The Use of Natural Refrigerants in Large AC Chillers

Earthcare Products Limited

Abstract

Large air-conditioning chillers have traditionally used HCFC-22 as the refrigerant. To address stratospheric ozone depletion, most manufacturers have adopted either R-407C (an HFC blend) or HFC-134a. However, both are potent greenhouse gases, restricted under the Kyoto Protocol. In response, Earthcare has adopted hydrocarbon refrigerants that are both ozone friendly and have a low global warming potential. The technical challenge has been to achieve compliance with the safety regulations governing the use of flammable refrigerants.

Background

The use of CFCs and HCFCs was effectively put to an end by the signing of the Montreal Protocol in 1987 and subsequent amendments in the 1990s. 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 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.
- HFC emissions will not be allowed to rise unchecked.

The EU has also 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 (HC). 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."

Development of Alternative

In response to these directives and regulations, in 2001, Earthcare Products developed a full range of HC air cooled chillers. Used on sites across the UK, these chillers have demonstrated solid performance and low running costs, and also run quietly. They have the added advantage of offering excellent environmental performance in their sector. These are the first air-cooled chillers operating on natural HC refrigerants to deliver very large cooling outputs; the largest model in the range offers 1,265 kW. HC chillers have been available on the UK market since 1995, but their capacities were previously limited to around 200 kW. Over the last three years, Earthcare has been developing larger sizes to extend the application of hydrocarbon environmentally benign refrigerants.

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.[1]

Very briefly, the safety principals relating to the use of hydrocarbon refrigerants in external air cooled water chillers are:

- Electrics should be sealed (to IP54 or better) or non-sparking (i.e., solid state)
- Access to the equipment must be restricted to authorised personnel only
- Steps must be taken to ensure that refrigerant cannot leak into the building

Bringing the Alternative to Market

The original Church House in Westminster Abbey, close to the Houses of Parliament was built to commemorate Queen Victoria's golden jubilee and the current building was opened by King George VI in 1940. It hosted the first meetings of the fledgling United Nations in 1945 and was also requisitioned by Winston Churchill as a temporary home for Parliament during the war because it emerged almost unscathed from a direct bomb strike only a few months after it was opened. In 2007, a 600kW air-cooled water chiller using the HC refrigerant R290 was supplied by Earthcare at the historic Church House building for comfort air conditioning.

The chiller was specified by Max Fordham consulting engineers and the installation, carried out by AMEC, involved closing two roads close to Westminster Abbey on a Saturday morning, diverting two bus routes and organising 12 vehicles to get the crane into position for siting the chiller. However, it is estimated that the long-term pay back, both financially to Church House and in reduced environmental impact, will more than offset all the capital, installation and disruption costs.

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

The project life cycle cost analysis is summarized in the table below:

Table 1: EHS Life-cycle Analysis

	Earthcare EHS2140	HFC134a Chiller
Cooling Output kW	625	625
COP	4.15	2.82
Power Input kW	150.6	221.6
Run Hours	3,000	3,000
Load Factor %	50	50
Annual Energy Consumption kWh	225,900	332,400
Cost of Energy £/KWh	0.063	0.063
Annual Running Cost £	14,231	20,941
Capital Cost £	69,830	60,000
10 year Running Cost £	142,310	209,410
10 year life cycle cost £	212,420	269,410
10 year saving £	56,990	
Percentage saving %	21.2	

The successful installation of the large HC refrigerant chiller at the historic Church House represents a milestone in the history of the air conditioning industry. This chiller achieves a minimized environmental impact through the combination of natural refrigerants and optimal energy efficiency, as discussed at more length in the section below. 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.

With governments and large corporations increasingly looking for cost-effective alternatives to HFCs, the installation of the HC refrigerant chiller at the Church House building serves as a practical demonstration of the cost-effective and practical solutions that natural refrigerants can offer across the whole range of building services applications.

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.[2]

[2] 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

A reduced environmental impact has been achieved through natural refrigerants and optimal energy efficiency. The Earthcare Hydrocarbon Series (EHS) range was designed within the constraints of the EU's Best Available Technology (BAT) protocol and uses the HC refrigerant R-290, which is a replacement for R-22 with an extremely low global warming potential.

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.

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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. "Our business is dedicated to bringing tomorrow's solutions to the market today. Our products minimise life-cycle costs in the most environmentally friendly manner possible", says Nicholas Cox, Managing Director of the company.