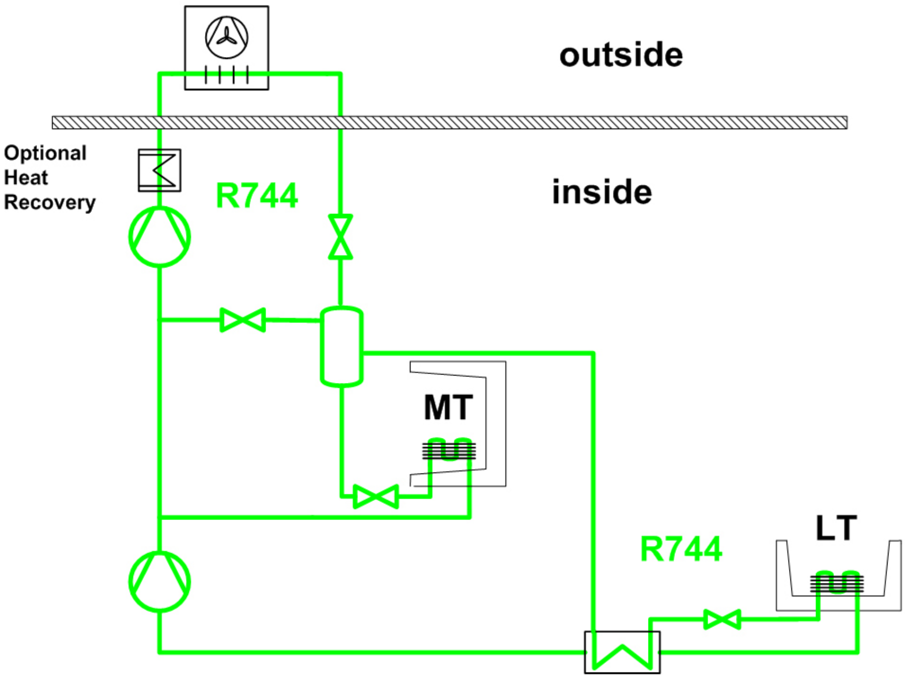

Figure 4: Central multiplex system with carbon dioxide as refrigerant.

Reducing energy consumption

Between 40 and 60 % of the electricity consumption of a typical supermarket is related to the refrigeration equipment.

The following steps can - among others - be taken during the design and construction phase of a supermarket refrigeration system in order to reduce energy consumption:

- Use glass doors or covers instead of open cabinets
- Improve insulation by greater thickness or higher heat resistance
- Place the fan motor outside the cabinet in order to avoid the heat of the motor adding to the cooling load
- Use an improved evaporator fan and/or fan motor, e.g. higher-efficiency fan blades or high-efficiency electric motor
- Improve the air flow in open multi-decks so that air loss to the sales area is minimised and air infiltration from the sales area is minimised

- Fit infrared-reflecting shades or baldachins in order to prevent heat load from shop lights and/or sun light
- Use improved anti-condensation heaters / dew point control in order to run at the lowest possible temperature
- Incorporate a siphon in the defrost drain rather than straight lines which can allow air to blow in
- Use hot gas defrost instead of electric defrost
- Use speed control of compressors, pumps, fans instead of on/off operation
- Improved expansion valve, e.g. electronic expansion valves
- Use an expansion machine, e.g. a turbine which recovers expansion work and supplies it to the compressor
- Improved evaporator, e.g. enhanced air side or enhanced refrigerant side or minichannels – every degree Celsius higher evaporation temperature reduces energy consumption by approximately 3 %
- Flooded evaporator instead of using between 20-30 % of the refrigerant side surface for superheat
- Defrost on demand by, for example, monitoring the fan current and starting to defrost when fan current increases
- Improved lights, e.g. LEDs or high-efficiency neon tubes, in combination with sensors which turn off the light whenever there are no costumers
- Reduced condensation temperature – every degree Celsius reduction in condensation temperature saves approximately 3 % energy
  - o Use the outside air temperature to adjust condensing temperature, rather than have a constant high condensation temperature all year round
  - o Evaporative cooling of condenser
  - o Reject condenser heat to the ground
- Free cooling – outdoor temperatures are lower than the average temperature in a supermarket, i.e. +5 °C, during certain times of the year and/or day in many countries

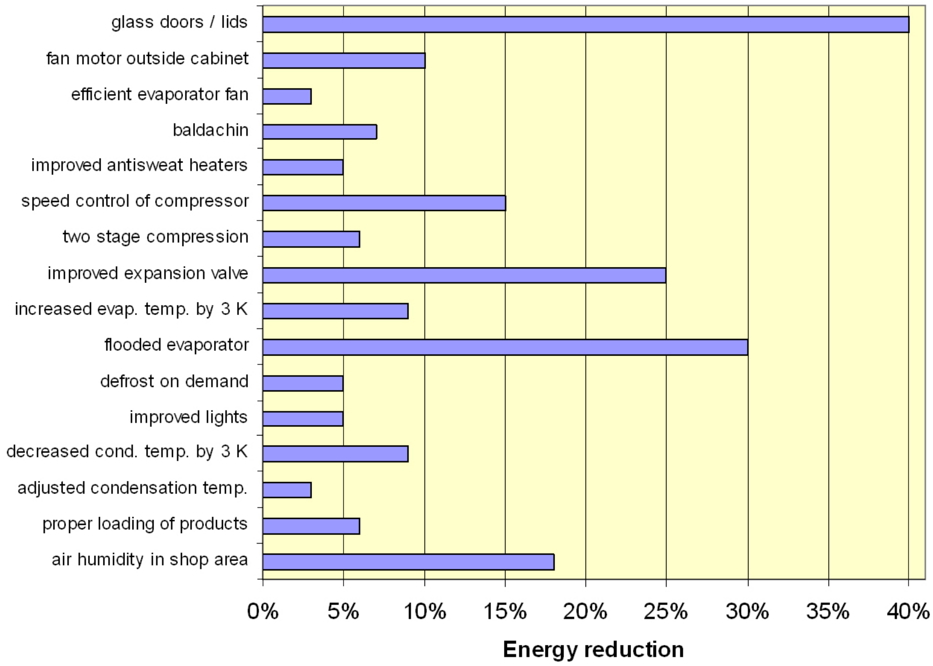

Figure 5: Energy savings by applying different measures. Many of the measures can be combined. The resulting energy savings can be estimated by multiplying individual values – NOT adding them! For example, if speed control of compressors gives 15 % and fan motor outside cabinet gives 10 %, the resulting total would be 0.9 times 0.85, equal to 0.765 or 23.5 % total energy reduction.

- Heat recovery and utilisation of this "waste" heat for heating purposes
- Cold storage, i.e. cooling a heat sink during the night, while the outdoor temperature is low and the condensing temperature can therefore be low too, to reduce energy consumption; the cold storage medium can be a separate tank with chilled water, an ice storage tank or simply the frozen food in the supermarket

The following steps should be taken during operation of a supermarket refrigeration system:

- Correct loading of products in order not to disturb the air flow in the cabinet
- Air humidity in the shop area should be at the lower end of the comfort range, i.e. approximately 40 % relative humidity
- Regular evaporator and condenser cleaning

Figure 5 shows the potential of some of these measures. Many of them can be combined in order to improve energy efficiency well above 50 % as compared to current design.

Reduction of energy consumption is important because it:

- reduces the contribution to global warming through indirect emissions depending on refrigerant, leakage rate and refrigeration system. Energy-related global warming contribution varies from 50 % for an R404A multiplex system with 300 kg refrigerant charge, 10 % leakage rate, to almost 100 % for a R290 plug-in freezer or an R744 central system.
- reduces the operating cost and thereby increases profit. Refrigeration accounts for 40-60 % of a supermarket's energy consumption; energy costs are sometimes of the same order of magnitude as the profit (1-2 % of turnover).

Using renewable energy

Supermarkets have quite large roof areas, which makes them suitable for roof-mounted photovoltaic (PV) systems. This is done by several supermarket chains in Germany. Some experimental stores have also erected wind turbines and/or use ground-source heat. Another possibility for a supermarket chain is to switch to a supplier of renewable energy, as a few supermarket chains in Germany and the UK have done. The use of daylight by north-facing windows is a simple way of reducing the need for electric lighting.

Discussion

It is technically and economically feasible to build and operate supermarket refrigeration systems with reduced climate impact. This can be done in several ways, as described above. Which way is selected depends on personal preferences, the availability of components and skills and on willingness possibly to pay a slightly higher system price to begin with. In many cases, the higher investment can be recovered by lower operating and/or maintenance costs of improved systems.

Conclusions

- HFCs can be replaced, or their charge quantities greatly reduced, at acceptable cost in all applications
- Energy efficiency of such alternative supermarket refrigeration systems is at least as good as state-of-the-art HFC technology
- Supermarket refrigeration systems offer energy savings potential up to 50 % and more at moderate costs
- In countries with appropriate legislation, e.g. Denmark, Norway and Sweden, many HFC-free or HFC-reduced systems are built with good energy efficiency
- Some supermarket chains have environmental protection as their strategy and build low-carbon emission supermarkets[1]
- HFC-free plug-in units with better energy efficiency, using hydrocarbon refrigerants, are available up to approximately 1 kW capacity

Acknowledgement

The work presented is a result of a project funded by the German Federal Environment Agency, FKZ 206 44 300. The author greatly appreciates this funding.

Nomenclature

CO_2	Carbon dioxide – as refrigerant also called R744
COP	Coefficient of Performance
GWP	Global Warming Potential
HC	Hydrocarbon
HFC	Hydrofluorocarbon
LED	Light emitting diode
LT	Low temperature, i.e. cooling of frozen food, usually at product temperatures around –18 °C
MT	Medium temperature, i.e. cooling of milk, meat and vegetables, usually at product temperatures around +5 °C
NH3	Ammonia – as refrigerant also called R717
ODP	Ozone Depleting Potential

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[1] The 400-member global retail-manufacturer alliance the “Consumer Goods Forum” has made commitments to address climate change on the first day of the Cancun Climate Summit in December 2010. On refrigeration, the forum agreed to begin phasing-out hydrofluorocarbon (HFC) refrigerants as of 2015 and replace them with non-HFC refrigerants. See http://www.ciesnet.com/ for details.

Using heat pumps for energy recovery in supermarket refrigeration systems

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Energy consumption of each conventional supermarket represents up to 50 % of the primary energy consumption for food cooling and freezing, while rejecting enormous amounts of excess heat outdoors. Basic heat recovery systems allow recovery by desuperheating up to 40 % of the compressors' discharge energy, but this amount of heat isn't sufficient for integral supermarket space and hot water heating in northern climates. Heat pumps and direct heat recovery heat exchangers may overcome this problem, and thus help improve the overall energy efficiency of supermarket refrigeration systems. This article compares the basic heat recovery method in direct-expansion supermarket refrigeration systems with other concepts using heat pumps and direct heat recovery coils. Measured parameters, such as refrigerant and warm secondary fluid temperatures, show potentials for using low- and high-temperature heat pumps in supermarkets located in cold and temperate climates.

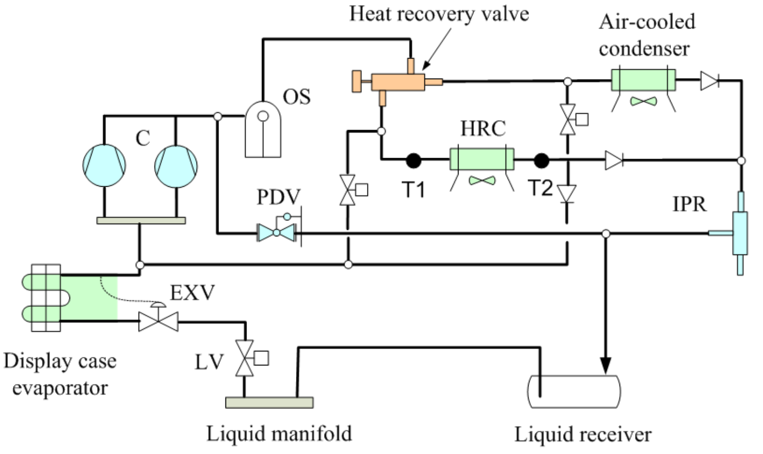
Introduction

Most supermarket refrigeration systems throughout the world still use direct-expansion (DX) processes and large quantities of primary refrigerants. However, the negative environmental impact of refrigerant leakages has stimulated the development of new supermarket refrigeration concepts, requiring less refrigerant charges and lower energy consumptions and costs. In supermarkets located in cold and temperate climates, heat recovery from refrigeration compressors is particularly suitable because the space and domestic/process water heating needs are coincident with the waste heat rejection.

Basic DX systems

Basic supermarket refrigeration systems are set up with direct-expansion evaporators. The low- and medium-temperature evaporators operate with evaporating temperatures of approximately –29 °C and –7 °C respectively. Heat available for recovery comes from the high-pressure, high-temperature discharge refrigerant vapour. Theoretically, both superheat (sensible) and condensing (latent) heat of the discharge gases can be recovered. When climate conditions and/or time of year are such that the most heat is required in the building, they also mean that the (outdoor) condenser will be condensing the gas to the lowest condensate return temperature. As the condensing temperature approaches a set minimum, the refrigeration compressors approach maximum capacity. Therefore, for a constant load on the refrigeration system, there will be fewer compressors running when the condensate is being returned at this low temperature, resulting in less heat available for recovery.

On the other hand, full condensing heat recovery yields higher total heat recovery amount but at much lower temperature than from desuperheating. In basic DX systems, a heat recovery valve allows heat to be recovered with heat recovery coils (HRC) (Figure 1a). When heat recovery is



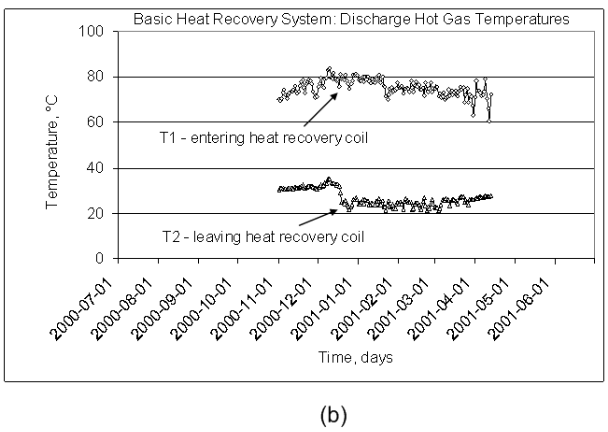


Figure 1 - (a) Basic refrigeration system with heat recovery coil; (b) Discharge gas temperature entering and leaving the heat recovery coil. C: compressor; OS: oil separator; LV: liquid valve; EXV: expansion valve

required, the refrigerant is directed toward the HRC. When heat recovery isn't required, the outdoor air-cooled condenser rejects the system excess heat.

Such a system can operate with floating condenser pressure control that allows the condensing pressure to vary with changing ambient conditions and thus reduces the compressor energy consumption. However, there are several operational problems, such as potential flash gas in the liquid line at the expansion valve inlet and the impossibility of heat recovery in cold climates because there will be no heat to recover at desired temperature levels. Consequently, when employing heat recovery, a head pressure control is required not only to maintain the liquid pressure at the expansion valve inlet, but also to ensure the availability of hot gas at the recovery heat exchanger. The head pressure is generally controlled by an inlet pressure regulating valve (IPR) located in the liquid line between the condenser and the liquid receiver. The IPR opens and closes only with changes in the condensing pressure in response to outdoor temperature changes. Since it is actually the receiver pressure that needs to be maintained, a bypass line with a pressure differential valve (PDV) responding to changes in pressure differences is required. The combined operation of the IPR and PDV valves is such that constant receiver pressure is maintained during the cold winter months.

In most cold climate systems, a simple holdback valve can be used instead of IPR/PDV valves, intentionally adjusted to maintain a higher condensing temperature for the purposes of higher quality (temperature level) of heat recovered. In this case, the electrical energy consumed by the refrigeration system may exceed the heat energy gained.

Figure 1b shows the temperatures of the refrigerant discharge gases entering (T1) and leaving (T2) the heat recovery coil in a Canadian supermarket equipped with a DX refrigeration system. Even though, in this application, the refrigerant enters the HRC at temperatures between 60 °C and 80 °C, the supermarket uses a supplementary energy source (propane gas) during the winter to meet the building's peak heating load [1]. This example demonstrates that the amount of heat recovered by simple desuperheating is not sufficient to provide full space heating capacity load in cold climates, or even in moderate climates. To address this issue, heat pumps can be used in order to upgrade the temperature level and the amount of heat supplied for space and/or hot water heating.

Two-stage systems

Two options for two-stage heat recovery are shown in Figure 2a (for a medium-temperature zone) and Figure 3a (for a low-temperature zone) [1]. The first stages of these systems contain refrigerant-to-refrigerant heat recovery coils (HRC), and the second stages include refrigerant-to-

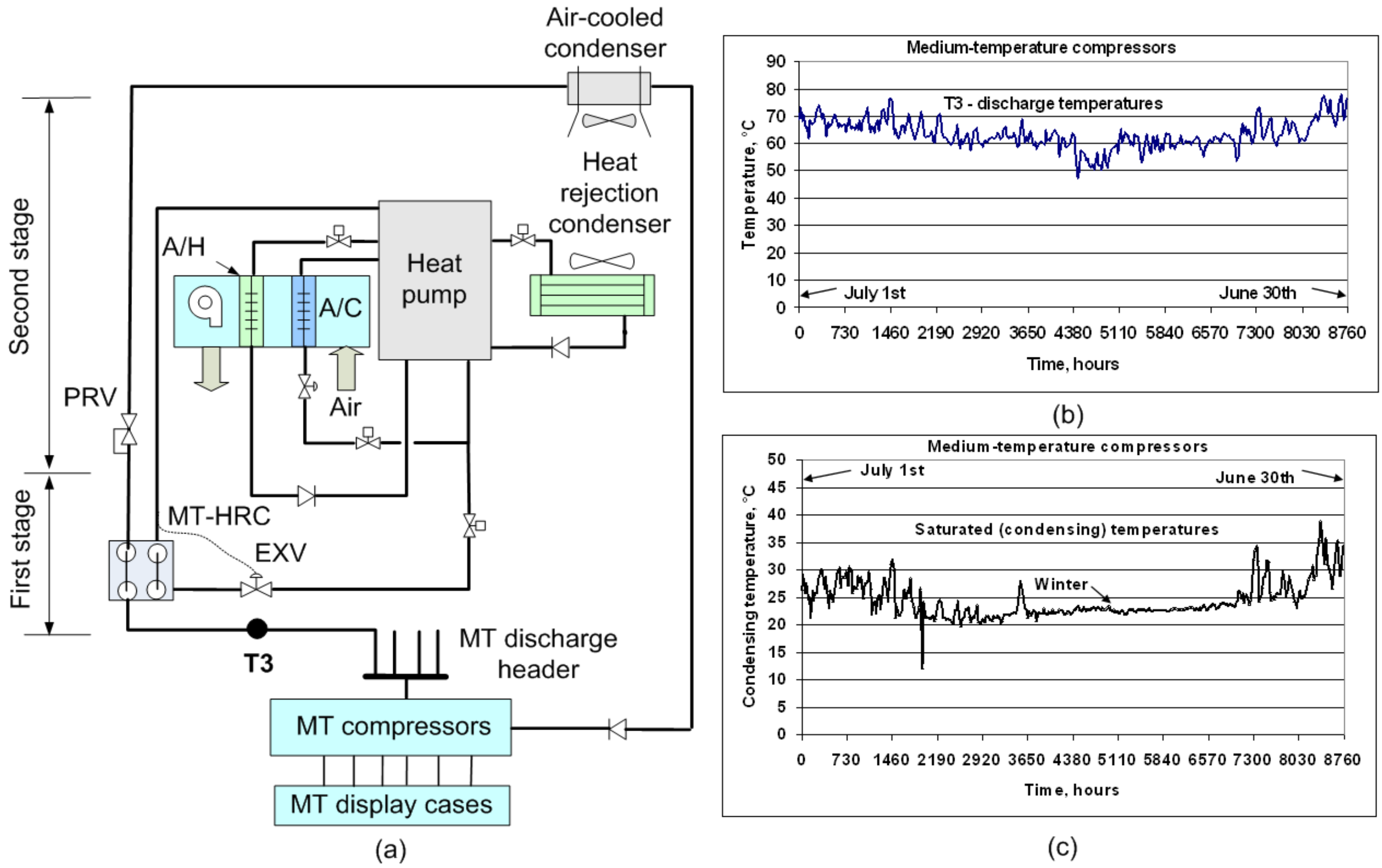


Figure 2 – (a) Two-stage heat recovery system in the medium-temperature zone; (b) Annual temperature profile of compressors' discharge gases; (c) Annual profile of condensing temperatures. MT: medium temperature; HRC: heat recovery coil; EXV: expansion valve; PRV: pressure regulating valve

air heat pumps. The compressor discharge gases are cooled by desuperheating and, then, partially or totally by condensing inside the first-stage heat recovery coils. The sensible and latent heats recovered represent energy sources for the second-stage heat pumps. During the winter, the pressure-regulating valves PRV maintain pressures inside the heat recovery coils corresponding to condensing temperatures higher than 10 °C. In both systems, the refrigerant discharge gases finish the condensing and sub-cooling processes inside remote air-cooled condensers.

In the medium-temperature refrigeration zone (Figure 2a), the heat pump includes refrigerant-to-air coils for air-heating (A/H) and air-cooling (A/C) purposes. During the heating season, the air heating coil acts as a condenser providing heat for indoor air heating. In the cooling season, the cooling coil cools and dehumidifies the supermarket indoor air. When heat recovery is not required, and also in cooling mode, the heat pump's additional heat rejection condenser rejects the excess heat to the outdoor air.

Figure 2b represents, as an example, the annual profile of the discharge gas temperature (T3) of medium-temperature compressors. During the winter, this temperature varies around 60 °C, providing important amounts of heat recovery by desuperheating and, also, by condensing at temperatures of around 22-23 °C (Figure 2c).

In the low-temperature zone (Figure 3a) the heat pump contains two heat exchangers: a refrigerant-to-air coil for space heating and cooling, and a heat rejection condenser used in cooling mode and also when no heat recovery is required. Figure 3b shows the annual profile of the discharge gases temperatures (T4) and Figure 3c shows the annual profile of condensing temperatures of low-temperature compressors. With discharge gas temperatures of around 80 °C in winter, valuable and efficient heat recovery is provided by desuperheating, as well as by total or partial condensing at temperatures varying around 22 °C. Both of the described two-stage heat recovery concepts allow running with compressor discharge pressures about 35 % lower than those required for basic DX heat recovery systems in similar weather conditions. As a consequence, energy savings are provided because less drive energy is needed for the compressor.

Warm heat rejection loops

Heat recovery from refrigeration systems with warm rejection loops reduces the primary refrigerant charges and also offers energy saving opportunities in supermarkets. Figures 4a and 5a represent DX supermarket refrigeration systems with warm heat rejection loops [2]. In the low-temperature (LT) freezing zone (Figure 4a), sensible and latent heat recovered from the hot discharge gases by the LT condenser is transferred to the LT heat rejection loop, where pump P circulates a water/

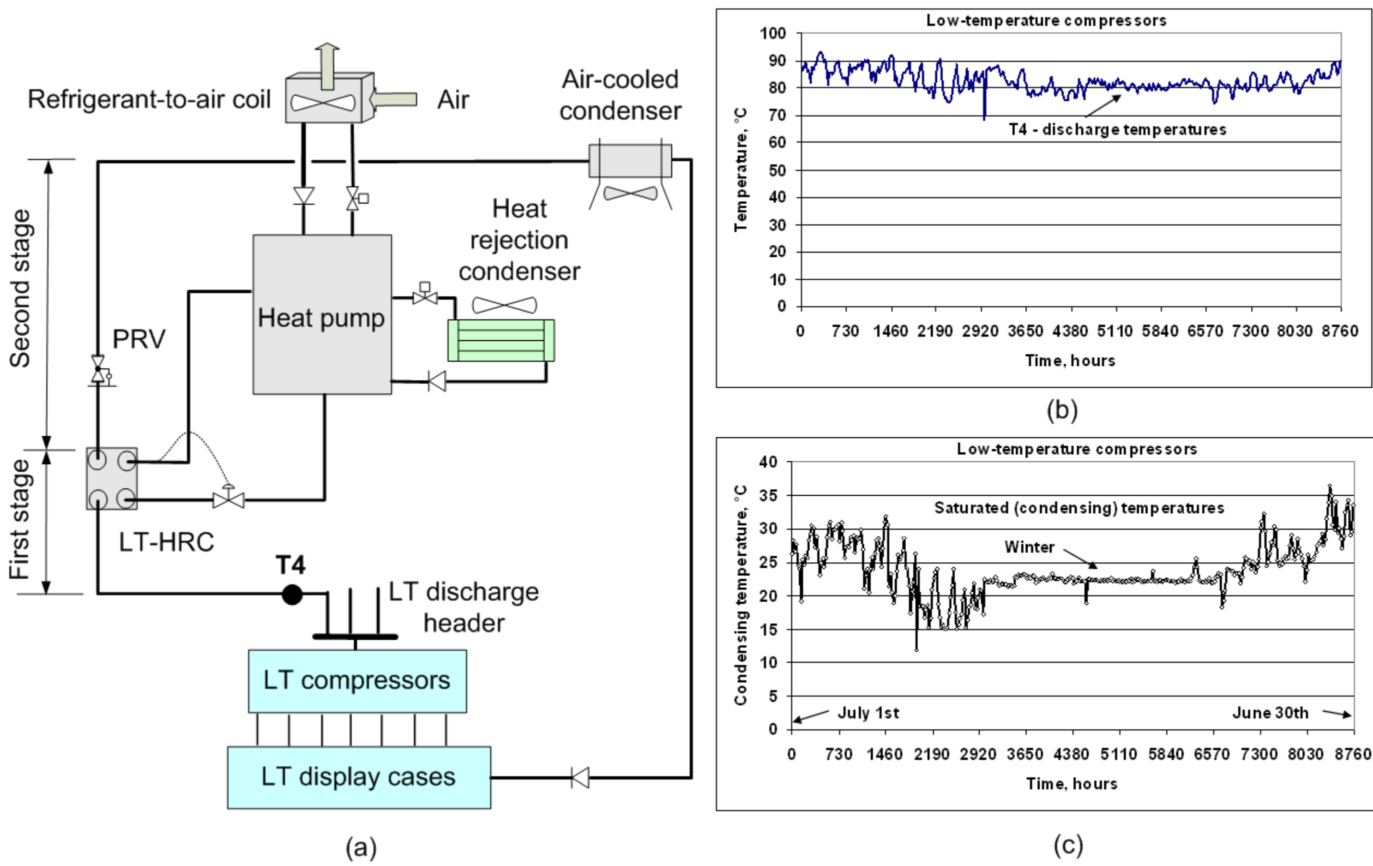


Figure 3 – (a) Two-stage heat recovery system on the low-temperature zone; (b) Annual profile of compressors' discharge gases temperature; (c) Annual profile of condensing temperatures. LT: low-temperature; HRC: heat recovery coil; T: temperature

glycol mixture. The brine air-cooled cooler rejects the excess heat of the system to the outdoor air.
Figure 4b shows that during the coldest week during a given typical winter in the Canadian cold climate, the average temperature of the brine leaving the LT condenser (T5) is at around 8-9 °C. At such temperatures, the low-temperature heat rejection loop represents a valuable energy source for heat pumps. As can be seen in Figure 4c, the coefficient of performance of such brine-to-air or brine-to-water heat pumps is as high as 4.

In the medium-temperature zone (Figure 5a), the superheated vapour from MT compressors is directed, when required, to the heat recovery coil HRC, which is a desuperheater/condenser, or to the MT condenser. Heat recovered from HRC is transferred to the indoor water loop. The MT condenser rejects heat to the MT heat rejection loop, where a brine cooler rejects it to the ambient. Average condensing temperatures of 41 °C (with R 407C) are high enough to heat the closed loop water up to 38 °C (T6 in Figure 5b) and the store space to around 20 °C with water-to-air convectors. On the other hand, the temperatures of brine leaving the MT heat rejection condenser (T7) vary between 4 and 8 °C during the coldest winter day, providing significant energy savings for space and/or hot water heating (Figure 5c). At such temperatures, heat pumps can successfully be used in the MT heat rejection loop as shown in Figure 5a. The COPs of such heat pumps vary between 3 and 4 (Figure 4c).

Totally secondary fluid systems

More advanced concepts consist of secondary fluid (brine) loops on the refrigerating, freezing and condensing sides of supermarket refrigeration systems (Figures 6a and 7a) [3, 4]. Such concepts reduce the required charge of primary refrigerants by more than 60 %. The low-temperature zone (LT) contains a warm secondary fluid loop for heat recovery with heat pumps and heat rejection via an air-cooled liquid cooler (Figure 6a). The brine-to-air heat pump units use the waste heat rejected by LT compressors as a heat source to heat supermarket areas such as entrances, merchandise reception and storage areas, and community rooms. Figure 6b shows that during the coldest day of the year in eastern Canada, the temperatures of the LT warm secondary fluid (T8) average 22 °C. At such a temperature, the heat recovery heat pumps operate in the heating mode with coefficients of performance as high as 4.6 (Figure 4c) while, at the same time, the outdoor temperatures may drop to –25 °C. As a comparison, at outdoor temperatures of around –25 °C, the conventional air-to-air heat pump operate with COPs of about 1.2 and, consequently, will be totally inefficient as a heating device. Figure 6c gives, as an example, the daily operating profile of such a heat pump installed in a Canadian cold climate supermarket as shown in Figure 6a.

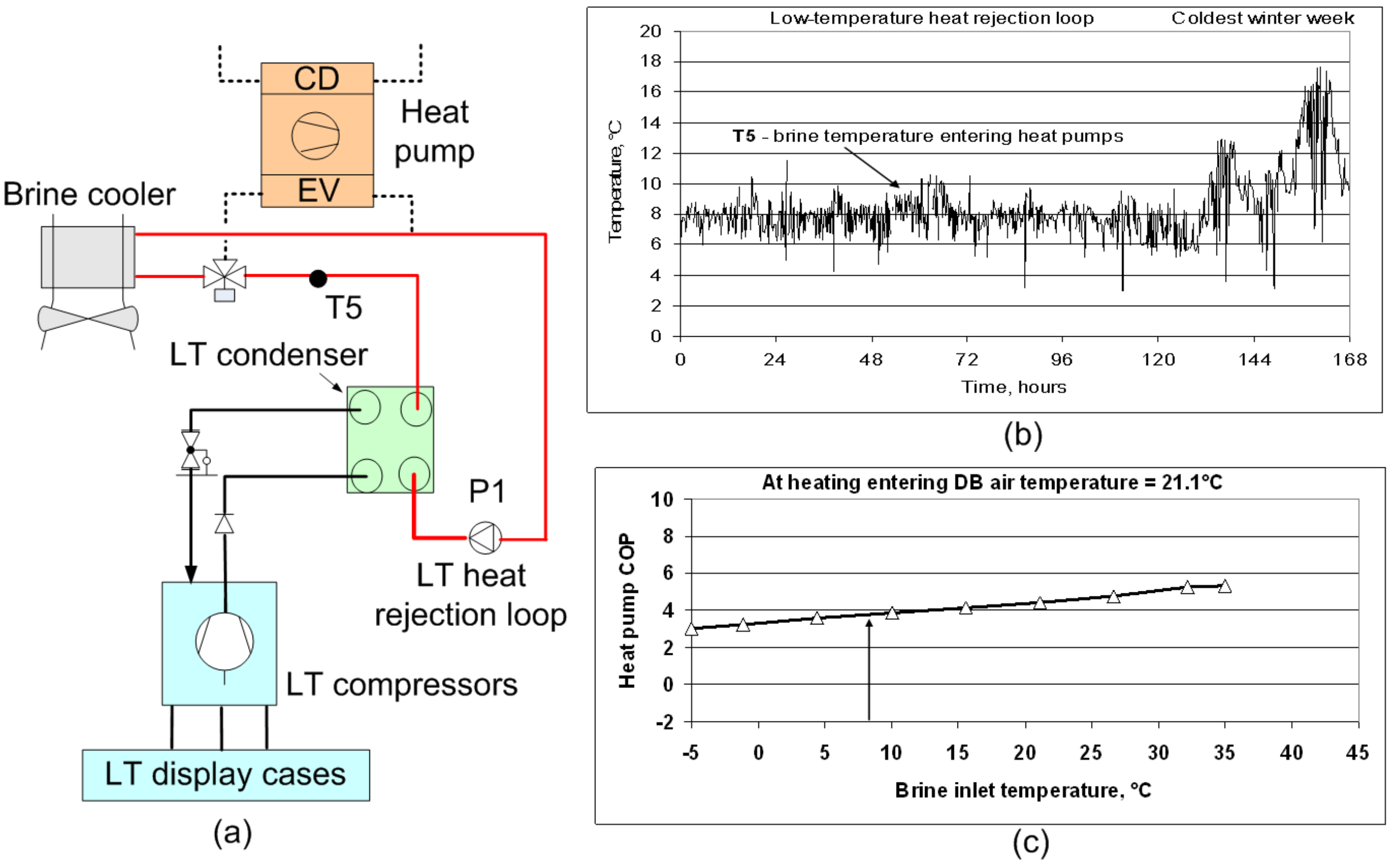


Figure 4 – (a) Heat recovery on warm secondary fluid loop of the low-temperature zone; (b) Weekly temperature profile of LT heat rejection loop; (c) Heat pump's COP as a function of brine inlet temperatures. LT: low-temperature; T: temperature; DB: dry bulb

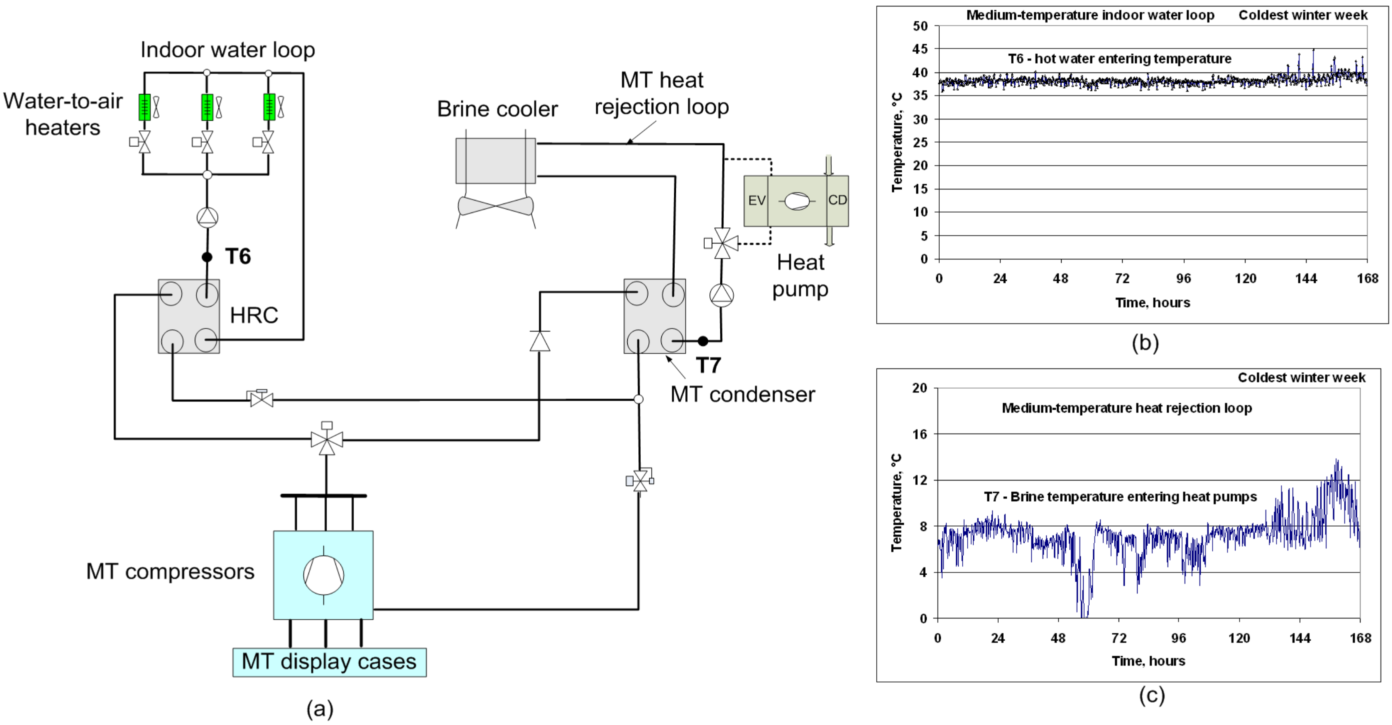


Figure 5 – (a) Heat recovery on warm secondary fluid loop of the medium-temperature zone; (b) Weekly temperature profile of water entering the indoor heat recovery loop; (c) Weekly temperature profile of brine entering the heat pumps. MT: medium-temperature; HRC: heat recovery coil; T: temperature

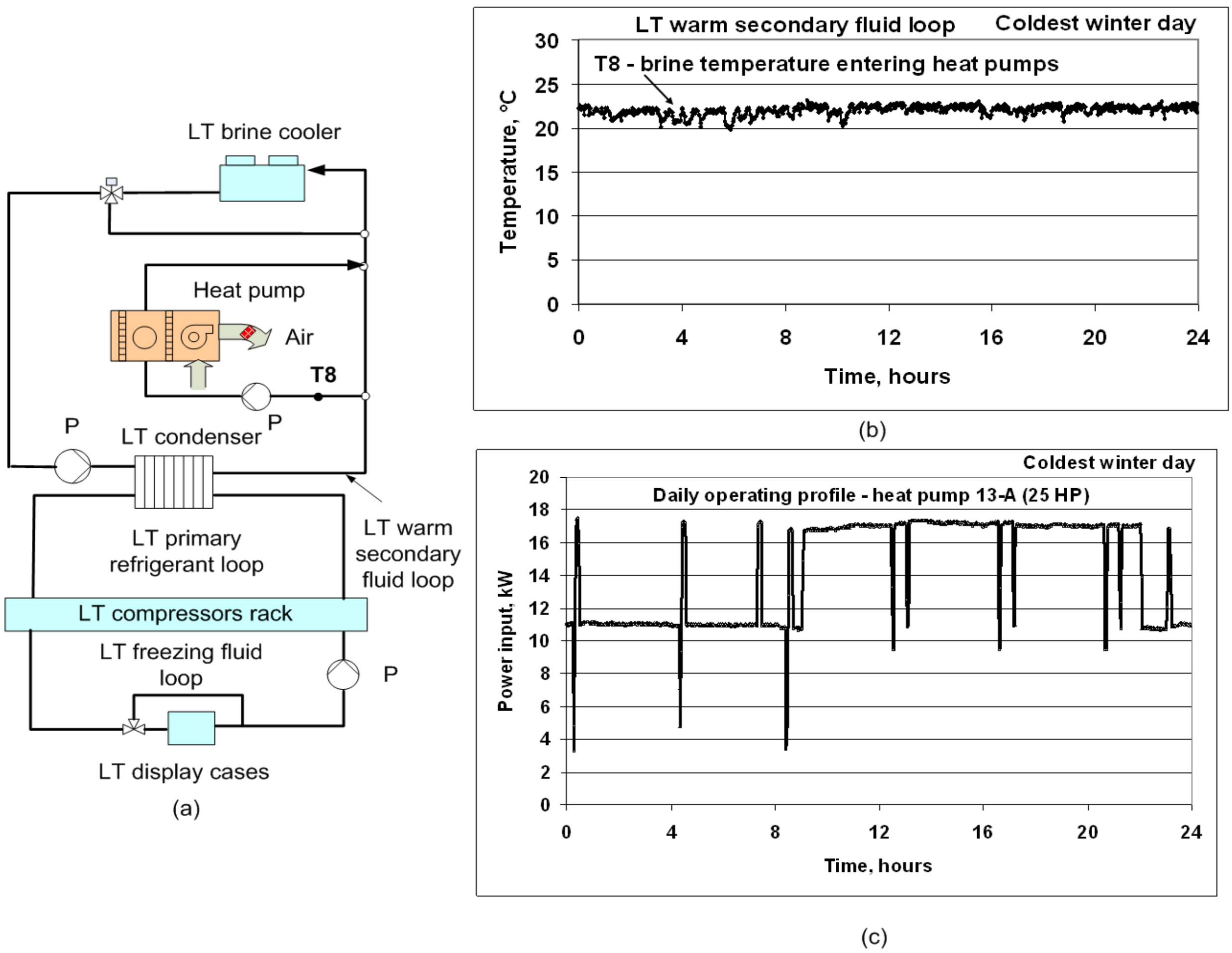


Figure 6 – (a) Heat recovery in a totally secondary fluid loop system: low temperature zone; (b) Temperature profile of warm brine entering the heat pump during the winter coldest day; (c) Daily operating profile of a 25-HP heat recovery heat pump. LT: low-temperature; P: circulating pump; T: temperature

The medium-temperature zone also contains a warm secondary fluid loop for heat rejection/heat recovery via a central HVAC unit (Figure 7a). The central HVAC unit is necessary because conditioning the outdoor air to the required space temperature and humidity conditions represents a significant amount of the HVAC load and energy consumption. It includes a condensing unit with direct-expansion air cooling coil CC, brine-to-air heat recovery HR coil, and back-up electrical heater.

Figure 7b shows that during the coldest winter day in eastern Canada, the temperature of the warm secondary fluid leaving the HR coil (T9) ranges from 20 °C to 30 °C. This means that (high-temperature) heat pumps could be installed to recover further waste heat and lower the brine temperature before rejecting it outdoors. With brine leaving the direct heat recovery coil at 20-25 °C, the heat pumps can operate with COPs of at least 4. However, the suitability of using reversible heat pumps for heating in winter and cooling/dehumidification in summer must be carefully analyzed.

CO_2 refrigeration systems

Carbon dioxide can be used in low-temperature applications as a phase-change coolant (Figure 8a) or in cascade systems with CO_2 compressors on the freezing loop sides (Figure 8b) [5]. Secondary loops with CO_2 evaporators and circulating pumps are simple to install and operate, while cascade systems are more complex. However, both offer opportunities to use secondary fluid (brine) rejection loops with air-cooled coolers. Depending on the brine temperature during the cold season, heat pumps can be installed upstream or downstream of the brine coolers. In both cases, three-way valves allow diverting the required brine flow through the heat pumps in order to heat the supermarket space and/or domestic/process hot water.

Conclusions

This article points out that waste heat recovery with heat pumps could be a key element of efficient supermarket operation, especially in cold and moderate climates. With efficient waste heat recovery, the use of fossil fuels for space and hot water heating can be substantially reduced or even eliminated in supermarkets. It is shown that two-stage heat recovery

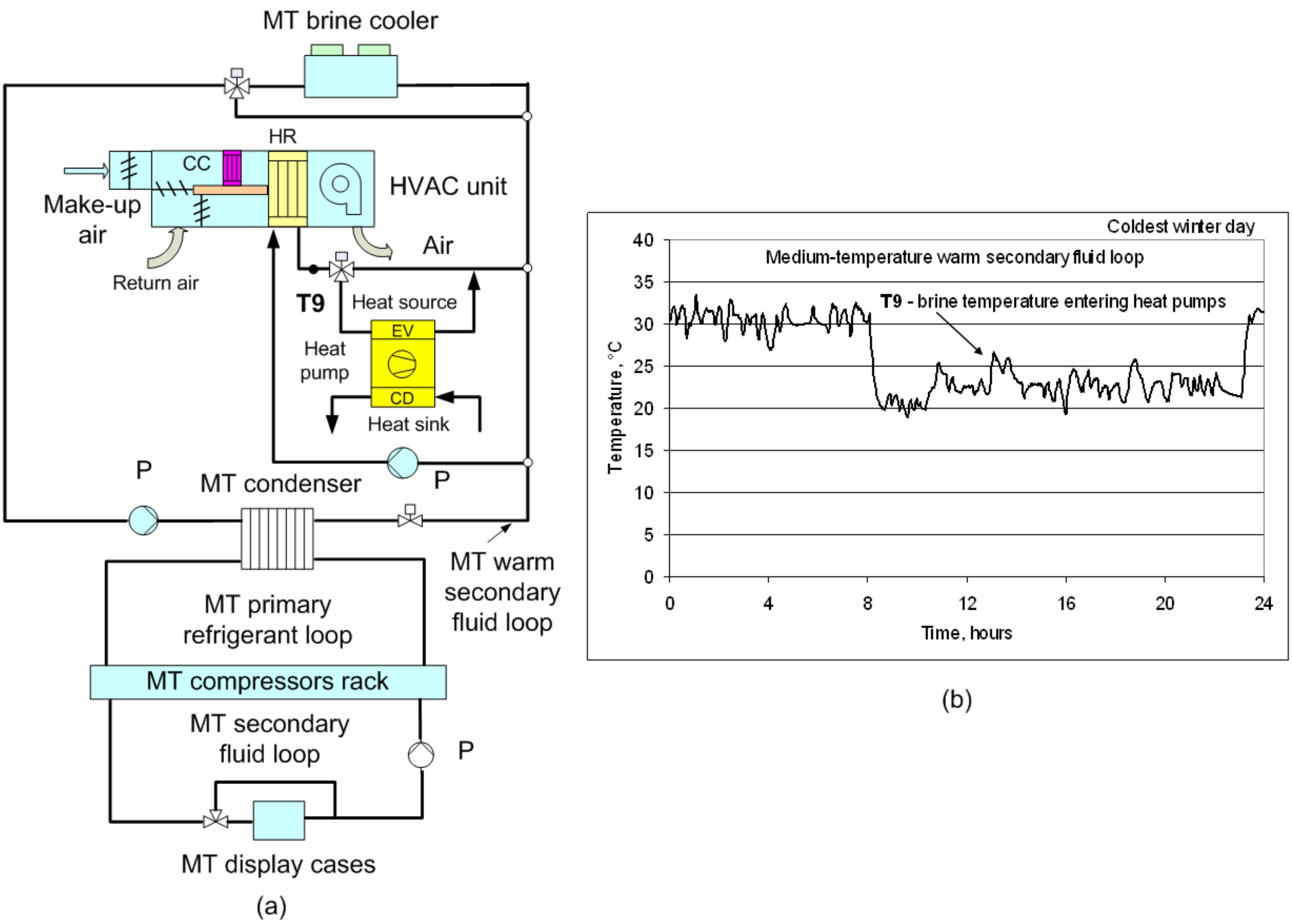


Figure 7 – (a) Heat recovery in a totally secondary fluid loop system: medium temperature zone; (b) Temperature profile of secondary fluid entering heat pump during the coldest winter day. MT: medium-temperature; P: brine circulating pump; CC: cooling coil; HR: heat recovery coil; EV: evaporator; CD: condenser.

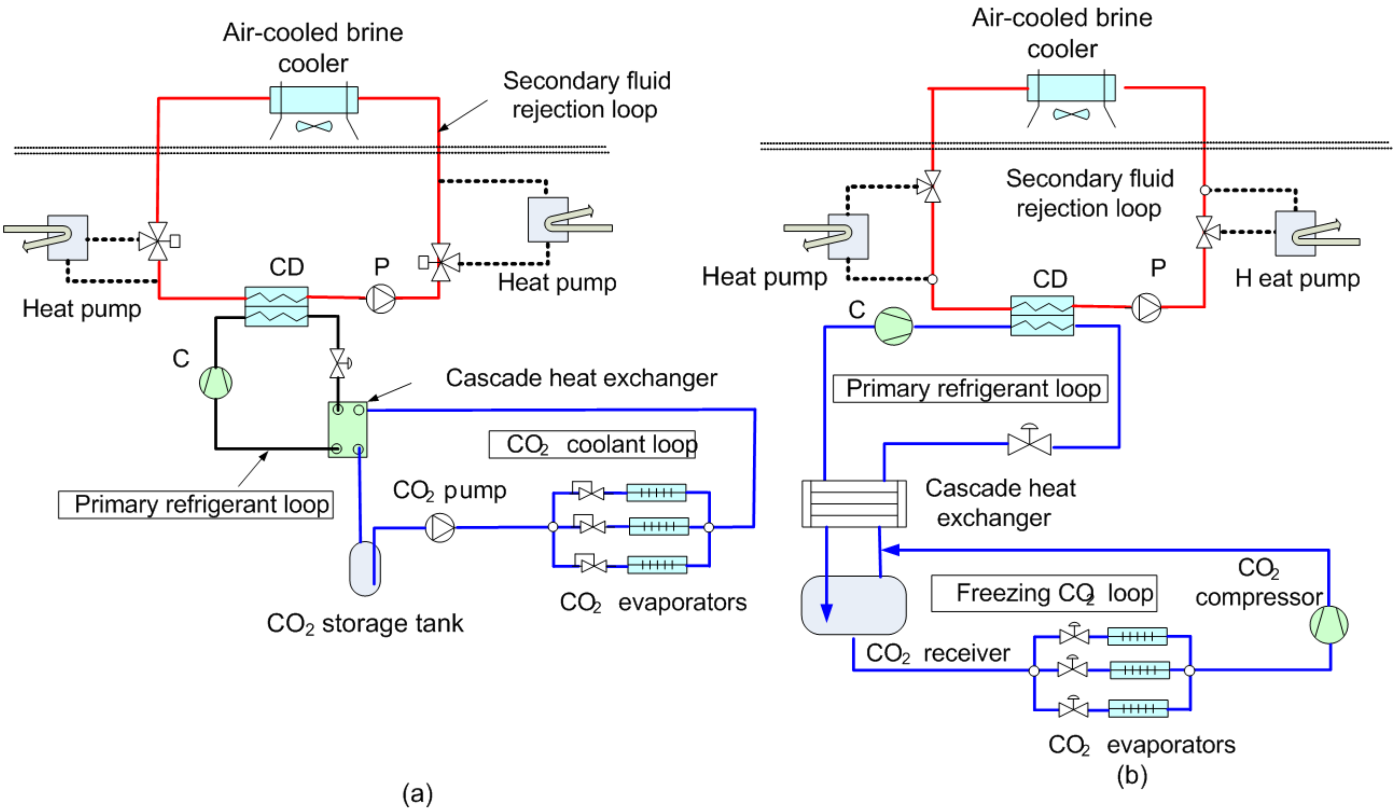


Figure 8 – Supermarket cascade CO_2 refrigeration system: (a) CO_2 as a secondary coolant; (b) CO_2 as a freezing refrigerant. C: compressor; CD: condenser; P: brine circulating pump.

concepts with desuperheating coils and refrigerant-to-refrigerant heat pumps allow efficient heat recovery, while reducing the artificial increase of compressors' head pressures by up to 35 %. Totally fluid secondary refrigeration systems allow efficiently recovering heat for space and/or domestic/process hot water heating. Systems with carbon dioxide as secondary coolant or low-temperature cascade refrigerant also permit integrating low- or high-temperature heat pumps for heat recovery. In all cases, it is essential to identify the technical and economical application limits of heat pumps, and to carefully design the systems in such a way that they can be technically and financially feasible. In this context, the financial balance of electrical and natural gas costs, along with the cost of equipment, installation and controls, are extremely important for each particular location and application.

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Glass Doored versus Open Vertical Display Cases: Energy and Sales

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The objective of this project was to compare the energy consumption and food product sales of an open refrigerated display case line-up to a glass-doored refrigerated display case line-up. It was found that 'doored versus open' had no effect on product sales and that per unit length of case line-up, the open display case line-up consumed approximately 1.3 times more energy than the doored display case line-up.

Introduction

Refrigerated display cases are utilized by supermarkets to store and display food products in a manner that extends food shelf life and ensures food safety. Supermarkets operate their refrigeration systems continuously to maintain proper food storage conditions, accounting for approximately 50% of their total electrical energy consumption.[1]

Infiltration accounts for over 70% of the refrigeration load in open refrigerated display cases.[2] Thus, reducing the infiltration into open display cases will lead to a significant reduction in the overall refrigeration load, thereby reducing the overall energy consumption.

One technique to reduce infiltration is to utilize glass-doored refrigerated display cases. Under controlled laboratory conditions, Faramarzi et al. found that installing glass doors on an open vertical refrigerated display case reduced the refrigeration load by 68%, resulting in an 87% reduction in compressor power demand.[3] However, the fear of a possible reduction in product sales prevents supermarket owners from implementing glass-doored cases.[4] Unfortunately, the available information regarding the merchandising productivity of display cases is vague and anecdotal. Thus, the objective of this project was to compare the energy consumption and food product sales of an open refrigerated display case line-up to a glass-doored refrigerated display case line-up.

Test Plan

Two supermarkets were identified as test sites: one received a new doored refrigerated display case line-up and the other received a new open refrigerated display case line-up. The two selected test sites were large public supermarkets with footprints of approximately 2,300 m^2, located in the Midwestern United States. The two supermarkets were similarly situated to ensure that climate, weather, time-of-year and economic conditions of the shoppers were comparable.

A "before and after" comparison of product sales was performed in each of the two stores. An existing display case line-up was identified in each store and the sales data of the products from that display case line-up were collected for a period of approximately two months. The existing display case line-up in each store was then replaced with a new display case line-up. Each new case line-up was then stocked with the same products, in the same location within the new case, as they appeared in the old case line-up. The sales data of these products from each new display case line-up were then collected for a period of approximately two months. Thus, a comparison between sales data was made "before and after" installation of the new display case line-ups to determine the effect that new case line-ups had on product sales.

In addition, the energy usage of each new display case line-up was monitored. Thus, comparisons could be made between the energy usage of a new open display case line-up versus that of a new doored display case line-up.

Display Cases and Products Studied

At Store #1, dairy products were studied that initially resided in a 13.4 m open, multi-deck case line-up, shown in Figure 1(a). During the test period, the sales of dairy products were monitored for a period of two months in the original case line-up. This case was then replaced with a new, medium temperature, 20-doored case line-up, nominally

Figure 1. (a) Initial Open and (b) New Doored Display Case Line-Ups at Store #1.

14.6 m in length, shown in Figure 1(b). After installation of the new case, the sales of the selected dairy products were monitored for a period of two months.

The energy consumption of a 10-doored portion, nominally 7.3 m in length, of the new 20-doored case line-up was measured for a period of two months and compared to the energy usage of the similarly sized 7.3 m open case line-up installed in Store #2.

Furthermore, at Store #1, a 3.7 m open, multi-deck case line-up merchandising beer was replaced with a 6-doored case line-up. Thus, while beer was not originally intended to be the primary product studied at this supermarket, the replacement of the old open beer case line-up with a new doored beer case line-up provided an opportunity to collect beer sales data for an old open case line-up versus a new doored case line-up.

At Store #2, beer was studied that initially resided in an open, multi-deck case line-up, nominally 7.3 m in length, shown in Figure 2(a). During the test period, beer sales were monitored for a period of two months in the original case line-up. This original open case line-up was then replaced with a new, medium temperature, open, multi-deck case line-up, nominally 7.3 m in length, shown in Figure 2(b). After installation of the new case, the sales of the selected products and the energy consumption of the new case were monitored for a period of two months.

Analysis of Energy and Sales Data

Energy-related data was collected and analyzed for the two new display case line-ups for the period 21 April 2009 through 1 June 2009. In addition, beer and dairy sales data from both stores were collected and analyzed before and after installation of the new display case line-ups for the period 4 January 2009 through 6 June 2009.

Analysis of Energy-Related Data

Based on ASHRAE Standard 72[5], Method of Testing Commercial Refrigerators and Freezers, the mean daily refrigerator load during the 42-day test period for the new open display case line-up was found to be 7.35 kW, which is significantly greater than that of the new doored display case line-up which was found to be 2.06 kW. Furthermore, based on ARI Standard 1200[6], *Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets,* and as shown in Table 1, the average daily compressor energy consumption during the 42-day test period for the open display case line-up was estimated to be 42.2 kWh/day while for the doored display case line-up, the average daily compressor energy consumption was estimated to be 11.7 kWh/day.

In Table 1, it can be seen that the lighting, fans and anti-sweat heaters of the doored case consumed an average of 32.0 kWh/day while the lighting and fan load of the open case was found to be 10.9 kWh/day. The total electrical energy consumption of the open display case line-up was found to be 7.25 kWh/day per meter while that of the doored display case line-up was found to be 5.61 kWh/day per meter. Thus, per unit length of case, the open display case line-up consumed approximately 1.3 times more energy than the doored display case line-up.

The anti-sweat heaters were the major contributor to the electrical load of the doored display case, accounting for 36% of the energy use. The compressors and lights each accounted for 27% of the energy consumption while fan energy consumption was 10%.

It should be noted that the energy consumption of the doored case line-up could be substantially reduced by using “no heat” doors and LED lighting. Assuming zero energy consumption for “no heat” doors and 265 watts energy consumption for LED lighting, it is estimated that the 10-doored case line-up could consume as little as 20.5 kWh/day or 2.63 kWh/day per meter.
The compressors accounted for approximately 79% of the electrical energy consumption of the open display case line-up while fans accounted for 11% and lighting consumed 10%.

Figure 2. (a) Initial Open and (b) New Open Display Case Line-Ups at Store #2.

From Figure 3, it can be seen that as the mean indoor relative humidity increased, the electrical energy consumption of the open display case line-up increased. The open case line-up consumed approximately 1.25 times more energy when the indoor relative humidity was 45% as compared to 20%. However, for the doored display case line-up, the electrical energy consumption remained relatively constant with increasing mean indoor relative humidity.

Analysis of Sales Data

From Table 2, it can be seen that beer sales increased after the installation of both the new doored and new open display case line-ups. Beer sales increased by 27% in the new doored display case line-up at Store #1, while beer sales increased by 29% in the new open display case line-up at Store #2. Statistically, it was found that these increases in sales were significant ($\alpha < 0.05$). Since the rate of increase in beer sales was essentially the same for both the new doored and new open display case line-ups, the data shows that 'doored versus open' had no effect on product sales.

From Table 3, it can be seen that before and after the installation of the new doored display case line-up, sales of dairy products remained the same in both supermarkets. Statistically, it was found that there was no significant difference ($\alpha > 0.05$) in dairy product sales in either store before and after installation of the new doored display case line-up in Store #1. Since the rate of dairy sales remained essentially the same in both stores before and after the installation of the new doored display case line-up, the data shows that 'doored versus open' had no effect on product sales.

Conclusions

The objective of this project was to compare the energy consumption and food product sales of an open refrigerated display case line-up to a glass-doored refrigerated display case line-up.

Table 1. Mean Electrical Energy Consumption of the New Doored and New Open Display Case Line-Ups Calculated Using ARI Standard 1200.[6]

Electrical Energy Consumption	New Doored Display Case (Store #1)	New Open Display Case (Store #2)
Compressors (kWh/day)	11.7	42.2
Lights (kWh/day)	11.9	5.18
Fans (kWh/day)	4.58	5.69
Anti-Sweat Heaters (kWh/day)	15.5	--
Total (kWh/day)	43.7	53.1
Total (kWh/day per m)	5.61	7.25

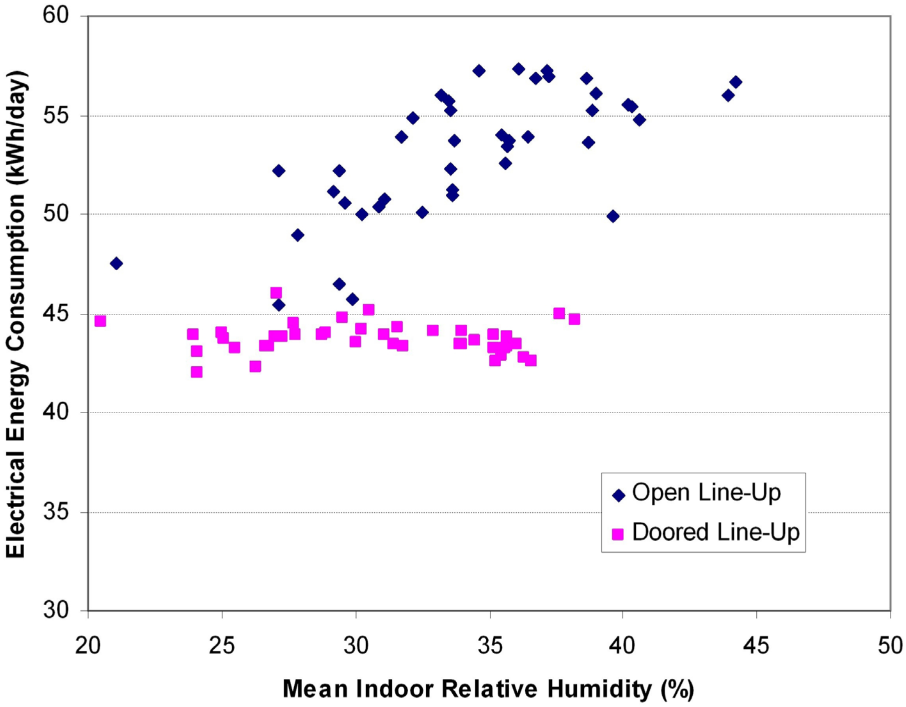

Figure 3. Electrical Energy Consumption versus Mean Indoor Relative Humidity for the New Open and New Doored Display Case Line-Ups.

Table 2. Summary of Weekly Beer Sales During Pre-Installation and Post-Installation of the New Doored and New Open Display Case Line-Ups.

Beer Sales Statistics	New Doored Display Case Line-Up (Store #1)	New Open Display Case Line-Up (Store #2)
Mean Weekly Quantity Sold, Pre-Installation	55.4	104.4
Standard Deviation of Weekly Quantity Sold, Pre-Installation	10.6	9.26
Mean Weekly Quantity Sold, Post-Installation	70.5	134.6
Standard Deviation of Weekly Quantity Sold, Post-Installation	11.1	26.7
Percentage Increase	27%	29%

Per unit length of case line-up, the open display case line-up consumed approximately 1.3 times more energy than the doored display case line-up. While the doored display case line-up had significantly less compressor energy consumption than the open display case line-up, the doored case line-up had a substantial anti-sweat heater energy consumption that the open case line-up did not have.

It was found that as the mean indoor relative humidity increased, the electrical energy consumption of the open display case line-up increased, while that of the doored display case line-up remained relatively constant.

Since the rate of increase in beer sales was essentially the same for both the new doored and new open display case line-ups, and since the rate of dairy sales remained essentially the same in both stores before and after the installation of the new doored display case line-up, the data shows that 'doored versus open' had no effect on product sales.

Table 3. Summary of Weekly Dairy Sales During Pre-Installation and Post-Installation of the New Doored Display Case Line-Up.

Dairy Sales Statistics	New Doored Display Case Line-Up (Store #1)	Open Display Case Line-Up (Store #2)
Mean Weekly Quantity Sold, Pre-Installation	639.4	3864
Standard Deviation of Weekly Quantity Sold, Pre-Installation	41.3	403.6
Mean Weekly Quantity Sold, Post-Installation	621.5	3846
Standard Deviation of Weekly Quantity Sold, Post-Installation	152.2	464.5
Percentage Increase	-2.8%	-0.47%

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Doors as energy-efficient technology and for improved food quality – measurements on vertical display cabinets with and without doors

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This article presents the main results from laboratory measurements on a single vertical cabinet with and without doors. Different opening frequencies of the doors were tested in the laboratory. The results show that the potential for energy saving and improved storage temperature conditions by retrofitting doors to open-front vertical cabinets is quite high. The secondary refrigerant (brine) inlet temperature to the cabinet could be allowed to be higher so that it was possible completely to avoid frost formation in the cabinet air cooler.

Using doors as an aid to energy efficiency improvement could also reduce the electricity input for the refrigeration system, and keep food at the correct temperature. This is a key to maximizing shelf life and food quality. The fitting of doors and avoidance of defrosting may also improve the quality of the refrigerated food.

Introduction

Supermarkets are significant energy users, particularly in the form of electricity, and storage of refrigerated food accounts for half of total electricity use. A substantial part of this use relates to open-front vertical display cabinets. The common design with an open front makes the cabinet sensitive to infiltration. Axell[1] and Faramarzi[2] have shown that infiltration accounts for approximately 70-80 % of the cooling load. A possible reduction of the infiltration problem, however, is the fitting of doors. Kaufeld[3] has shown that fitting doors or lids to open cabinets can give a potential for savings in supermarket refrigeration systems of up to 40 %.

However, fitting doors to display cabinets will have an impact on the store's general heating, ventilation and air-conditioning (HVAC) system. If the cold air spillage from cabinets is reduced, then the surrounding air temperature will rise. Consequently, an air conditioning system becomes more important, especially during warm and humid summer days.

The main objective of this paper is to present measurements made in the laboratory on an indirectly cooled vertical display cabinet. The results show the influence of the doors on the heat extraction rate (cooling load), and the temperature of the test packages.

In addition, results from field measurements are presented in this article. They show results under real conditions (winter), saving potentials for the electrical energy supply for the supermarket (refrigeration and as a total) and the impact on indoor environment and storage temperatures with and without doors installed (retrofitted).

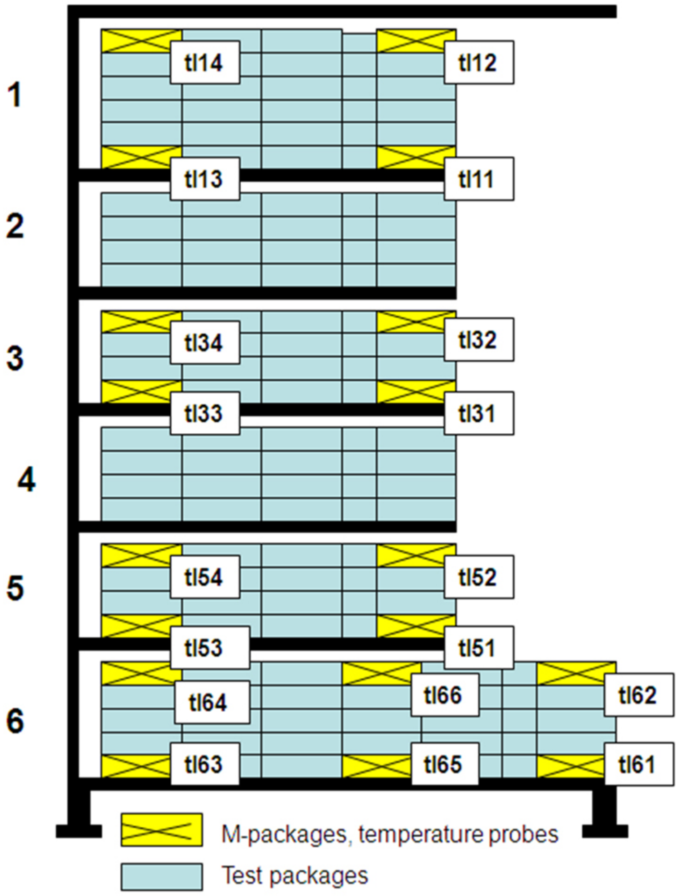
Controlled test conditions in a climate chamber

Test conditions in the climate chamber were in accordance with ISO 23953[4]. The tested climate corresponds to a summer day. An open-front vertical display cabinet was used for the tests. This type of front-loaded cabinet is commonly used in many Swedish supermarkets. Doors were hinged vertically to the cabinet. The door height was 1.42 m and the width 0.60 m. Four double glass doors were installed (retrofitted) to the cabinet. The cabinet was provided with two air curtains, with the outer one being a warmer air curtain fed with surrounding air from the top of the cabinet. The indirect cooling to the cabinet was supplied by a secondary refrigerant.

Method used in the climate chamber

The studies included measurements under controlled conditions, based on ISO 23953-2 [4], which defines different test conditions and classifications of cabinets. As the standard is under revision, some comments included in the revision work, together with experience from field measurements, have been considered. From the laboratory study, this article covers calculated heat extraction (cooling load), positions and temperatures of the test packages.

The cabinet was loaded with commercially available test packages, with a total mass of about 1 tonne. Fifty-four of the test packages were equipped with temperature probes positioned in the centre of each package. Such packages are named M-packages, and were loaded on four different shelves, as shown in Figure



	Position in the cabinet	Day/ Night
Cond-ition[1]	Warmest M-package	Temp. (°C)
A	tm62	8.7/8.2
B	tr62	7.5/7.9
C	tr62	8.2/8.1
	Coldest M-package	
A	tl13	0.4/0.4
B	tm53	4.8/4.8
C	tm53	6.0/6.6

[1]Climate measuring point, acc. ISO 23953 and at different conditions as explained in Table 2.

Figure 1: Tested 6-shelf cabinet without doors (a) side view (leftside) and loading pattern for the test packages. The M-packages with temperature probes are marked with a cross and named individually. There are 18 packages on the left, l, with similar positions in the middle, m, and on the right, r, side of the cabinet. (b) the positions for the warmest and coldest M-packages at the different test conditions are given. Length of the cabinet without end walls is 2.50 m, height 2.0 and depth 1.0 m.

1. The packages were loaded against the rear of the cabinet. A test period consisted of a 12 h day and 12 h night period. The test period, starting with day operation, commenced after a stabilisation period of at least 24 h, i.e. all temperatures were within ±0.5 °C of the mean temperature.

Two different opening frequencies (openings per hour) were programmed. The two frequencies were six seconds ten times per hour, and six seconds 30 times per hour. Table 2 shows the conditions for the tested cabinet. First, the cabinet was tested in the original configuration, without doors (A). The four doors were then fitted (B), and the outer air curtain and night-curtains were removed, and defrosting turned off. The inlet temperature of the secondary refrigerant was increased until the highest temperature of warmest M- package was +8 °C (temperature class S1), the same classification as before the installation of the doors. Additional lights (3 x 28 W) were installed on the frame. It is common that extra lights are installed at the same time as doors, as requested by the merchandiser to provide additional light on the goods.

Table 2: Laboratory measurement program, conditions A-C for Climate Class II (temperature of 22 °C and relative humidity of 65 %). Cases are named A, without doors, and B and C, with doors, but with different opening frequencies and different inlet temperatures of the secondary refrigerant for the cabinet.

Surrounding test condition[1], t_{amb} °C / φ_{amb} %		**Doors installed**	**Door opening frequency** Openings per hour for each door		**Inlet temperature,** °C
			Day Operation	Night operation	
A	22/65	No	-	Night covers	-8
B	22/65	Yes	10	Doors closed	+2
C	22/65	Yes	30	Doors closed	+2

[1]Climate measuring point, positioned according ISO 23953-2: in front of the centre of the cabinet.

The doors affected heat extraction rate temperatures of the M-packages

In the laboratory, and with doors, the heat extraction rate for the Case B cabinet decreased substantially (-66 % during the day, and –53 % during the night). The heat extraction rate during the day increased by 15 %

when the door opening frequency increased from ten openings per hour to 30 openings per hour, see Figure 2.

The secondary refrigerant inlet temperature for the cabinet with doors was increased so that Case B and Case C temperatures of the warmest M-packages were similar to the corresponding temperatures in cabinets without doors. Figure 3a shows that, without doors, there is greater variation in temperatures between the different packages. During the day the difference is 8 K between the warmest and coldest M-package on Shelf 6. With doors, Figure 3b, the temperature for the M-packages is more even. With doors during the night, compared with night curtains, the temperature difference between the packages is less. During the night, the on and off cycling of the refrigeration system can be seen, as the temperature lines are not as straight as during day operation. The warmest temperatures were found in places with most exposure to the surrounding air at the front of the cabinet on Shelf 6, probably due to the fact that the air curtain is weaker there. Without doors, Case A, the highest temperature of the warmest M-package during the day was 8.7 °C. The overall mean temperature of M-packages was 3.5 °C, without doors. With doors, and with an increased inlet temperature of the secondary refrigerant, the mean temperature increased by 3 K.

Discussion

The trade-off between glass doors and indoor environment is an issue that is closely evaluated by supermarket operators. Both laboratory measurements under controlled conditions and field measurements under real conditions can give further knowledge for the operators. To provide a good climate in supermarkets consideration of goods, staff and customers is required. The doors will affect indoor environment, energy use and storage temperatures.

In the laboratory, and with doors, the heat extraction rate for the cabinet decreased substantially (-66 %). An increased inlet temperature to

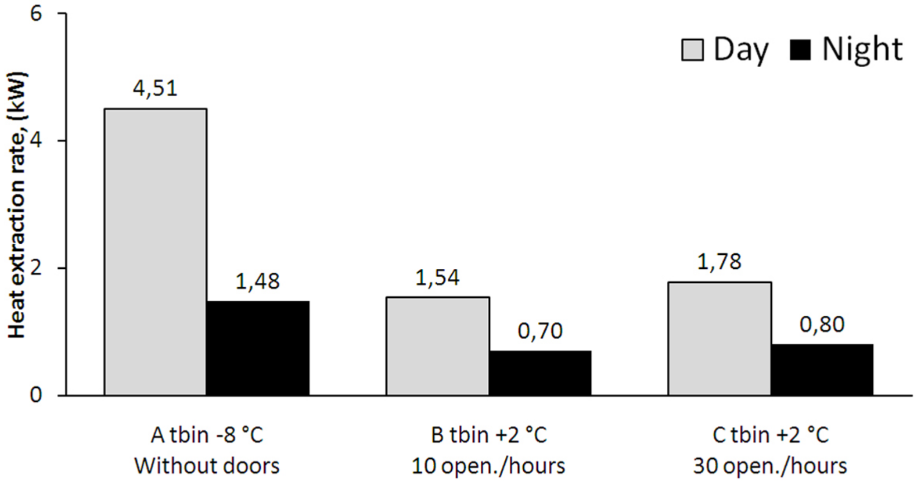
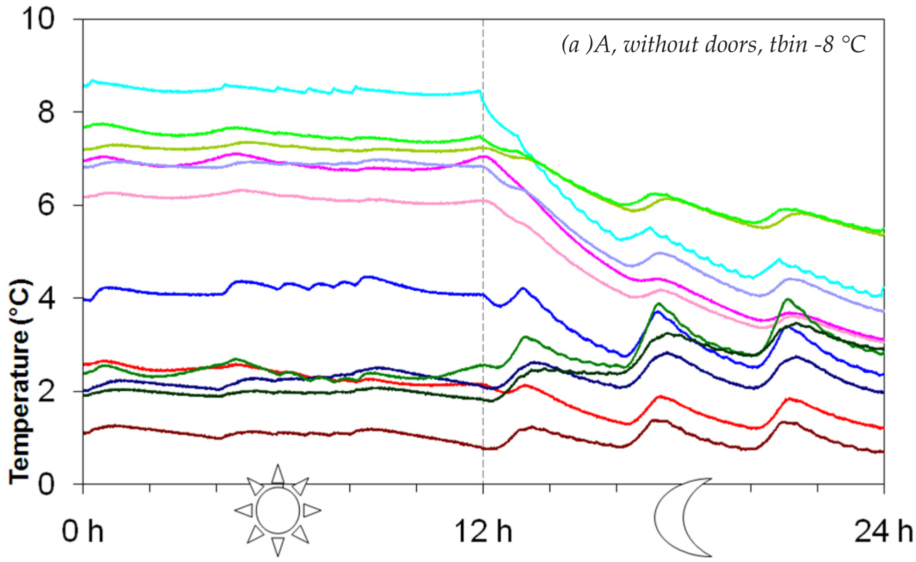


Figure 2: Results of laboratory measurements: Heat extraction rate as average values, for day and night operation at different conditions, A-C, at the same ambient condition, dry bulb temperature of 22 °C and relative humidity 65 %. The cabinet is tested without doors, A, with doors, B and C, and frequencies 10 times per hour, B, and 30 frequencies per hour, C. The inlet temperature (tbin) to the cabinet increased from – 8 to +2 °C.



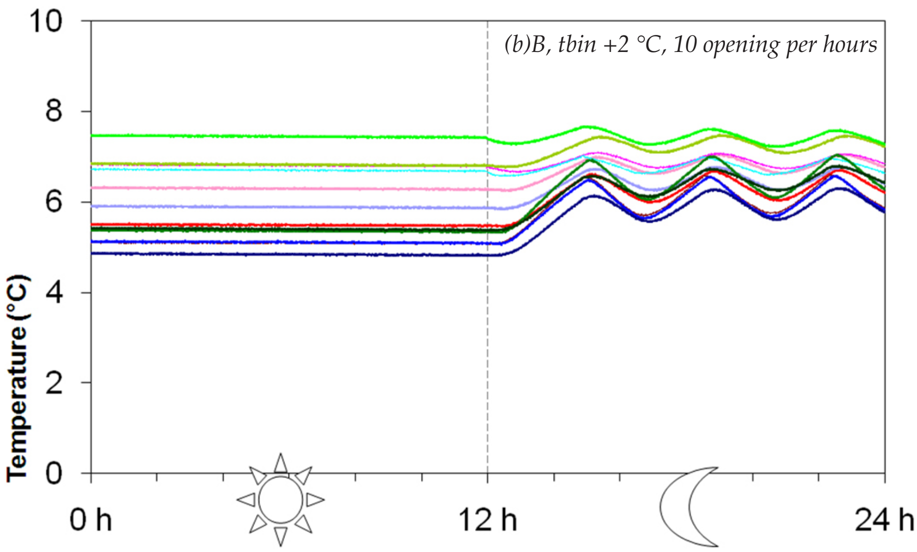


Figure 3: Results of laboratory measurements: Temperatures for a full test period (starting with a 12 h day following 12 h night). The different temperature lines are for the 12 M-packages on shelf 6 (base deck) in the cabinet for test conditions A and B.

the display cabinet will considerably increase the COP of the refrigeration system. An increase of 10 K in evaporator temperature can increase the COP by up to 34 %, based on the same conditions as presented by Haglund Stignor [5].

In the laboratory, with doors, the storage temperature decreased. Also results[6] from the field measurement in a supermarket performed under real conditions before and after retrofit installation of doors indicate that the retrofit glass doors directly affect the supermarket indoor environment, the direct electrical energy use for the refrigeration system, and the storage temperature of the refrigerated food. In the supermarket, with (retrofitted) doors, the direct electrical supply required for the refrigeration system decreased by 26 %, while the interior temperature and variation between maximum and minimum interior air temperature decreased.

In order to get the most benefit from doors, the refrigeration system and the cabinet must therefore be modified after installation of doors. If the temperature was adjusted and the foodstuffs could still be kept at the correct temperature, it would be possible to save more energy. As a rule of thumb, a reduction of 1K in evaporator temperature corresponds to 3 % savings in electrical energy for the chiller(s). This indicates that more than 30 % of the electrical energy could be saved with doors. The direct total electricity demand for the entire supermarket fell by 6 % with doors fitted. However, as the heating cost for the supermarket is fixed and included in the rent, the reduced heating demand due to less cold air spillage will not benefit the retailer. The impact on customers' perceptions, and more details from the field measurements and laboratory measurements, have been presented previously by Lindberg[6-8].

However, this comparison in a supermarket was made only for a short period and under winter climate conditions. Longer measurement periods, as well as measurements under summer climate conditions, are needed in order to see how doors affect performance over a whole year. However, summer climate conditions were also tested in the laboratory.

Conclusions

From the laboratory measurements it is concluded that, with doors and with an increased temperature of the inlet temperature of the secondary refrigerant, the heat extraction rate for the cabinet decreased substantially (-66 % during day operation, each door opened for six seconds ten times per hour, in a summer climate). The overall mean temperature of the 54 M-packages increased (by at least 3 K), and the temperature distribution between the packages was more even.

In the laboratory, with retrofitted doors, it was possible to run the cabinet at a much higher inlet temperature (+2 °C instead of –8 °C) for the same classification on the cabinet. This also shows that it is possible to maintain the storage temperature with a secondary refrigerant temperature that entirely avoids frost growth on the cooling coil. Frost-free operation not only improves the temperature quality in the display cabinet, but also increases the COP of the refrigeration system. Alternatively, instead of reducing the secondary refrigerant temperature, the storage temperature of the food could be reduced.

The main conclusion from the supermarket study is that fitting doors to the cabinets reduced the direct electric energy use for the refrigeration system (-26 % for a winter climate). At the same time, the interior air temperature for storage of goods decreased up to 4 K during the day and 5 K at night.

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Over a decade of research towards increasing energy efficiency of refrigerated open, vertical display cases

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This article summarizes over a decade's worth of key research efforts by Southern California Edison's Technology Test Centers. The findings have provided valuable information for understanding and improving the operation and performance of open vertical refrigerated cases. Results revealed high thermal vulnerability of these cases, identified the impact of energy-efficient equipment on overall case performance, and determined the key geometric and flow parameters that affect infiltration through the air curtain. These efforts resulted in establishing new and more accurate methodologies and tools for measuring infiltration and optimizing air curtain performance.

Introduction

The number of supermarkets in the United States is about 34,000, making up 17 % of the total retail food stores. Supermarkets, with annual energy usage of 2 to 3 million kWh per store, are one of the most energy-intensive commercial building types. Over half of this total energy consumption is for the refrigeration of food display cases and storage coolers [1].

The refrigerated display cases are categorized either as low-temperature (LT) or medium-temperature (MT). LT cases account for 32 % of a store's total case line-up, and are used to merchandise ice cream and frozen food. The remaining 68 % of the total display case line-up are MT, used to merchandise dairy, deli, fish and meat. Most notably, open vertical (or multi-deck) refrigerated display cases (OVRDCs) make up 46 % of a store's total case line-up [1]. They are the key contributor to total refrigeration energy consumption. Figure 1 is a photograph of MT OVRDC line-up in a supermarket.

The aim of this article is briefly to present research efforts and findings during the last decade by Southern California Edison's (SCE's) Technology Test Centers, (TTC) for understanding and improving the performance of OVRDCs.

Overview of Research Efforts

Investigating the energy efficiency improvement opportunities in OVRDCs requires knowledge of the cooling load components of these cases. Therefore, in the late 1990s, SCE conducted a series of laboratory tests to better understand cooling load components of cases. Results revealed that the main sources of heat gain and their contribution to the total cooling load are [2,3]:

(1) conduction load – heat conducted through display case envelope, accounting for about 4 % of total load;

(2) radiation load – thermal radiation from the adjacent space, making up 8 to 12 % of total load;

Figure 1. Line-up of open vertical refrigerated display cases in a typical supermarket

(3) internal load – heat dissipated from case lighting (8 % of total load) and from the evaporator fan motors (3 % of total load);
(4) infiltration load – warm and moist air that infiltrates from the adjacent space (i.e., store's sales floor area) into the refrigerated space across the display case air curtain, accounting for 70-80 % of the total load. In this context, 'air curtain' refers to the invisible air barrier that separates the refrigerated space from the adjacent space. This barrier is created by the cold air that flows from the top front of the case, called discharge air grille or DAG, and through slots located on the back panel of the case, and then returns to the evaporator for cooling from the bottom front of the case, called return air grille or RAG (Figures 2 and 3).

The knowledge gained about OVRDC heat gain constituents set the stage for subsequent studies. Infiltration is the biggest contributor to the total case load and is a relatively complex phenomenon. Research studies to characterize and better understand this load constituent were undertaken. These made use of advanced experimental and numerical methods for fluid flow visualization and quantification field to display cases, including digital particle image velocimetry (DPIV), laser doppler velocimetry (LDV), and computational fluid dynamic (CFD) methods.

Figure 3 shows an infra-red image of air temperatures in the refrigerated and adjacent spaces. It also shows the air velocity vector map of the air curtain and refrigerated space using DPIV. As one of the early studies of the air curtain, this investigation provided a framework for understanding the dynamics of airflow in open display cases. Thermal testing of OVRDCs confirmed and validated that it is infiltration that constitutes the major portion of the cooling load. More importantly, the results set forth a clear definition for infiltration and how it occurs. Overall, results demonstrated that mixing between the cold air curtain and the air in the warm adjacent space cannot be

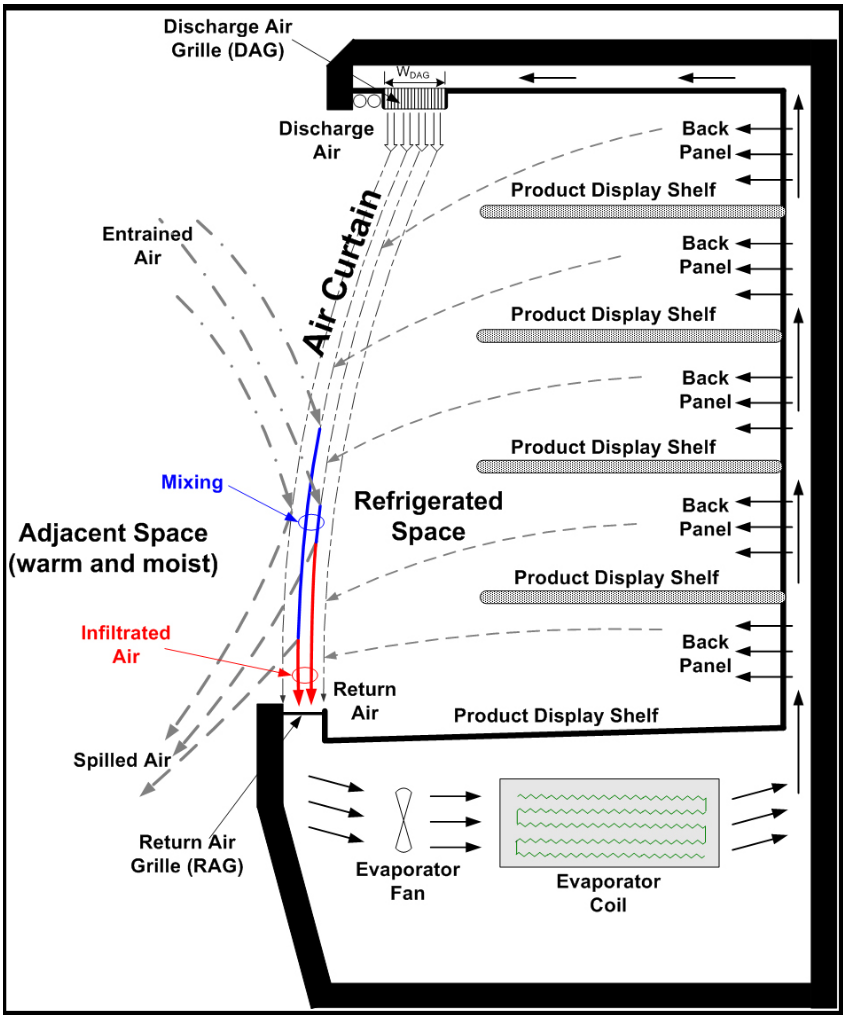

Figure 2. Schematic of a typical open refrigerated vertical display case and air circulation pattern (side view)

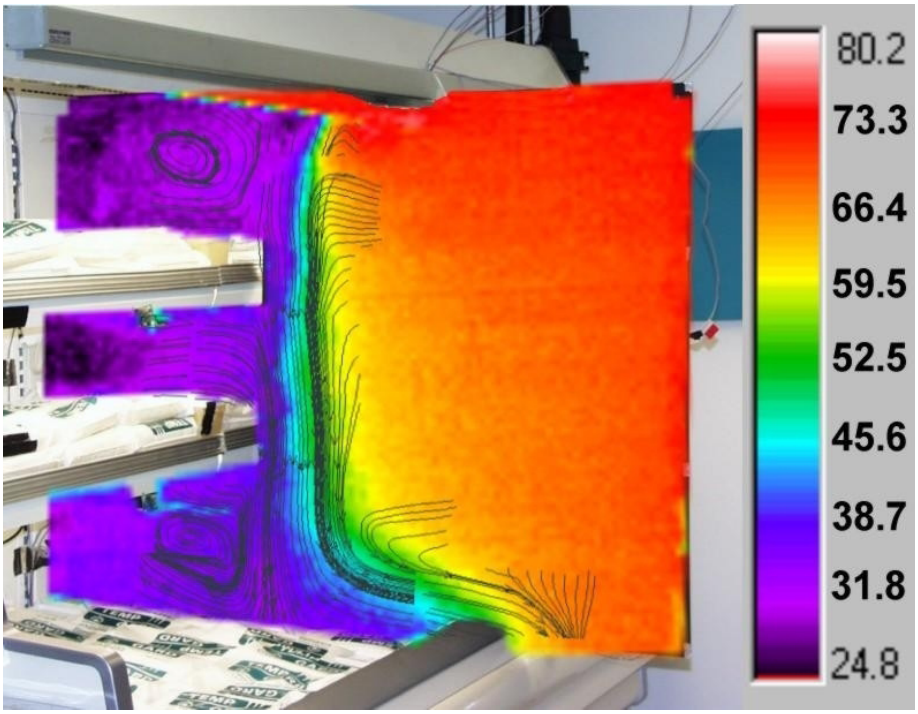

Figure 3. Infra-red image of air temperatures (°F) and air velocity vector map in the refrigerated and adjacent spaces.

avoided, as part of the cold air spills over the display case and is replaced by the adjacent air. That is, because part of the cold air flows out of the air curtain, the adjacent warm air flows into the air curtain and mixes with the cold air. This is called *air entrainment*. A portion of this entrained air mixes with the cold air, and the rest spills out of the case. Further, a fraction of the entrained air that mixes with the cold air spills over, and the rest flows into the RAG. This is called *air infiltration*. The amount of warm and moist air that finds its way into the thermodynamic cooling boundary of the case through the RAG is called the infiltration rate, and is the direct cause of infiltration load in open display cases (see Figures 2 and 3).

The studies outlined above were the building blocks for investigating improvements in the thermal performance and air curtain of OVRDCs. A research study evaluated the thermal performance of a standard 8-ft (2.44 m) MT OVRDC before (baseline case) and after (prototype case) implementing a number of energy efficiency measures [2]. These energy efficiency measures included:
(1) case lighting – super T8 fluorescents, with electronic ballast outside the case;
(2) evaporator coil assembly – new staggered fin design coil with large surface area, enhanced tubing, and dual-port expansion valve;
(3) air distribution system – tangential evaporator fans, electronically commutated motors with variable speed controller;
(4) liquid-to-suction heat exchanger – micro-channel. The results showed that the prototype case used 20 % less evaporator fan power and 21 % less lighting power than the baseline case. The improvements associated with the refrigeration cycle reduced the compressor power by 10 %. Coupling the decrease in the power and run time of the compressor resulted in a 14 % reduction in daily energy usage of the compressor. The collective impact of all these measures was a 22 % improvement in total system energy efficiency ratio, leading to daily energy savings of 6 kWh or 15 %.

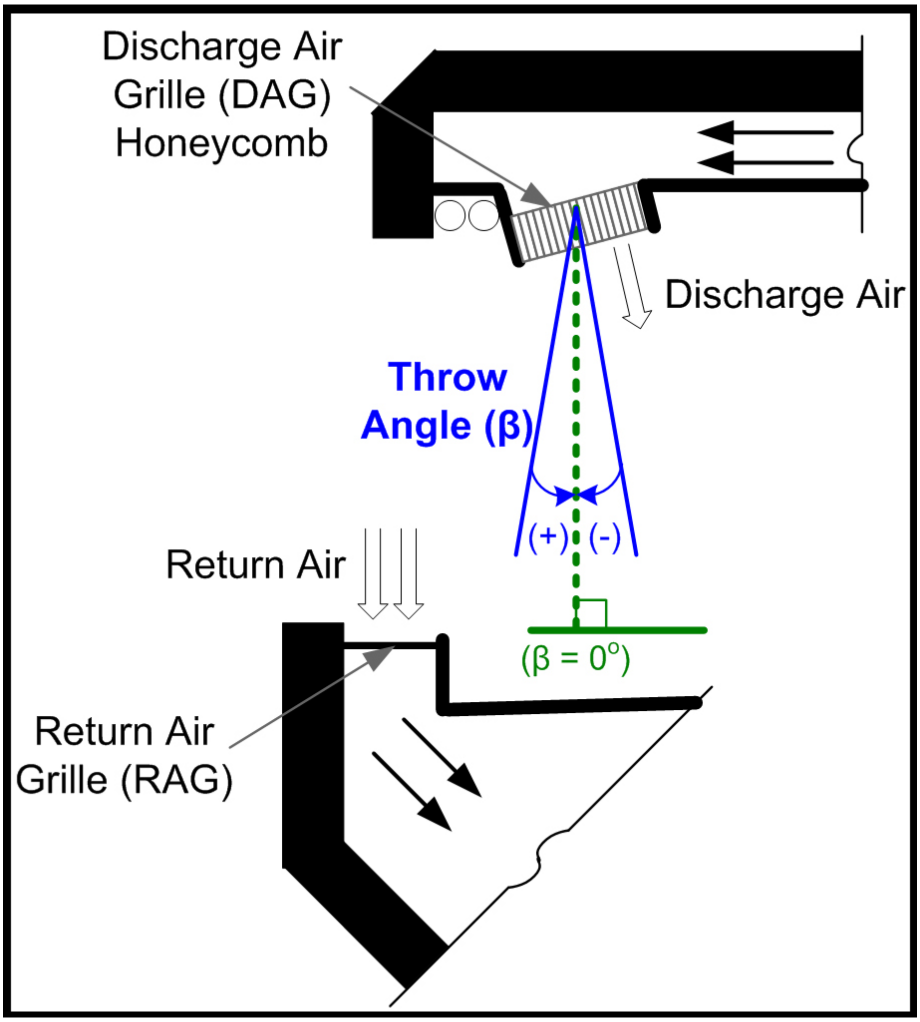

Figure 4. Schematic of discharge air throw angle

Finally, in 2008 a study was carried out that focused entirely on improving the air curtain performance, hence reducing the infiltration rate in OVRDCs [3]. One of the major steps was to develop a method for finding the optimum geometric and flow parameters to minimize infiltration through the air curtain. To accomplish this, a modular proof-of-concept air curtain was built for examining the impact of various important geometric and flow parameters on the infiltration. For these efforts, in addition to DPIV, LDV, and CFD as experimental and analytical tools, the CO_2 tracer gas method was used for direct measurements of infiltration rate. Validated experimental and numerical infiltration values were used to train an artificial neural network (ANN) program, which provided the optimum design values. The design values with the least impact on case fabrication were selected: (1) speed of the air at the DAG; (2) throw angle. Thermal and CO_2 tracer gas tests were conducted on an 8-ft (2.44 m) MT OVRDC prior to any modifications to its air curtain (baseline case), and after modifications to its air curtain (prototype case). The speed of the air at the DAG was changed from 88 feet-per-minute (fpm) or 0.45 m/s (for baseline) to 62 fpm or 0.31 m/s (prototype), while maintaining relatively fixed volumetric flow rate of the case. The throw angle was changed from 0 degrees (for baseline) to -7 degrees (prototype). Figure 4 shows the throw angle (β).

The results obtained were in close agreement with ANN program predictions, and demonstrated that infiltration and cooling load of the prototype case was reduced by 7-8 %. As a result, the compressor power decreased by 4 %. Reduction in the infiltration rate made it possible to operate the evaporator coil at slightly higher temperatures. This yielded an additional power saving of 9 %, while maintaining product temperatures below 41 °F (5 °C). The ANN and experimental results also revealed the possibility of up to 10 % additional reduction in infiltration rate by lowering the turbulence intensity at the DAG from 14 % to 3 %.

In addition to optimizing the air curtain performance, this research provided a tool to enable "global" and "local" optimized display case design. It showed that for a "targeted" minimum infiltration rate, the solution may not be unique. That is to say, several design parameter combinations can lead to the same infiltration rate. This will provide many ways to optimize air curtain performance of an OVRDC.

Conclusions

Empirical research studies presented in this article have provided definitive and invaluable information on the operation of OVRDCs. The most remarkable research achievement has been the recognition of the high thermal vulnerability of OVRDCs as well as the identification of important geometric and flow parameters affecting the infiltration through the air curtain of OVRDCs. Equally important, the air curtain performance studies resulted in establishing new and accurate methodology such as tracer gas for measuring the infiltration rate and total case flow rate. In addition, an ANN program was validated that can be used to estimate infiltration rates.

The knowledge and findings from these research studies contributed significantly to the entire industry, namely display case manufacturers, engineering societies and energy agencies. Currently, display case manufacturers can use ANN program and tracer gas to improve their case design by minimizing infiltration. The findings have been incorporated into engineering handbooks as well. Information from these studies have been instrumental in supporting the US Department of Energy's appliance regulations and efficiency rule-making efforts.

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Modeling Supermarket Refrigeration with EnergyPlus™

Therese K. Stovall and Van D. Baxter, Oak Ridge National Laboratory, USA

Supermarket refrigeration capabilities were first added to the EnergyPlus energy simulation software package in 2004. At that time, it was possible to model a direct expansion (DX) rack system with multiple refrigerated cases. The basic simulation software handles all the building energy uses, typically on a 5 to 10 minute time step throughout the period of interest. The original refrigeration module included the ability to model the sensible and latent interactions between the refrigerated cases and the building HVAC system, along with some basic heat recovery capabilities. Over the last few years, the refrigeration module has been expanded to handle more complex systems, such as secondary loops, shared condensers, cascade condensers, subcoolers, and walk-in coolers exchanging energy with multiple conditioned zones.

Introduction

Refrigeration systems in supermarkets represent a significant portion of the total store energy use. Further, the refrigerated cases are located within conditioned zones, so there are complex energy exchanges between these cases and the building HVAC system.

The EnergyPlus energy simulation software package is a powerful tool that can be used to examine the energy use of any building, including supermarkets (http://apps1.eere.energy.gov/buildings/energyplus). The software computes all building energy uses, typically on a 5 to 10 minute time step for a given simulation time period (e.g., one year).

Over the last few years, new refrigeration system configurations have been considered in an effort to reduce energy use and greenhouse gas emissions. EnergyPlus has been continually revised to enable modelling of these newer systems.

Model Description

Supermarket refrigeration capabilities were first added to EnergyPlus in 2004 by the Florida Solar Energy Center. The primary focus initially was on properly accounting for the sensible and latent energy exchanges between the refrigerated cases and the building HVAC system.

Store refrigeration systems are modelled with a logic and system-driven approach, as opposed to the pipe and node approach used to model other building systems. This simplifies input requirements for users but also limits the system configuration to a pre-defined set of options. For example, a refrigeration system specification (see Fig. 1) lists the names of the refrigerated cases served, the curve fit describing the rack performance, location of display cases, operating schedules, etc.

Originally, an air-cooled rack, representing the performance of the combined compressors and condensers as a function of the heat rejection temperature, was the only system configuration available. Even in that first implementation, it was possible to reject heat either outdoors or within the conditioned zone (as is necessary for a self-contained system).
The refrigerated case model itself has changed little since then, because most desired features were included in that original implementation: multiple defrost types, lighting options, anti-sweat heater systems, and fans. Scheduling capability was provided for all these features, along with schedules for night covers and stocking loads. Under-case return air connections to the HVAC system were also accommodated. Multiple models were provided for the latent and sensible energy exchange mechanisms, based upon previous ASHRAE research projects. These references and all other of the details of the refrigeration module are provided in the

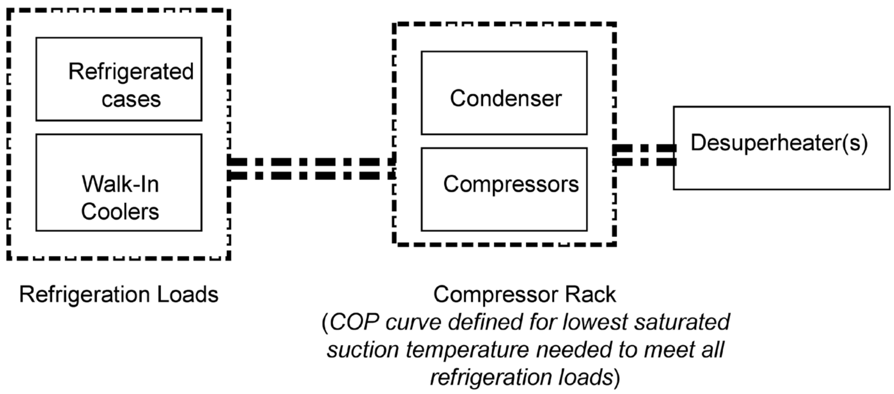

Figure 1 Simple supermarket refrigeration system schematic layout diagram for EnergyPlus

EnergyPlus Engineering Reference document. [1]

Over the last few years, as the focus on reducing energy use in supermarkets has grown, the refrigeration module in EnergyPlus was expanded to model additional equipment configurations. One of the most significant changes is the expanded ability to transfer heat between and among multiple refrigeration systems (see Fig 2).

The first stage of the model expansion was to add water-cooled and evaporative-cooled racks as heat-rejection options to the rack model. The second step introduced separate models for the condensers and compressors, permitting a better examination of the energy use impact of variable condensing and evaporating temperatures, as well as increasing model opportunities for heat rejection and subcooler arrangements.

A model for walk-in coolers exchanging energy with multiple conditioned zones was added. As with the refrigerated cases, the sensible and latent energy exchanges with the zones and the walk-ins was based upon published ASHRAE work.

After those fundamental changes, capabilities were added to accommodate additional refrigeration systems and components, such as secondary loops, shared condensers, cascade condensers, and subcoolers.
Secondary loop systems use less refrigerant leading to lower refrigerant losses than for conventional DX systems. Three types of secondary loops are available: cascade condensers, liquid circulation (glycol or brine), and liquid overfeed (low temperature CO_2, see Fig 3). Cascade condensers act as a load on a medium temperature system while providing heat rejection for a low temperature system. The refrigerant/liquid heat exchangers (HX) of secondary loop or liquid overfeed systems impose HX ΔT and liquid pumping power penalties that DX systems do not suffer. This is partially offset by the greatly reduced length of primary refrigerant piping. In fact pipe heat losses become an important piece of comparison between

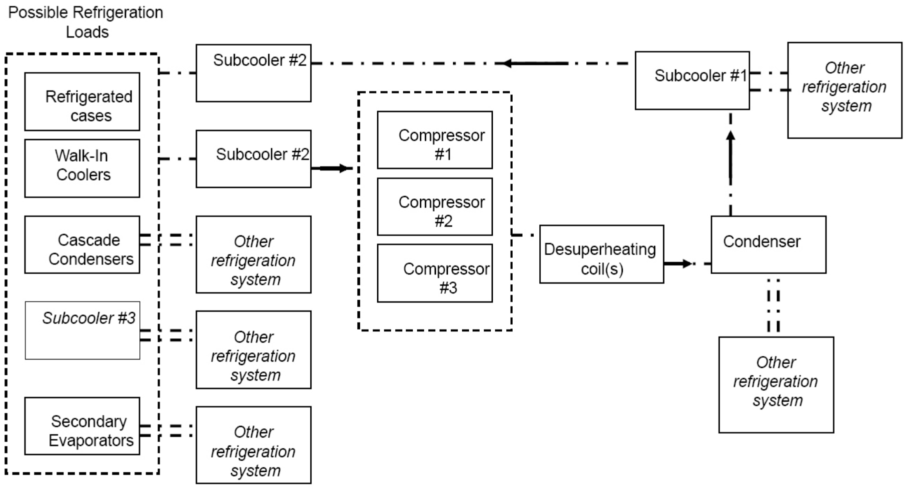

Figure 2 Detailed supermarket refrigeration system schematic layout diagram for EnergyPlus

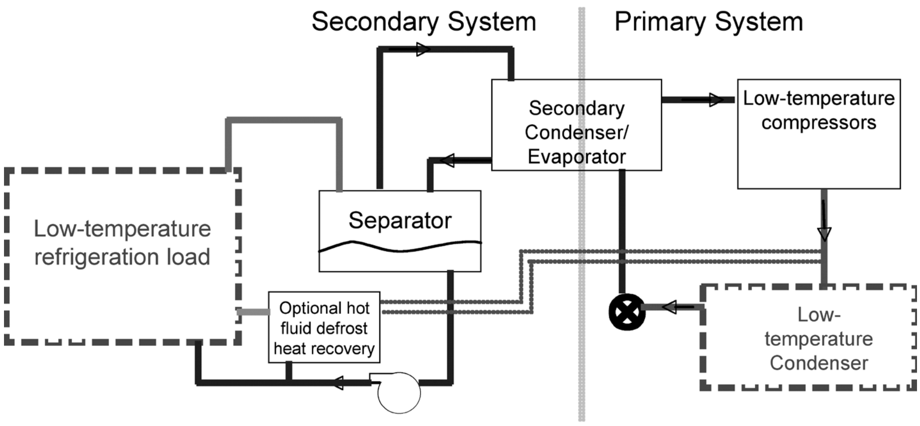

Figure 3 Low-temperature CO_2 secondary system schematic layout diagram for EnergyPlus

DX and secondary systems. Some secondary refrigerants (CO_2 for instance) can utilize piping of smaller diameter which have lower pipe heat gains than DX systems. Heat exchange between the store zones and the refrigerant piping is evaluated in the refrigeration module to properly reflect the impact of this parameter.

EnergyPlus has a library of data for R22, R123, R134a, R404a, R410a, R507a, NH3, and low pressure CO_2, as well as a number of secondary refrigerants. Thermodynamic data for new refrigerants can be easily added.

One of the main drawbacks to EnergyPlus has been the extensive input data required to simulate a system. Obviously, detailed models can only produce reasonable estimates if they are given reasonable input data. For the major cycle equipment elements, input data is requested in a form readily available from manufacturers' published data. In addition, libraries of input data have been provided for commercially available compressors and refrigerated cases. For other elements, short-cuts have been provided to offer a level of user convenience. For example, four types of condenser fan curves have been pre-programmed for the users' selection. Eighteen example input files are provided that exercise every option available in the refrigeration module. These are listed in Table 1.

What's next? A model for a refrigeration system appropriate for use in a refrigerated warehouse is under development. Other new features will include additional compressor staging logic, trans-critical CO_2 compressors, and a primary cycle liquid-overfeed arrangement.

Table 1. Available EnergyPlus Example System Input Files for Buildings Utilizing Food Refrigeration, Display, and Storage Equipment.

Building type	Sample files available	Comments
Supermarkets	11	At least one for each system type available in EnergyPlus
Restaurants	2	One formal type and one fast food type
Hospitals	2	
Schools	2	
Hotels	1	

A full graphical user interface (GUI) input tool is under development and is expected to be released in the next year or so. Figure 4 shows a preview of one of the proposed refrigeration system description pages.

IEA Annex 31

The EnergyPlus refrigeration module development was the principal U. S. contribution to the IEA HPP Annex 31 "Advanced Modeling and Tools for Analysis of Energy Use in Supermarket Systems." Task 5 of the Annex included case study results for all of the simulation tools evaluated during the Annex including EnergyPlus. [2]

Conclusions

Refrigeration systems, especially walk-in coolers are found in many building applications, such as hospitals, schools, and food preparation. The robust refrigeration system model included with the broader EnergyPlus capabilities can be used to explore possible building and equipment designs and minimize the total energy demand for buildings that include refrigeration systems.

Acknowledgement

EnergyPlus is the U. S. Department of Energy's (DOE) trademark name for its flagship building energy simulation code. The work described in this article was sponsored by the DOE Building Technologies Program under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

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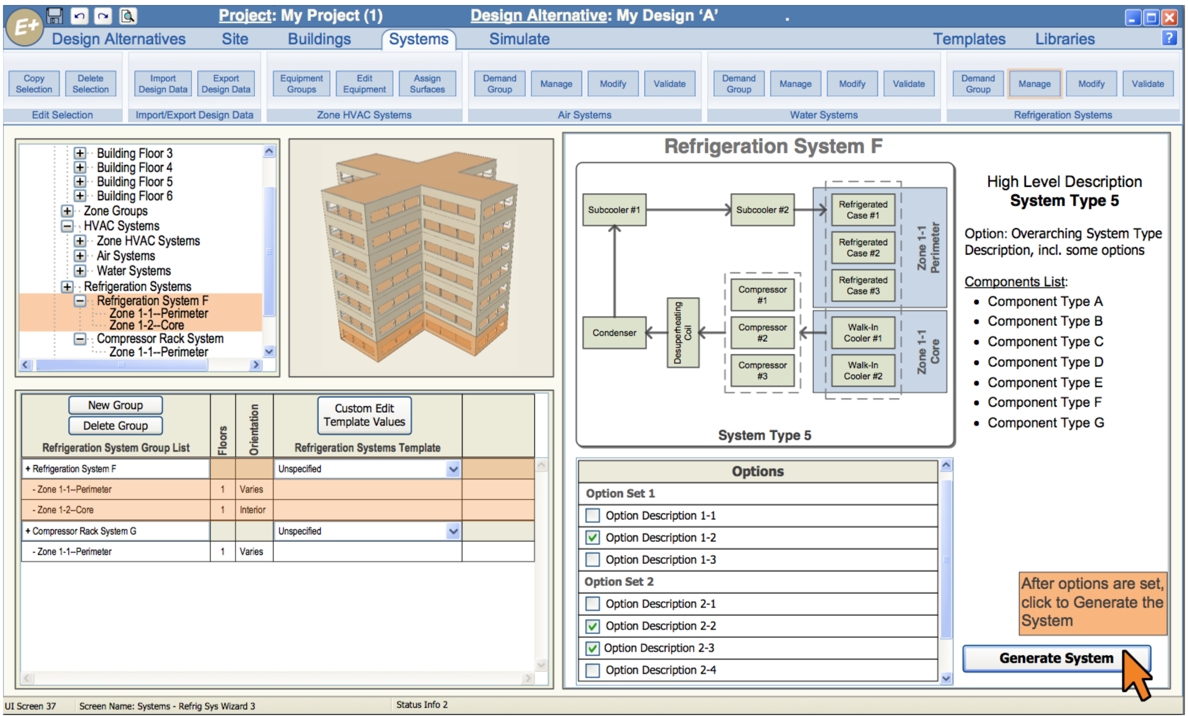

Figure 4 Proposed refrigeration system page in new EnergyPlus GUI

Evaluating Interactions Between Refrigeration and Comfort Cooling in Supermarkets

Michael Brandemuehl, University of Colorado, USA

ASHRAE has recently initiated a research project with the objective of providing a comprehensive assessment of the potential for energy savings in supermarkets by optimized design and operation of the combined HVAC and refrigeration systems. Preliminary work has shown that significant variations of indoor humidity can occur in supermarkets, which could be exploited to improve the performance of both refrigeration and air conditioning systems.

Introduction

Supermarket energy costs for heating, cooling, dehumidification, and refrigeration are a major store operating cost and often exceed store profits. While most of this cost is associated with maintaining refrigerated conditions for products, much is also spent on maintaining suitable environmental conditions in the supermarket sales area. Each of these requirements is inexorably linked to the other. Failure to control store temperature and humidity can cause excessive energy consumption by refrigeration equipment, and hamper product marketing due to frost build-up on frozen products and fogging of display cases. On the other hand, most of the energy used to operate the refrigeration equipment serves to reduce the building cooling and dehumidification requirements.

The interacting effects between the heating, ventilating, and air conditioning (HVAC) system, which controls space conditions, and the refrigeration system, which controls product conditions, are well known. In general, the low evaporator temperatures of refrigerated cases are relatively less efficient than the air conditioning equipment used for space conditioning, suggesting that cooling and dehumidification loads are best met by HVAC equipment. Most significantly, the energy required by the HVAC equipment to maintain the space conditions at controlled, and relatively low, relative humidity can be offset by savings in the energy required by the refrigeration equipment. Unfortunately, the refrigerated cases provide more sensible cooling than dehumidification, which burdens HVAC equipment with an unusual, and difficult, mix between cooling and dehumidification requirements. Difficulties with energy management are exacerbated in humid climates by the requirement to maintain store humidity levels. Proper control of store temperature and humidity levels often requires energy to over-cool, and subsequently reheat, the air. Dehumidification requirements become a dominant load on the HVAC system

Recent studies have been conducted to establish guidelines for the impact that humidity reduction can have on energy use [1]. It has also been shown that reducing the store humidity level from 55 % to 35 % RH can produce a significant decrease in refrigeration system energy use, including compressors, anti-condensation heaters, and defrost energy. Estimates of refrigeration system energy savings range between 5 % and 28 %, depending on system characteristics [2]. These savings are available to offset additional energy use by HVAC equipment to maintain lower humidity.

ASHRAE Research Project 1467-RP

ASHRAE has recently sponsored Research Project 1467-RP, Balancing Latent Heat Load between Display Cases and Store Comfort Cooling. The overall objective of this project is to provide a comprehensive assessment of the potential for energy savings in supermarkets by optimized design and operation of the combined HVAC and refrigeration systems. The assessment includes the effects of climate, space temperature and humidity setpoint controls, HVAC system type and characteristics, and the design and operation of the refrigerated cases. Furthermore, the project addresses the overall layout of HVAC and refrigeration system components in supermarkets, including HVAC zoning, the location of supply and return air, and the overall air distribution patterns in the supermarket.

The two-year project began in late 2009. The project team at the University of Colorado has completed much of the preliminary project work, including a review of previous research and alternative simulation environments, and surveyed the current state of supermarket design and equipment performance. The project team has selected EnergyPlus as the modelling tool for the analysis, has developed a prototypical supermarket simulation model, and has validated the simulation environment with experimental data. The team is currently developing the framework for a comprehensive simulation analysis, and exploring the general impact of influential variables.

While much work remains, preliminary work has produced interesting results that will guide the main project analysis. One of the studies, briefly presented here, explored the effect of refrigerated case spatial distribution on supermarket humidity profiles.

Case Location and Air Distribution in Supermarkets

One of the preliminary concerns regarding the latent heat balance between refrigerated cases and store comfort cooling systems involves the airflow patterns and humidity distributions in a supermarket. While the sales area of a supermarket is typically a single large room, and is usually modelled as a single zone in building energy simulations, the refrigerated cases could potentially have a local effect on store humidity. The distribution of low- and medium-temperature cases throughout the store is likely to have an effect on the humidity distribution. The location of HVAC equipment and the airflow patterns within the store could also affect the distribution – a single air handler for the sales area could disperse these local effects, while local HVAC systems stabilize and promote these local effects.

An analysis of the effects of refrigerated cases on supermarket humidity profiles has been performed using computational fluid dynamics (CFD). The basic store layout is shown in Figure 1.

The base model was configured to match a supermarket with a floor area of 4500 m^2. Experimental data from the store, which included separate humidity measurements in the refrigerated case aisles and the dry goods aisles, were used to calibrate the model.

The analysis includes an evaluation of four different scenarios:

- Base Case: A single air handler, delivering supply air with a greater quantity near the front of the store (top of figure) and all return air removed at the rear.
- Side Location: Same as base case, except the refrigerated cases are redistributed to be all on one side of the store.
- Scattered Location of Cases: Same as base case, except the refrigerated cases are redistributed to be scattered throughout the store.
- Separate AHUs: Base layout with two separate air handlers delivering different supply air streams to the

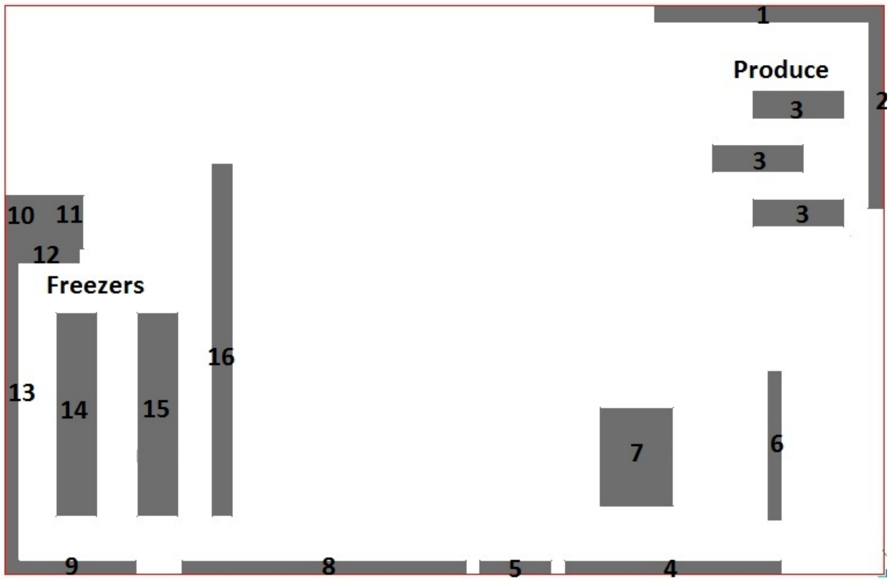

Figure 1 Refrigerated case distribution in base store layout

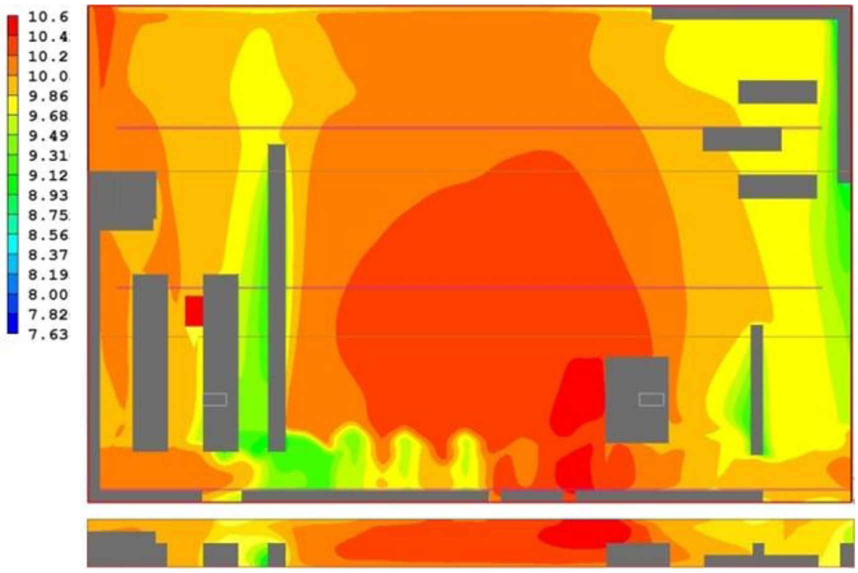

Figure 2 Humidity ratio (g/kg) profile for base case

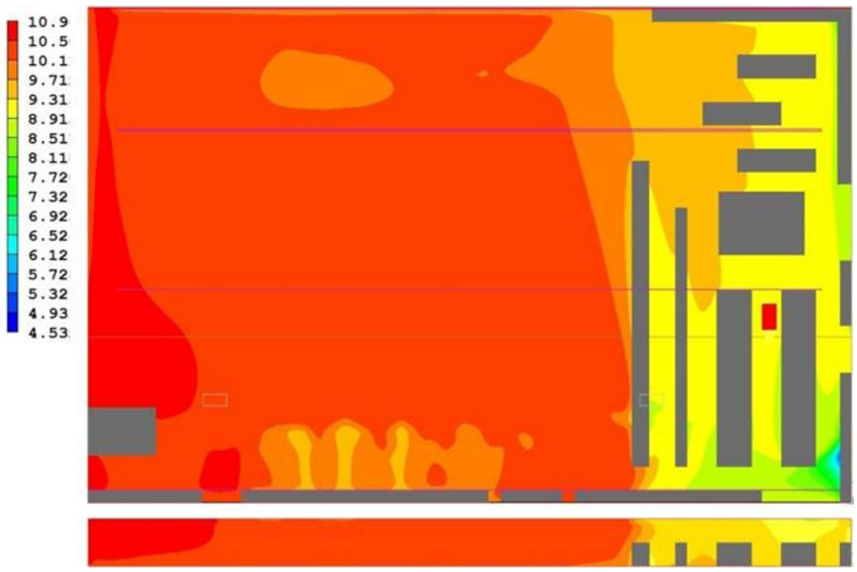

Figure 3 Humidity ratio (g/kg) profile for side location

freezer area and the main sales area. The air handler over the freezer aisles delivers air at a lower humidity to improve case performance.

Humidity ratio (g/kg) profiles within the supermarket are shown in Figures 2-4 for representative distributions. Note that there are significant variations in humidity ratio in the vicinity of the refrigerated cases. By locating the cases in one area of the store, the humidity value in the dry goods area is distinctly higher, but relatively uniform across the space. Scattering the cases throughout the store produces a very uniform humidity profile across the store. The presence of a dedicated dehumidification system accentuates the local effects of the moisture removal by the cases.

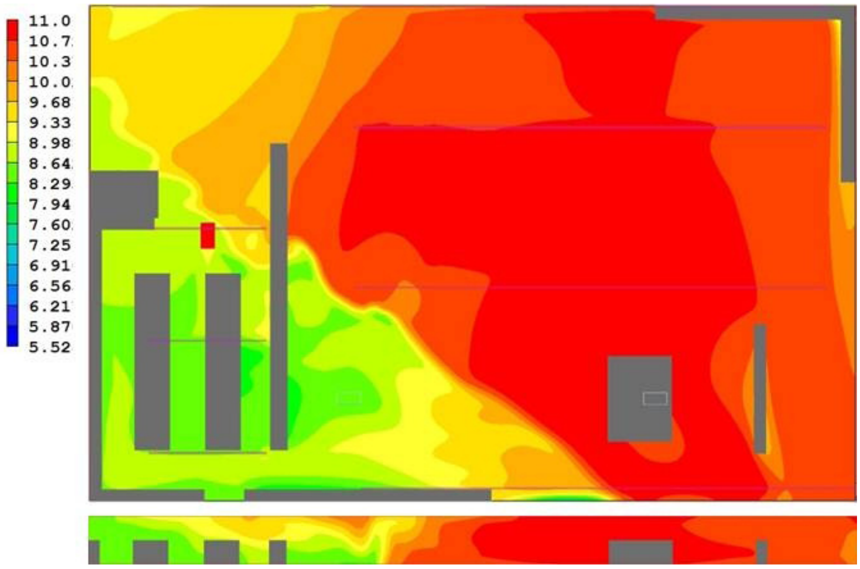

Figure 4 Humidity ratio (g/kg) profile with separate AHUs

A summary of the humidity differences between the freezer aisles and the dry goods aisles is shown in Figure 5. The results show that significant humidity gradients can be encountered in the open spaces of a supermarket due to local effects. However, the gradients can be completely eliminated by other case distributions. The results suggest that an isolated area of refrigerated cases, as might occur in a very large retail store with a supermarket area on one side of the store, could be modelled as a separate space with the same characteristics as a stand-alone super-market. They suggest that there could be opportunities for energy savings by exploiting the humidity gradients in stores. They also suggest that case and HVAC distribution are important parameters for the project analysis.

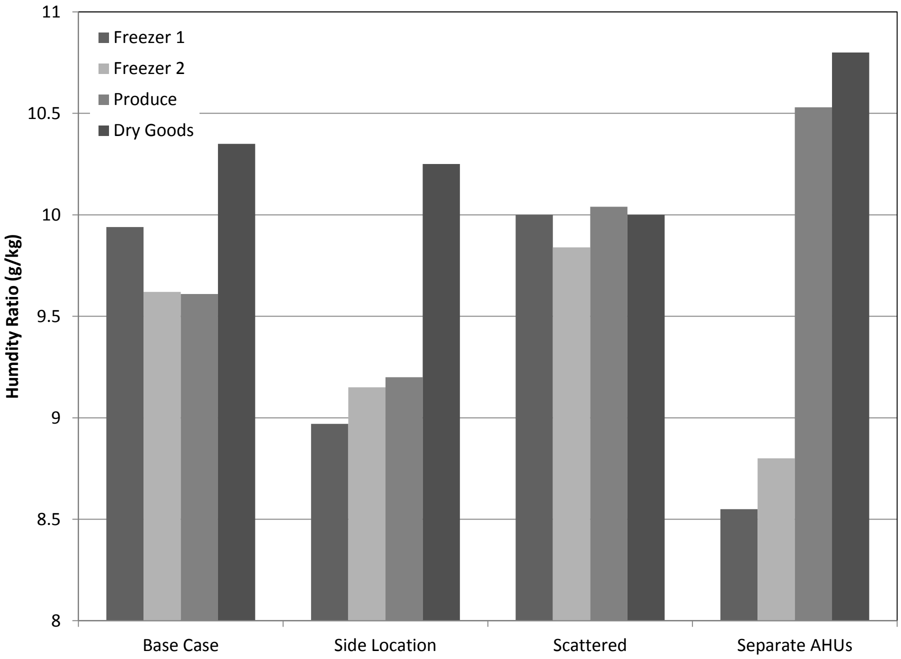

Figure 5 Humidity distributions in supermarket for various case layouts

Conclusions

Supermarket humidity levels can have a significant impact on the energy use of both refrigeration and HVAC systems. ASHRAE has initiated a project to optimize the design and operation of supermarket systems to minimize overall energy consumption. Preliminary results suggest that there may be opportunities to maintain lower humidity levels in the vicinity of refrigerated cases, reducing refrigeration system energy use, without requiring dehumidification of the entire supermarket. The project is expected to be completed by late 2011.

Acknowledgement

This article is an account of R&D work sponsored by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) under ongoing Research Project #1467. The authors gratefully acknowledge the assistance and guidance provided by members of ASHRAE Technical Committee 10.7, Commercial Food and Beverage Cooling, Display, and Storage.

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Refrigerant Report

The latest edition of Bitzer's Refrigerant Report is now available for download from the company's website. Now in its 16th edition, this 40-page report covers all the currently available refrigerants, their applications, thermodynamic properties and environmental impacts. As well as covering the transitional gases, the report discusses the latest developments with the new low-GWP HFO refrigerants and blends.
http://www.bitzer.de/eng/Home
[click on Products & Services/ Documentation/General/General leaflets /a-501-16]

World Energy Outlook 2010

The world appears to be emerging from the worst economic crisis in decades. Many countries have made pledges under the Copenhagen Accord to reduce greenhouse gas emissions. Commitments have also been made by the G20 and APEC leaders to phase out inefficient fossil-fuel subsidies. Are we, at last, on the path to a secure, reliable and environmentally sustainable energy system? What more must be done and spent to achieve the goal of limiting the global temperature increase to two degrees Celsius? What would be the impact of these actions on oil markets?

How will emerging economies increasingly shape the global energy landscape? Where will their policy decisions lead us? And will China sustain and intensify the four-fold improvement in energy intensity that it has achieved in the last thirty years?

How quickly will the contribution of renewables to meeting the world's energy needs grow? How much will it cost? And to what extent does growth in deployment and use of renewable energy depend on government support?

All these questions and many others are answered in the World Energy Outlook 2010 (WEO-2010). The data are extensive, the projections more detailed than ever, and the analyses are compelling.
http://www.iea.org/w/bookshop/add.aspx?id=422
See also http://www.iea.org/press/pressdetail.asp?PRESS_REL_ID=402

CO_2 Emissions from fuel combustion

In recognition of fundamental changes in the way governments approach energy-related environmental issues, the IEA has prepared this publication on CO_2 emissions from fuel combustion. This annual publication was first published in 1997 and has become an essential tool for analysts and policy makers around the world.
http://www.iea.org/w/bookshop/add.aspx?id=570

Refrigerant ruler for iphone

Bitzer has introduced an iphone application program that calculates the pressure/temperature characteristics of refrigerants. This provides a modern alternative to the traditional refrigerant ruler. The digital refrigerant ruler shows most current refrigerants, can use imperial and metric units simultaneously, and can display them in any desired combination.
(JARN Oct 25, 2010)

2011

21 January
European Conference on 'The Latest Technologies in Renewable Energy'
Edinburgh, UK
http://www.euenergycentre.org/conferences/our-conferences/80-uk2011

29 January - 2 February
ASHRAE Winter Meeting
Las Vegas, USA
http://www.ashrae.org/events/page/562

31 January - 2 February
International Air-Conditioning, Heating, Refrigerating Exposition (AHR Expo)
Las Vegas, USA
Co-sponsored by ASHRAE and ARI
www.ahrexpo.com

10-12 February
4th CEP® Clean Energy & Passivehouse International Trade Fair for Renewable Energy and Passive House
Stuttgart, Germany
http://www.cep-expo.de/index.php?id=7&L=1

26 February- 2 March
EuroShop
Düsseldorf, Germany
www.euroshop.de

1-3 March
Chillventa Rossija
Moscow, Russia
http://www.chillventa-rossija.com/en/default.ashx

5-7 April
Sources/Sinks alternative to the outside Air for Heat Pump and Air-Conditioning Techniques (Alternative Sources - AS), IIR International Conference
Padua, Italy
http://www.aicarr.org/Pages/PadovaIIR2011/home.aspx

6-8 April
International Sorption Heat Pump Conference (ISHPC11), IIR International Conference
Padua, Italy
http://www.aicarr.org/Pages/PadovaIIR2011/home.aspx

13-15 April
Conference V.E.R.T.E '11 On Energy Valorization of Thermal Effluents and Environment
Paris, France
http://sites.google.com/site/verte2011

14-16 April
IIR Ammonia Refrigeration Conference
Ohrid, R. Macedonia
http://www.mf.ukim.edu.mk/web_ohrid2011/ohrid-2011.html

8-13 May
World Renewable Energy Congress (WREC) 2011
Linköping, Sweden
http://www.wrec2011.com/

16-19 May
10th IEA Heat Pump Conference 2011
Tokyo, Japan
http://www.hpc2011.org

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International Energy Agency

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

IEA Heat Pump Programme

International collaboration for energy efficient heating, refrigeration and air-conditioning

Vision

The Programme is the foremost worldwide source of independent information and expertise on environmental and energy conservation benefits of heat pumping technologies (including refrigeration and air conditioning).

The Programme conducts high value international collaborative activities to improve energy efficiency and minimise adverse environmental impact.

Mission

The Programme strives to achieve widespread deployment of appropriate high quality heat pumping technologies to obtain energy conservation and environmental benefits from these technologies. It serves policy makers, national and international energy and environmental agencies, utilities, manufacturers, designers and researchers.

IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC). 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.

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