The Use of Natural Refrigerants in Supermarket Systems

Earthcare Products Limited

Abstract

Supermarket systems have traditionally used R-12, a CFC, and R-502, a CFC/HCFC blend, as the refrigerant. In addressing the ozone depletion problem, most manufacturers have adopted either R-404A, and HFC blend, or R-134a. However, both are potent greenhouse gases, restricted under the Kyoto Protocol. So in solving the ozone depletion problem, most supermarket refrigeration equipment contributes to global climate change. In response, Earthcare has adopted hydrocarbon refrigerants that are both ozone-friendly and have low or no global warming potential. The technical challenge has been to achieve compliance with the safety regulations governing the use of flammable refrigerants.

Background

Business, government and institutions are becoming more aware of the threat to the environment that their activities pose, and increasingly see that in meeting the challenge of minimising their environmental impact, they can simultaneously realise significant benefits. Whether through simple energy savings or in an improved standing amongst stakeholders, supermarkets are beginning to reap the “green dividend.”

Cooling is the largest single demand on electrical consumption in the world. Synthetic refrigerants are adding significantly to climatic change and ozone depletion. As such, the process of cooling poses a double threat to the global environment. It is no wonder, therefore, that businesses and public bodies alike are being hit by legislation and regulation as governments seek to avoid this damage. The response must not be just to pay the bill; instead, it should be to find ways of avoiding extra costs and making real savings.

Legislation is having an immediate impact upon users of chemical refrigerants. The ban on chlorofluorocarbons (CFCs), further restrictions on hydrochlorofluorocarbons (HCFCs) and tough new requirements for the handling of refrigerants are all likely to have a serious cost impact unless very carefully managed. Supermarkets will wish to avoid the adverse implications of new regulations but at the same time gain the benefits that novel techniques and refrigerants will bring. The aim should be to obey the law, anticipate future legislation, and improve the bottom line, all at the same time. The use of CFCs and HCFCs was effectively put to an end by the signing of the Montreal Protocol in 1995.

With a GWP 1300 times higher than CO_2, it has been calculated that the release of only 1 kg of HFC-134a is equivalent to driving the average family car for 4,490 kilometres (2,790 miles). Releasing the same amount of R-404a refrigerant is equivalent to driving 15,679 km (9,743 miles).

The question marks over HFCs date back to the Earth Summit in Rio de Janeiro in 1992 and were settled at Kyoto in 1997 when, at the instance of the United States, HFCs, along with the other Potent Industrial Greenhouse Gases became restricted substances.

The UK Government's position on HFCs was presented to Parliament on 17th November 2000, the key elements are:

- HFCs should only be used where other safe, technically feasible, cost-effective and more environmentally acceptable alternatives do not exist;
- HFCs are not sustainable in the long term—the government believes that continued technological developments will mean that HFCs may eventually be able to be replaced in the applications where they are used; and
- HFC emissions will not be allowed to rise unchecked.

In 2006, the EU established a Directive dealing with fluorinated gases (F-gases) used in mobile air conditioning and a Regulation addressing the use of F-gases in stationary applications. The Regulation

aims to improve containment, and will be reviewed after four years. The effectiveness of the Regulation will be assessed, and F-gases restrictions will be identified for additional applications.

The Charted Institute of Building Services Engineers (CIBSE) recommends the use of alternative refrigerants with zero or low global warming potential (GWP) such as ammonia and hydrocarbons. An additional incentive for the use of natural refrigerants is that the Building Research Establishment's (BRE's) Environmental Assessment Method (BREEAM) (2005) awards an additional point for refrigerants with a GWP below 5 and states that "Hydrocarbons and Ammonia are now widely available and are valid alternatives to HFCs in all buildings."

Speaking at the RAC 2007 Exhibition, senior representatives of the supermarket chains ASDA, M&S, Sainsbury's, Somerfield, Supermarkets and Waitrose said the long-term viability of synthetic HFC refrigerants was undermined by their high GWP. This was incompatible with increasing concern over climate change, and the legislative uncertainty created by the forthcoming F-gas review. Continued large scale reliance on HFCs was also inconsistent with their high profile policies on environmental responsibility. As a result, they are investing in new technologies that run on natural refrigerants, such as carbon dioxide and hydrocarbons.

HCFCs and HFCs should therefore be avoided on both environmental and premature obsolescence grounds. As to alternatives, there are natural refrigeration options, such as absorption cooling, ammonia and hydrocarbons, which may give the best opportunities for reliable and cost-effective cooling. Energy efficiency benefits are in addition to the inherent environmental advantages and reduced running costs that natural refrigerants offer.

Development of Alternative

In 2005, Earthcare completed the Carbon Trust funded development of an integrated low energy refrigeration, air conditioning, and heating system for supermarkets. The technology design is based around the provision of Earthcare's Integrated Chiller Water Loop (ICWL): hydrocarbon chillers coupled with air conditioning circuits and water-cooled refrigeration units.

The ICWL is an energy efficient supermarket refrigeration system intended for use with natural refrigerants. It makes use of some of the results from Annex 22 of the International Energy Agency Heat Pump Programme, which addresses heat pumps, air conditioning and refrigerating systems using natural working fluids. The UK Annex 22 work programme, carried out by EA Technology, an independent research organisation, focussed on supermarket refrigeration systems using natural refrigerants.

Part of the work was to construct computer models of various innovative supermarket refrigeration systems and analyse their performance compared to current technology. This work is described in a paper "A Supermarket Refrigeration and Heating System using Hydrocarbon Heat Pumps and an Ammonia chiller."[1]

The ICWL consists of a water chiller, a chilled water circuit, water cooled condensing units and an air handling unit. There is the option to add a hot water capability by incorporating heat recovery to the chiller. The chiller provides water at a temperature of 7˚C and the system is designed for a return temperature of 12˚C, allowing the use of chilled water cooled air conditioning systems. The refrigeration condensing units also reject their heat to the Chilled Water Loop. In a supermarket this would consist of chilled and frozen food display cabinets and storage.

Hot water can be generated by the use of a de-superheater or heat recovery condenser on the chiller. From a simple energy balance it can be seen that the store's heating can be provided if the total refrigeration and chiller absorbed electrical power exceeds the heating requirement.

[1] Castle T. P., Green R.H. "A supermarket refrigeration and heating system using hydrocarbon heat pumps and an ammonia chiller", IEA Annex 22 Workshop Proceedings, December 1997.

Earthcare selected hydrocarbons because of their compatibility with mineral oil, their low GWP, good thermodynamic and transport properties, lower pressure ratios and lower densities, all of which entail inherent energy efficiency benefits over synthetic refrigerants.

P.J. van der Weyde of Philadelphia first used hydrocarbon refrigerants in 1866; this is not new technology! The greatest success of hydrocarbons has been the application of R600a to domestic refrigerators. Since 1992, over 120 million such refrigerators have been produced worldwide without a single fatality due to the flammability of the refrigerant. Domestic refrigerators using isobutane are at least as safe as those using halocarbons; they are more efficient and quieter. The UK safety standard BS4434 was amended in 1995 to permit the use of flammable refrigerants in commercial applications. This was superseded by BS EN 378, an incorporated European Standard. The Institute of Refrigeration Code of Practice for A3 Refrigerants is the principle code by which these Standards should be implemented.

All the above has now been summarised in the UK Air Conditioning and Refrigeration Industry Board (ACRIB) guidelines for flammable refrigerants covering all aspects of working with hydrocarbon refrigerants – 'Guidelines for the Use of Hydrocarbon Refrigerants in Static Refrigeration and Air Conditioning Systems' – which has received the support of the UK Department of Trade and Industry.[2]

Very briefly, the safety principals relating to the use of hydrocarbon refrigerants in supermarket cabinets are:

- Electrics should be sealed (to IP54 or better) or non-sparking (i.e., solid state);
- Room sizes should be sufficient to ensure that a catastrophic leak could not produce a concentration more than 20% of the lower flammable limit; and
- Refrigerant charge sizes are restricted to 1,500 grams.

Bringing the Alternative to Market

For new stores, the aim should be to achieve energy consumption levels of less than half that of current systems. New stores should be significantly more energy efficient and use natural refrigerants not only to reduce energy consumption but also to save the company from criticism for contributing to global climate change. By adopting energy efficiency measures and using natural refrigerants, supermarkets could achieve considerable cost savings, meet the high standards of environmental performance and avoid unnecessary expenditure in the future. This will maximise the "green dividend" by reducing running costs and avoiding replacement costs, whilst making a significantly smaller demand on the Earth's resources.

By re-thinking the whole process of cooling provision – from the mechanics of supermarket refrigeration to the creation of "power by the hour" cooling contracts – we wanted to bring about a step-change in the value supermarkets get from their cooling systems. That is why Earthcare developed the Pioneer Store, presented in November 2002 and independently tested by EA Technology against existing performance criteria, a process that was concluded in September 2003. Consequently, Earthcare has developed a design for residential low noise sites – as an example of the Pioneer Store concept. Our ambition is simple: to deliver increased convenience, reduced costs and improved environmental performance to supermarket stores in as short a time as it is possible and sensible to achieve.

The technical development of the system was straightforward; the most time consuming element was optimising the selection of compressors, heat exchangers and valves for our more efficient, "non-standard" conditions. The main barriers faced in developing the technology, were initially getting selection data for components using hydrocarbon refrigerants and more recently, getting components CE marked.[3]

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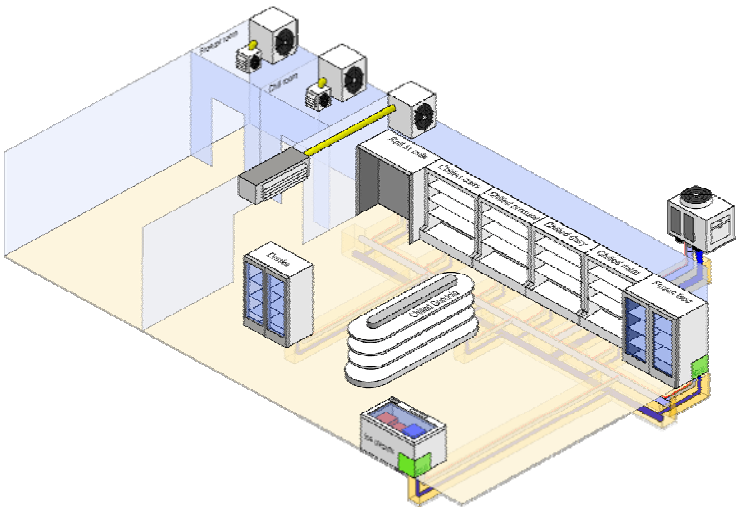
[2] http://www.acrib.org.uk/Use%20of%20Hydrocarbon%20Refrigerants%20Guidelines.pdf.

[3] The CE mark is a mandatory conformity mark on many products placed on the single market in the European Economic Area (EEA).

Impacts of Switch to Alternative

In this project, Earthcare met the objective of an energy efficient and environmentally friendly supermarket by utilising an innovative design that allows chilled water fan coil air conditioning units and chilled water-cooled refrigeration systems to operate on a common water loop. This system will not only meet the store's refrigeration and air conditioning requirements, it will do so with efficiency savings unobtainable from either conventional direct expansion (DX) or secondary technologies. Energy savings are conservatively estimated to match Annex 22 predictions which concluded that the use of natural refrigerants in conjunction with optimised design could achieve reductions in electricity consumption of 20% compared to conventional direct expansion (DX) systems, and reductions in Total Equivalent Warming Impact (TEWI) of 36% compared to conventional DX systems.[4]



The system runs on natural refrigerants, eliminating the need for ozone depleting or global warming synthetic refrigerants. The use of water-cooled condensers allows integrated refrigeration within the display cases in a self-contained configuration, thus greatly reducing refrigerant charge and leakage potential. The heat from the refrigeration equipment is removed by the circulating chilled water, and can be recovered to provide all the store's heating, provided the cooling of the absorbed electrical power exceeds the heating requirement for the store.

Examples of all items of equipment that would be required for a supermarket installation have been tested. This trial version of the system has been analysed, refined and optimised in order to minimise energy consumption. The results are entirely consistent with the computer modelling carried out in earlier studies. Based on these initial results, Earthcare believes that commercial use can commence.

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About Earthcare Products: Founded in October 1997, Earthcare provides advice, products and services that are at the cutting edge in terms of energy efficiency and sustainable low environmental impact. It has become the first point of contact for engineers who wish to specify the most energy efficient and environmentally friendly cooling solutions. The company is increasingly called upon by industry leaders to help solve the most difficult of their technical challenges.

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[4] Annex 22 - Compression Systems with Natural Working Fluids - Final Report & Guidelines for Design and Operation.