The Use of Natural Refrigerants in Small Air Conditioners & Heat Pump Split Systems

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Abstract

Small air conditioning and heat pump split systems have traditionally used the refrigerant HCFC-22. In addressing the ozone depletion problem, most manufacturers have adopted either R-407C (an HFC blend), or more recently R-410A (also an HFC blend). However, both are potent greenhouse gases, restricted under the Kyoto Protocol. Thus, in solving the ozone depletion problem, many split systems contribute to climate change. In response, Earthcare has adopted the use of 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 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

Earthcare sought to investigate improvements to the energy efficiency of small split air conditioning systems. The exercise formed part of a wider ranging project—funded in part by the UK Department of the Environment, Transport and the Regions under the "Partners in Technology" scheme—to look at energy saving opportunities at the time of refrigerant replacement.

The project was successful, and the recommendations of the joint working party were partially incorporated into a range of Very Environmentally Friendly (VEF) split systems in 1998. These systems minimise environmental impact by combining natural refrigerants with optimised energy efficient technologies. Earthcare's approach enabled both the direct and indirect aspects of global warming

impact to be addressed. All of the units have been re-engineered to optimise their performance with HC refrigerants—thereby eliminating the HFC and HCFC alternatives, which are potent greenhouse gases—whilst the use of motor voltage controllers brought indirect emissions down with reduced energy consumption. The result is an impressive efficiency gain of 20% over the original HCFC-22 systems.

The safe application of hydrocarbon refrigerants has been achieved by compliance with 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 small air conditioning heat pumps 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
- Refrigerant charge sizes are restricted to 1,500 grams
- Although the ACRIB guidelines for flammable refrigerants remains the best working document for the safe use of flammable refrigerants, EN378 has now been updated and the 2007 version contains some useful advise, particularly on leakage tests

Bringing the Alternative to Market

The range of VEF split systems was launched at the I. K. K. Exhibition in Nuremberg in 1998, and have been sold on the UK market ever since. Earthcare Products was invited to devise cooling solutions for a number of hospitals and universities using refrigerants that have no ozone depletion potential and minimal global warming potential (GWP). Earthcare's approach combined good energy efficiency with a minimal use of HC refrigerant in the following projects:

- South Downs Health Authority – Six split air-conditioning systems, five wall-mounted and one ducted, were required for medical laboratories, scanning rooms, computer rooms and mental health isolation areas.
- Medway Health Authority – Five wall mounted units were installed in treatment rooms
- University College, London – One wall mounted unit and two twin condenser ducted units were installed for lecture theatres and computer rooms.
- Pembury Hospital – A fully ducted split system was installed for the new operating theatre.
- Great Ormond Street Children's Hospital – Eight split systems were installed in technical areas.

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-

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

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]

Impacts of Switch to Alternative

Direct global warming impact was minimised in several ways:

- The amount of refrigerant held within the units was minimised.
- Traditional flared copper joints, which are responsible for a high percentage of refrigerant leaks, were removed from the systems and replaced with brazed joints. Copper capillary lines (small pipes for instrumentation and sensors that are particularly prone to cracking) were also eliminated and replaced with braided hoses.
- The system was charged with the HC refrigerant R290, which has a GWP of 3,[3] a small fraction of the GWP of the competing HFCs.

Indirect global warming was also minimised by maximising energy efficiency:

- The thermodynamic properties of HC refrigerants are well suited to this type of application, competing favourably on efficiency with all other alternatives.
- The refrigerant charge was optimised in laboratory trials, and the installation process achieves precise repetition of optimum charge for each unit.
- The indoor unit (evaporator) was optimised using larger heat exchangers where necessary.
- Floating head pressure control was used. This allows the condensing temperature to float as low as 20°C if ambient conditions allow, instead of being held artificially at around 40°C. This can achieve up to a 30% increase in efficiency compared to fixed head pressure.
- The systems used fully flooded evaporators. This increases the cooling capacity and efficiency.

These were all comparatively small changes which, when combined, made a big difference. In re-designing the split system from bottom up, Earthcare wanted to maximise the advantage that could be gained by matching sensible heat ratio to climate. Most split system manufacturers optimise for comfort conditions based on a worldwide average climate model. On typical sites surveyed by Earthcare, the majority of the cooling requirement is for equipment or process cooling of a sensible nature. However, units are used that are unsuitable to the temperate climate of the UK. As an example, a commonly used 4.9 kW split system has a sensible heat ratio of 0.76, based on UK cooling conditions of 23°C dry-bulb and 16 wet-bulb indoor, 30C dry-bulb outdoor. This heat ratio can be compared to 0.93 for a similar Earthcare model. Therefore, by simple optimisation of the indoor coils to suit the specific climate of operation, it is possible to achieve an average 6% improvement in sensible heat ratio, which in turn becomes a further 6% improvement in energy efficiency.

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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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[2] The CE mark is a mandatory conformity mark on many products placed on the single market in the European Economic Area (EEA).
[3] Climate Change 2007: The Fourth Assessment Report of the IPCC.