



Low Energy Commercial Refrigeration for High Ambient Conditions

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1. Introduction

India's retail and logistics industry comprises of over 14 million outlets employing about 40 million people. In November 2011, India's central government announced retail reforms for both multi-brand and single-brand stores. These market reforms paved the way for innovation and competition with multi-brand retailers such as Walmart, Carrefour and Tesco. Existing Indian retail firms such as Spencer's, Foodworld Supermarkets Ltd, Nilgiri's and ShopRite support retail reform and international competition. They expect a flurry of joint ventures with global majors providing expansion capital and opportunities to gain expertise in supply chain management. Competition and investment will provide benefits to consumers through lower prices, wider availability and significant improvement in supply chain logistics.

Supermarkets traditionally used R-12, a CFC, and R-502, a CFC/HCFC blend, as refrigerants. To address the ozone depletion problem, most supermarkets have now adopted HFCs, either R-404a or R-134a. However, both are potent greenhouse gases, many thousands of times more powerful than CO₂ in terms of their global warming impact and therefore restricted under the Kyoto Protocol. HFCs are part of a family of chemicals – halocarbons – that account for 13% of the world's man-made contribution to global warming, so most supermarket refrigeration is making a huge contribution to climate change. In fact about one quarter of the carbon footprint of supermarkets comes from refrigerants – and that's before you take account of energy to power the equipment! To demonstrate this in a way that readers can visualise, it has been calculated that the HFC leakage from a typical European supermarket causes the equivalent global warming to driving a typical family car around the earth 72 times per annum!

It is technically feasible for supermarkets and other commercial refrigeration users to switch away from using highly destructive HFCs. For new stores, the aim should also be to achieve energy consumption levels of less than half that of current systems. By adopting energy efficiency measures and using natural refrigerants, supermarkets could achieve considerable cost savings, meet the highest standards of environmental performance and avoid unnecessary expenditure in the future. This will maximise the "green dividend" by reducing running costs and avoiding premature replacement costs, whilst making a significantly smaller demand on the Earth's resources.

In 1997, EA Technology in the UK studied the merits of various distributed and secondary refrigeration systems supermarket refrigeration systems using natural refrigerants as part of the Annex 22 of the International Energy Agency Heat Pump Programme. In 2005, Earthcare completed a project to develop low energy refrigeration for supermarkets as part of a UK Carbon Trust funded project titled "The Development of Low Energy Integrated Commercial Refrigeration Technology". This developed one of the refrigeration systems described in Annex 22 and the results were presented at the 7th IIR Gustav Lorentzen Conference on Natural Working Fluids, Trondheim, in 2006, and at subsequent conferences.

2. The Development of Low Energy Integrated Commercial Refrigeration

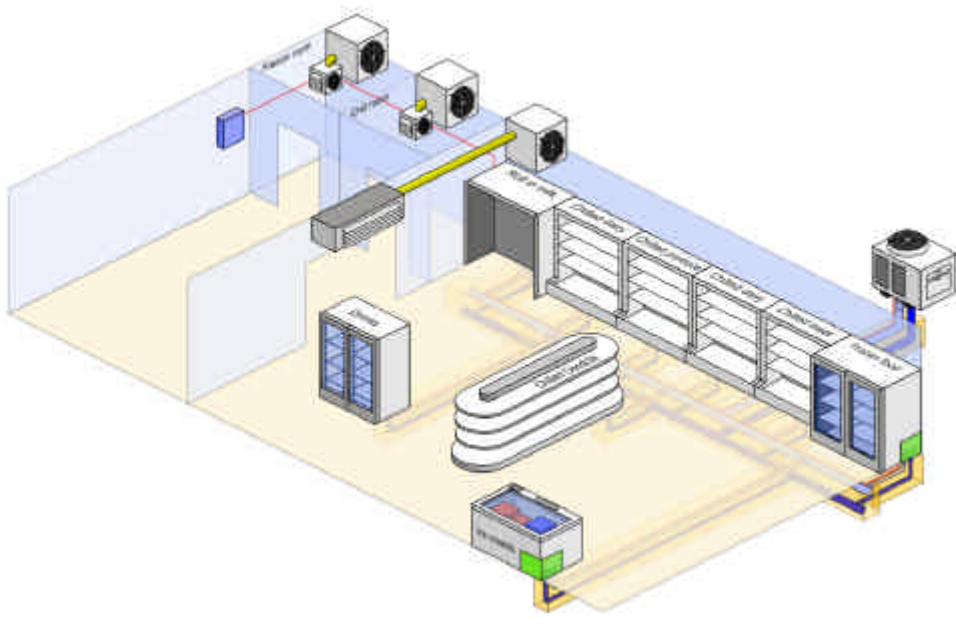
As a result of this project we were able to develop an energy efficient and environmentally friendly innovative design that will not only meet a store's refrigeration and air conditioning requirements, it will do so with efficiency savings unobtainable from either conventional direct expansion (DX) or secondary technologies.

The system runs on natural refrigerants, eliminating the need for ozone depleting or global warming synthetic refrigerants. The heat from the refrigeration equipment can be recovered to provide all the store's hot water requirements.

Energy savings are conservatively estimated to achieve reductions in electricity consumption of 22% and reductions in Total Equivalent Warming Impact (TEWI) of 36% compared to conventional DX systems.¹ Examples of all items of equipment that would be required for a supermarket installation have been tested and the system has been analysed, refined and optimised. The results are entirely consistent with the computer modelling carried out in earlier studies. Based on these initial results, Earthcare believes that commercialisation can commence, and Waitrose in the UK have since adopted a similar design concept.

By re-thinking the whole process of cooling provision – from the mechanics of supermarket refrigeration to the creation of "power by the hour" cooling energy contracts – Earthcare wanted to bring about a step-change in the value supermarkets get from their cooling systems. The design delivers increased convenience, reduced costs and improved environmental performance to supermarkets.

¹ Annex 22 - Compression Systems with Natural Working Fluids - Final Report & Guidelines for Design and Operation.



3. The Concept

We met the objective of an energy efficient and environmentally friendly supermarket, 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 circuit. The design not only meets the store's refrigeration and air conditioning requirements, it does so with efficiency savings unobtainable from either conventional direct expansion (DX) or secondary technologies. Energy savings are conservatively estimated to be at least 22% better than the best available alternative technology and 50% better than standard practices.

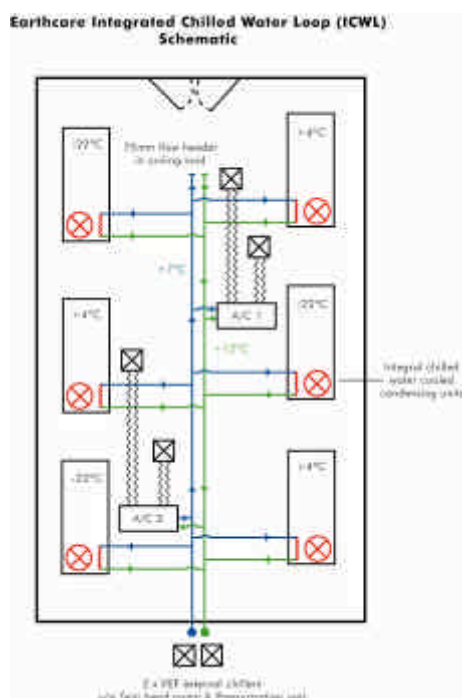
The system runs on natural refrigerants, eliminating the need for synthetic refrigerants. Refrigerant charges are minimized to less than 1500g per circuit in indoor units and to less than 25kg per circuit in each outdoor unit. The use of water-cooled refrigeration allows refrigeration equipment to be integrated within the display cases in a self-contained configuration, thus greatly reducing refrigerant charge and leakage potential. The heat from the refrigeration equipment is dispersed outside the building through the circulating chilled water. Noise levels internally are reduced to those of a remote refrigerator.

At every stage in the design process, Earthcare has sought to produce a simple solution to a complex challenge. For instance, as we utilize a single flow and return circuit, as opposed to the triple circuit high medium and low circuits required for secondary systems, labour and pipework costs are kept to a minimum. Prefabricated plastic pipework is used throughout and there is no need for specialist low temperature fittings or high specification insulation. The condensing units have only the minimum of electrical requirements. There is no need for expensive and corrosive secondary fluids. Multiple chiller units are connected in parallel so the system will continue to operate at full efficiency in the event of one chiller failing.



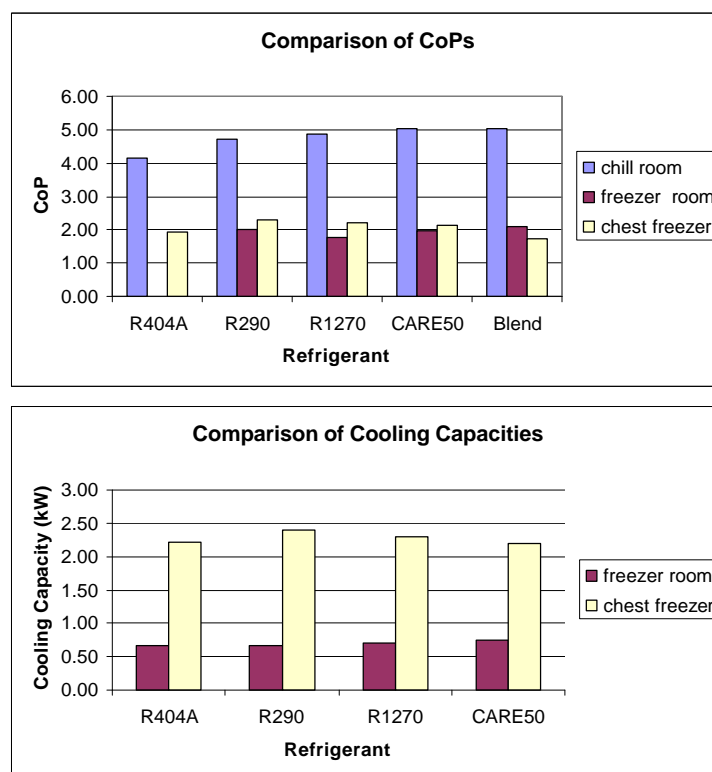
4. The Integrated Chiller Water Loop

The Integrated Chiller Water Loop (ICWL) consists of a water chiller, a chilled water circuit; water cooled condensing units and an air handling unit. The ICWL is effectively a cascade refrigeration system consisting of a water chiller and a chilled water loop which cools low temperature and high temperature condensing units which in turn provide the store refrigeration. Hot water can be generated by the use of a de-superheater or heat recovery condenser on the chiller. Simply put, the ICWL has a number of advantages that raise it above conventional systems: it enables one refrigerant to be used throughout; it optimises energy efficiency; it reduces noise to a minimum; it offers an extraordinarily robust integrated system; it minimises maintenance and installation costs. A principle feature of the system is the use of computer designed and prefabricated plastic pipework systems, assembled off-site in factory controlled conditions. Such is the flexibility of this system that the launch of the ICWL has allowed *Earthcare* to start to re-think many of the most basic functions of traditional refrigeration services.



5. Refrigerant Comparison

As part of the overall project, Earthcare quantified the efficiency advantage of natural refrigerants over synthetic refrigerants in commercial refrigeration. Five refrigerants were compared, the first being the synthetic HFC refrigerant, R-404a. The rest were natural hydrocarbon refrigerants. The best performance was obtained from a previously untested propane and propylene hydrocarbon blend now designated as R-433. This performed, in one case, 20.5% better than R-404a. If repeating the tests now, the preferred refrigerant would be ECP410A, a hydrocarbon blend which gives similar performance to R-410A. ECP410A is a patented Earthcare product. (See Cooling India Aug 2011 article "New High Pressure Low GWP Refrigerant Blends").



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. However, safety regulations restrict the use of hydrocarbon refrigerants in supermarkets leading to a preference for carbon dioxide, also called R-744. But R-744 systems are more expensive and there are efficiency issues at higher ambient which are still being addressed. Alternatively, ECP744 is a near azeotrope which shows promising improvements in system efficiency compared to pure R-744, whilst also operating at significantly lower pressures. It is considered to be particularly applicable to supermarket refrigeration equipment. The improvement in efficiency is a significant benefit, but the main commercial benefit arises from the reduced pressure (compared to R-744), allowing a larger number of standard refrigeration components to be used, and the use of silver soldered joints. Since a major problem for R-744 refrigeration systems is the high pressure, realistically all joints should be TIG welded stainless steel, but few refrigeration technicians have the necessary skills and specialist welding services are not commercially viable. Consequently, most R-744 installations (in the UK) have used compression fittings or silver soldered joints which leak at more than 25% per annum. The use of this lower pressure blended refrigerant will overcome this problem. ECP744 is a patented Earthcare product. (See Cooling India Aug 2011 article "New High Pressure Low GWP Refrigerant Blends").

6. Chilled Water-Cooled Refrigeration Cabinets

Earthcare has worked with refrigeration cabinet manufacturers to develop a range of HFC free integral cabinets, quiet, with no heat of rejection into the store, and low power consumption, complying with EN378, i.e. less than 1.5KG of hydrocarbon refrigerant per refrigeration circuit.

It would be possible to deliver these cabinets pre-chilled and per-merchandised. We can deliver two full size cabinets with a 20 kW heat of rejection, pre-chilled on a 13 tonne flat bed truck, capable of transporting 2 x 6 meter supermarket cabinets side by side, with an under-slung refrigeration unit producing chilled water from R-1270 refrigerant, powered from a 24 KVA alternator.

To facilitate servicing where change out is not practical or desirable, we will adopt the refrigeration cassette concept (i.e. refrigeration plug) whereby the refrigeration unit can be unbolted from the top of the cabinet and changed for a service replacement without touching the refrigeration circuit on site.

The whole system has been designed around R-290 Hitachi horizontal scroll compressors. Not only is the configuration ideal for cabinet design, but the operating range permits condensing temperatures down to 5c, thus maximising the benefits of the ICWL concept.



7. Air Cooled Water Chillers

In 2001, Earthcare Products developed a range of air cooled water chillers for use with the hydrocarbon refrigerant R-290, which is a replacement for R-22 with an extremely low global warming potential. These are the first air-cooled chillers operating on hydrocarbon refrigerants to deliver very large cooling outputs; the largest model in the range offers 1,265 kW. Hydrocarbon refrigerant chillers have been available on the UK market since 1995, but their capacities were previously limited to around 200 kW. Manufactured to our exacting specifications, this range consists of some of the most efficient, quiet and reliable chillers on the market today. Used on sites across the UK, these chillers have a proven record of accomplishment for solid performance and low running costs. They have the added advantage of offering unparalleled environmental performance in their sector.

Earthcare believes that there will be increased demand for this type of solution because, until now, specifiers and users of screw compressor chillers have been restricted to choosing between expensive ammonia chillers or HFC chillers. Ammonia chillers suffer from disproportionately higher capital costs because ammonia is not compatible with copper, so "industrial grade" steel components have to be used. Typically ammonia chillers cost two to three times more than HFC chillers. With mass production, HC chillers could be produced for a premium of less than 10% over HFC chillers.



Indirect global warming impact is reduced by maximising energy efficiency through a combination of factors including the favourable thermodynamic characteristics of HCs, the use of subcooling circuits, which improve coefficient of performance (COP) and floating head pressure control that allows the condensing temperature to float as low as 20°C if ambient conditions allow, instead of the normal 40°C. This is particularly beneficial for chillers that operate year round or at night when ambient temperatures are lower. The combined effect of all energy efficiency measures results in a potential energy savings in excess of 50% for chillers that operate year round when compared to minimum first cost chillers without energy saving features.

The larger screw compressor models use specially selected polyglycol oils, which are resistant to dilution by hydrocarbons. Tests have indicated up to an 18% improvement in volumetric efficiency over conventional refrigerant and oil combinations. Earthcare predicts further improvements through development of its vapour injection economised screw initiative.

The use of natural refrigerants minimises direct global warming and we have taken steps to minimise indirect global warming by maximising energy efficiency. All units are available as reverse cycle heat pumps, details upon request. The larger screw compressor models use specially selected polyglycol oils, which are resistant to dilution by hydrocarbons. Tests have indicated up to an eighteen percent improvement in volumetric efficiency over conventional refrigerant and oil combinations. We predict further improvements when we finish development of our vapour injection economised screw initiative.

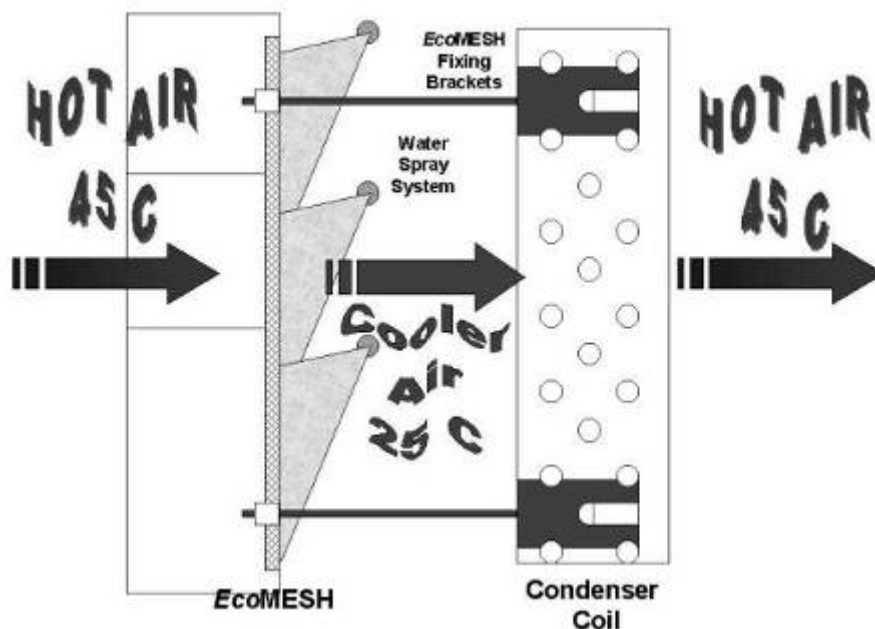
The combined effect of the energy efficiency measures result in a potential energy saving in excess of 50% for chillers that operate year round when compared to minimum first cost chillers without energy saving features. For high ambient applications including the Indian market, Earthcare will recommend R-600a refrigerant or subject to further development work, R-600 or ECP600, an optimised blend with normal boiling point around zero centigrade and very high critical temperature (See Cooling India Mar April 2011 article "Alternative Refrigerants for High Ambient Temperature Conditions").



Earthcare believes that even more is possible. Our ambition is simple: to deliver increased convenience, reduced costs and improved environmental performance to every supermarket. We wholeheartedly endorse the Better; Simpler; Cheaper philosophy, but feel that minimum life cycle costs will be obtained by adding one or several of the following optional enhancements. However, we condone them with the very strong caveat that they should only be used to reduce costs and not to showcase “clever” design, which in itself achieves nothing.

8. Floating head pressure control in conjunction with adiabatic panels

This allows the condensing temperature to float as low as 25° C if ambient conditions allow, instead of the high ambient design 45° C. This is particularly beneficial for chillers that operate year-round, or at night when ambient temperatures are lower. In order to maximise this effect we propose to fit a water spray to the condensers to bring the condensing temperature down under high ambient conditions. Using the adiabatic panel concept we can reduce the air on temperature to the wet bulb condition, giving up to a 30% increase in efficiency.

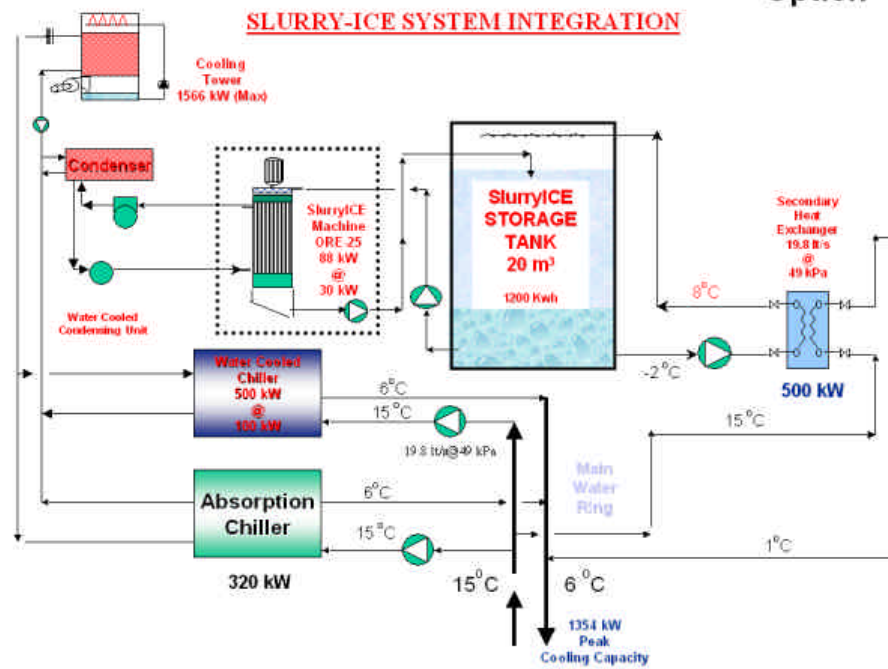


It is estimated that this additional adiabatic ambient cooling before the condenser coil should provide an increased capacity of 14 ~ 15% in comparison with the original chiller design. This corresponds to ~26 % energy efficiency improvement.

9. Buffer Tank Thermal Storage

Incorporating a buffer tank will improve efficiency, not only by reducing chiller cycling, but by allowing more of the heat of rejection to occur at night when the ambient temperature is lower. Moreover, thermal storage will allow the use of solar powered absorption chillers to provide the bulk of the cooling load. Thermal storage capacity can be enhanced by utilising pumpable slurry ice, or preferably, eutectic mixtures selected for phase change at the designed water loop temperature.

Option - 1



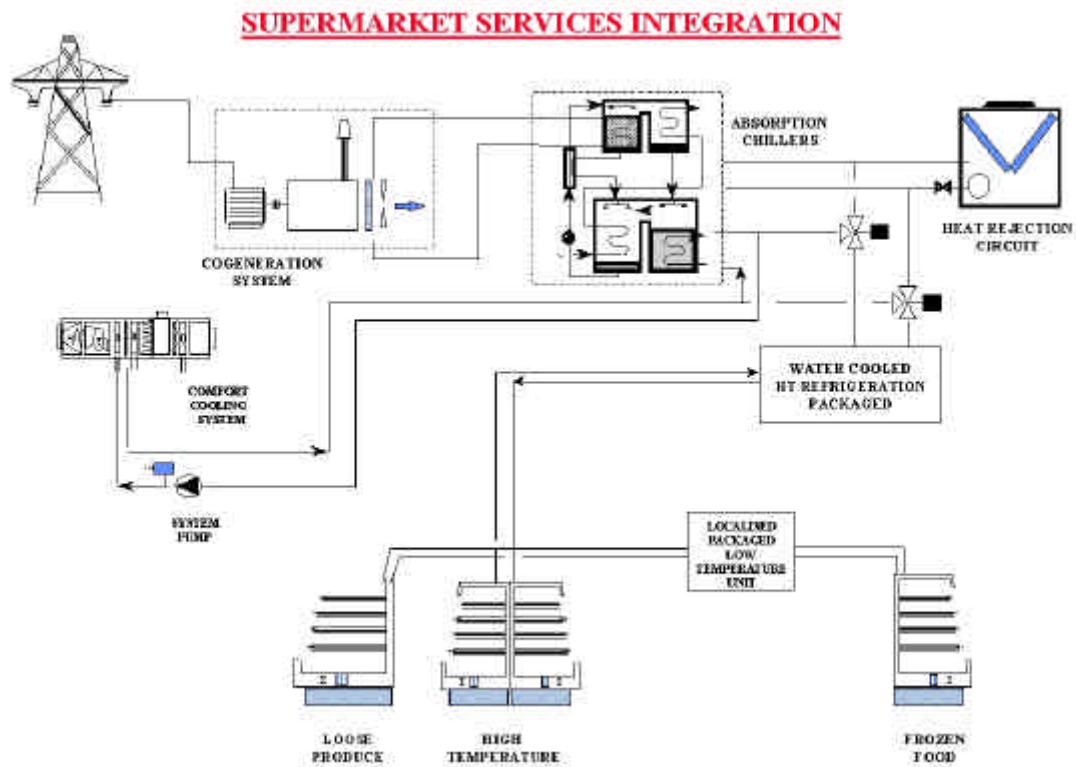
10. ICWL Integrated into CHP with Absorption

The ICWL concept is ideal for use with solar powered absorption chillers:



11. ICWL Integrated into CHP with Absorption

The ICWL concept can be applied equally well to absorption chillers used in conjunction with on site combined heat and power:



12. Conclusions

To conclude, it would be fair to say that the changes in refrigeration technology, spurred on by legislation and environmental concern, give supermarkets an unrivalled opportunity to adopt energy efficient equipment utilising natural refrigerants. Earthcare Products was founded in 1997 and has never used HFCs with a GWP higher than 50. Our continued existence and commercial success is proof that the refrigeration industry does not need high GWP gases. Although not yet a global player, Earthcare will continue to work towards this end, tackling multi-national corporations head-on when necessary. Earthcare believes that with vision, action and commitment the campaign for a sustainable refrigeration industry is winnable and to this end we are actively seeking partners and funding for a practical demonstration project to showcase the best way to provide supermarket refrigeration in high ambient climates as described in this article.

Table 1 – The Refrigerants mentioned in this article

Refrigerant number	Refrigerant Name	ODP	GWP	Critical Temperature, °C	Normal Boiling Point, °C
R-12	Dichlorodifluoromethane	1	10,900	112.0	-29.8
	Blend of chlorodifluoromethane and chloropentafluoroethane	0.221	6,200		-45.3
R-502				80.7	
	Blend of pentafluoroethane, 1,1,1,2-tetrafluoroethane and 1,1,1-trifluoroethane	0	3,922		-46.2
R-404a				72.4	
R-134a	1,1,1,2-tetrafluoroethane	0	1,430	101.1	-26.3
R-433	Blend of propane and propene	0	3	93.2	-45.5
ECP410A	Blend of propene and fluoroethane	0	6	95.5	-49.2
R-410A	Blend of pentafluoroethane and difluoromethane	0	2,090	72.8	-48.5
R-744	Carbon dioxide	0	1	31.1	-78.4
ECP744	Blend of carbon dioxide and fluoromethane	0	46	37.9	-84.5
R-1270	Propene	0	2	91.0	-47.8
R-290	Propane	0	3	96.6	-42.1
R-22	Chlorodifluoromethane	0.055	1,810	96.2	-40.8
R-600a	Isobutane (methylpropane)	0	3	134.7	-11.7
R-600	Butane (n-butane)	0	3	152.1	-0.5
ECP600	Blend of hydrocarbons	0	3	174.6	+2.8

NICHOLAS COX F.INST.S.M.M.GCGI M.INST.R



Nicholas Cox, the Managing Director of Earthcare Products Limited, is considered a leading authority on environmentally friendly refrigeration and air conditioning. During a long career in this field, he has presented many papers on the subject. A fellow of the Institute of Sales and Marketing Management, he was awarded a graduateship of the City and Guilds of London Institute for his work on how industry could better utilise natural refrigerants and energy efficiency. He has advised both the UK government and the EU commission on environmental aspects of refrigeration and air conditioning, and he has carried out reviews and submitted written responses to proposed and pending policy documents and legislation regarding refrigerant issues.

He is at the forefront of industry developments:

In 1986, he designed, installed and commissioned a water source heat pump cooling system for the London Docklands Development Corporation.

In 1989, he developed a heat recovery refrigeration unit for cooling beer cellars.

In 1994, he was the first person in the UK to use propane as an alternative refrigerant for air conditioning systems.

In 1996, he developed and launched a new range of Very Environmentally Friendly (VEF) Chillers

In 1997, he developed the first hot & cold drinking water dispenser to use hydrocarbon refrigerants.

In 1998, using grant funding from the DETR 'Partners in Technology Scheme' he developed and launched a new range of Very Environmentally Friendly heat pump and air conditioning split systems.

In 1999, he designed, installed and commissioned the largest air conditioning thermal storage system in the UK, using ammonia and aqueous urea slurry-ice.

In 2005, he completed development of an integrated low energy refrigeration, air conditioning, and heat recovery system for supermarkets.

In 2008, he developed and patented a range of high pressure blended natural refrigerants.

Earthcare Products

Earthcare is dedicated to providing complete climate solutions to its clients. From equipment supply and consultancy through to installation and maintenance, we serve our clients from the beginning of a project to its realisation and beyond. We are the world leaders in the provision of green refrigeration and air conditioning. Our clients are drawn from both public and private spheres and include:



Heathrow Terminal 5
Horsham Arts Centre
Forensic Science Service
Transport For London
DVLA
Middlesex University
Brighton Library
DEFRA
Roche
DFT
National Trust
DEFRA
Church Of England
GSK
Local Authorities from Derby to the New Forest
Many hospital trusts including Great Ormond Street

Our history

Founded in 1997, Earthcare Products Limited is a fast growing company providing consultancy, selling, installing and servicing commercial cooling products to businesses and the public sector. The company enjoys unparalleled experience and intellectual property (IP) in its areas of operation and expertise including the practical application of natural refrigerants and is working with refrigeration and air conditioning manufacturers to commercialise the resultant opportunities.

Earthcare provides end-users with a full complement of sustainable cooling products, from small refrigerators to large custom-built building services plant. Earthcare has achieved considerable success in bringing these products to market and has now sold them into a wide range of public and private bodies, servicing the smallest to the largest possible applications. Earthcare offers a complete range of products to provide green end-users with a “one stop shop”. Earthcare’s principal sales are achieved in large commercial air conditioning chillers and small commercial air conditioning split systems.

Earthcare has championed the cause of NIK cooling in the United Kingdom and, in the case of hydrocarbon refrigeration, has created a market which it now dominates.

Our future

Earthcare's work is not completed yet, as global CO₂ emissions are spiralling out of control and there is an urgent need to start replacing fossil fuel boilers with heat pumps. Moreover, anyone who thought that the F Gas Regulations have neutralised the HFC problem needs to think again. The formidable F Gas lobby continues to exert its malevolent influence and halocarbon emissions still account for some 13% of man made global warming. To counteract this Earthcare is campaigning for:

- The EU to provide funding for the research and promotion of F gas alternatives as committed by the EU environment directorate climate change program priority measures for F gas abatement, but never implemented.
- The EU to implement the F gas regulation commitment on the promotion of alternatives
- The EU to ensure that the F gas review considers natural refrigerants not just leakage reduction.
- The EU to recommend natural refrigerants within the eco-design directive.
- The EU to investigate how trade standards hinder the adoption of natural refrigerants.
- UNEP to stop subsidising the manufacture of ozone depleting refrigerants and to start providing carbon credits for the conversion of equipment manufacturing factories from ozone depleting refrigerants to natural refrigerants.

The changes in refrigeration technology – spurred on by legislation and environmental concern – give users an unrivalled opportunity to adopt energy efficient equipment utilising natural refrigerants. Current and proposed legislation will make it even more important to meet environmental best practice requirements. Earthcare is not yet a global player but will continue to tackle corporations head-on when they disagree with them. They believe that with vision, action and commitment the campaign for a sustainable future for our industry is winnable and that they will be on the winning side.



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