Where is the perfect refrigerant?

By Peter Dinnage, Climalife UK Commercial Manager

In an ideal world, there would be only one refrigerant. It would be non-toxic, non-flammable, work across a large range of applications, with excellent energy efficiency, working at manageable pressures and giving the required cooling capacity. It would be cheap, readily available and have no detrimental effect on the environment. Thomas Midgley thought he had found such a refrigerant, but 84 years ago the term carbon footprint would have meant something completely different to him and Ozone Depletion and Global Warming Potential (GWP) were unheard of. We now know he didn't have that elusive refrigerant and whilst we may not live in an ideal world, our health, lifestyle, workplace environment and the food chain have all improved immeasurably thanks to refrigeration and air conditioning in its many guises.

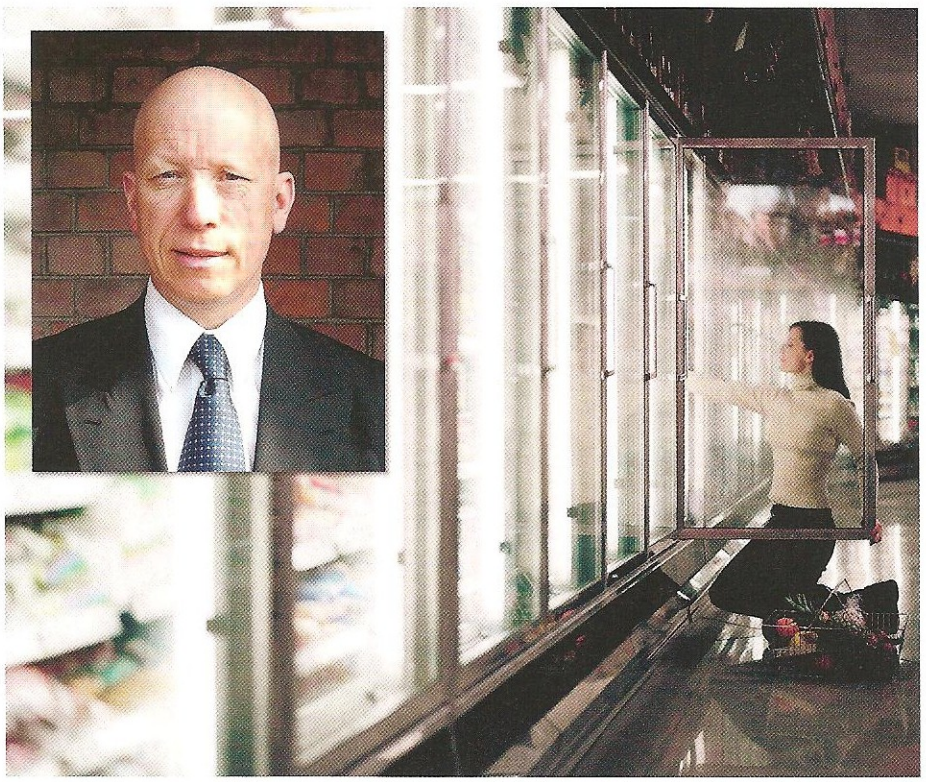
In 2012 we have plenty of refrigerants to choose from and there are more new ones to come, each with properties that make them better suited for certain applications than others.

For politicians and environmentalists, R22 is finished and a ban is in place. For those still with R22 systems, the reality is a little different, relying on reclaimed product availability. We are at half-time in terms of R22 phase-out in Europe. In just over two years its use for servicing will be banned, making conversion or new equipment the only choice. Although R422D (ISCEON MO29) has been used extensively to replace R22, R438A (ISCEON MO99) is also a very versatile and close match for R22 across a wide range of air conditioning and refrigeration applications. Equally it is still unclear how REACH may affect Reclaimed R22 beyond May 2013.

F Gas and climate change

Although any detail on the proposed new F Gas regulations has been delayed until at least the second half of this year, the talk is of improved containment, better enforcement and a phase down of HFCs, with the emphasis on the move to lower GWP refrigerants.

There are signs that both containment and training in the UK are improving, along with a better understanding of the refrigerants in use. The engineer of today may increasingly be required to be conversant with more refrigerants, with many different hazards. Leak prevention is very important irrespective of the refrigerant used as an under charged system can reduce energy efficiency significantly and potential safety issues with leaks, should not be under-estimated. Improved containment improves efficiency and reduces the carbon footprint of any refrigeration system.



Energy efficiency is key and there is growing data being accumulated on improved technology with the different refrigerants and equipment options to allow informed decision.

Whilst the industrial sector has successfully installed ammonia and secondary systems with glycol or similar fluids, some in the commercial sector have chosen the CO_2 route where new challenges are presenting themselves. Once again better training and qualified engineers are required to handle these fluids. Such expertise takes time, needs investment, and doesn't come cheap. Similarly equipment design and ongoing maintenance needs to be much more robust.

New refrigerants

DuPont and Honeywell seem to be leading the way with their Opteon and Solstice, brands and their formulators are working on various blends looking for optimum efficiency and capacity. Others are more secretive about their research.

HFOs such R1234yf and HFO blends, however, are probably 2-3 years away from commercial availability for the non-automotive sector, although R1234ze is available now and the results from one chiller installation look very promising in terms of energy efficiency.

A new ASHRAE classification of A2L has been brought in to designate mildly flammable refrigerants such as R1234yf, R1234ze, R32 and some blends. These would need to be handled slightly differently from A1 refrigerants, but not in the same way as A3 refrigerants such as R290 and R600a. It is hoped that some industry guidelines will be available shortly to help with training.

Options for 2012

In the meantime there are some easy options to move to lower GWP refrigerants now.

R404A is one of the most commonly used refrigerants in Europe, yet it has a high GWP (3922). Products such as Performax LT (R407F) not only have much lower GWP (1824), but also offer worthwhile energy savings making it of interest for new and existing equipment instead of R404A.

The use of R134a in new medium and high temperature applications has potential, as the GWP of 134a (1430) is lower than other HFCs and in a few years' time, the equipment could be converted to a low GWP HFO or HFO Blend.

Some of the other HFO blends under development could be used in existing equipment and converting to a low GWP refrigerant should be possible for some equipment.

With a plethora of refrigerants and legislation to circumnavigate, good advice and experience have never been so important to help choose the most suitable refrigerant for your application.

Refrigerants at the ACR Show

Literally the life blood of all mechanical air conditioning and refrigeration systems, refrigerants were promoted from a number of stands at the ACR Show and were the focus for several technology seminars.

Low GWP refrigerants – today and tomorrow

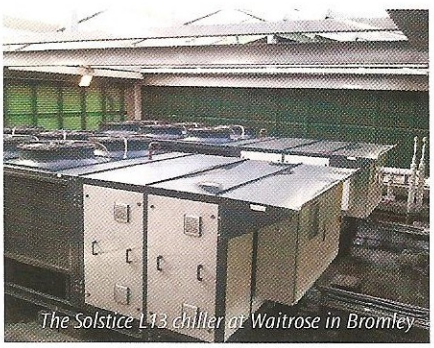
With the conclusions coming soon from the review of the F Gas Regulation, all UK supermarkets are continuing to look for low GWP refrigerants to replace R134a and its blends. A well-publicised field trial undertaken at ASDA's Hunt Cross store compared Honeywell's Genetron Performax LT refrigerant with popular refrigerants R404A and R407A. The trial concluded that Genetron Performax LT delivered up to 15% savings in energy bills, up to 40% reduction in system CO_2 emissions and up to 10% improvement in system running costs.

Nacer Achaichia, Technical Manager at Honeywell Fluorine Products stressed the importance of delivering a low GWP refrigerants within a range of hfc products. "Industry should be free to choose the best refrigerant for each application," he said. "There is no such thing as a natural refrigerant, all refrigerants are man-made. What is important is its impact on the environment, which means GWP and energy efficiency."

Reducing GWP even further are the so-called 4th generation, HFO-based refrigerants. These were designed primarily to find a substitute for R134a in the automotive industry, with HFO 1234yf likely to be widely used. However, HFO 1234ze – marketed by Honeywell as Soltice L13 – is soon to be produced in commercial quantities and has already been used very successfully in a chiller on field trial at a Waitrose store in London.

"HFO 1234ze is available today," confirmed Nacer Achaichia. "But capacity is being increased to make commercial quantities available from 2013 onwards."

Editor's opinion *Genetron Performax LT is obviously a great alternative to higher GWP refrigerants but I believe the demand for HFO's and HFO blends could grow significantly. Those production facilities need to come on line soon otherwise customers may be disappointed.*



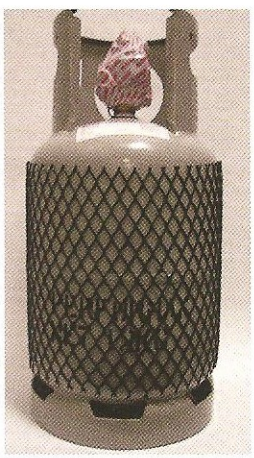
The Solstice L13 chiller at Waitrose in Bromley

A-Gas promotes low GWP refrigerants

A-Gas is a preferred supplier of Honeywell's Genetron Performax LT refrigerant. This is part of A-Gas's extensive portfolio which also includes a CO_2 filling station and dedicated cylinder fleet, along with hydrocarbon (HC) refrigerants.

In addition, A-Gas' unique refrigerant separation technology enables the re-processing of much larger quantities of used refrigerants and boosts supplies of reclaimed refrigerants. This technology allows A-Gas to reclaim gases even from a cocktail of returned refrigerants.

Editor's opinion *The ability to separate and re-use mixed up hfc blends is a great trick and should be used much more rather than to incinerate reclaimed gases.*



Leak detection from TQ

TQ Environmental plc is based in Wakefield, West Yorkshire, and manufactures a wide range of single and multi-point leak detection systems.

Top of the range, the TQ4300 Refrigerant System is a compact, low cost solution to multipoint, multi gas leak detection, specifically designed for dual gas applications. With proven reliability and minimal maintenance, the TQ4300 is designed for both industrial and commercial use. It is suitable for all refrigerant monitoring, carbon dioxide, hfc's or both. Ammonia detection is also available.

Editor's opinion *Manual and automatic leak detection are still mandated within the F Gas Regulation. The onus is on the end-user to ensure systems do not leak.*

IDS Refrigeration now trading as Climalife

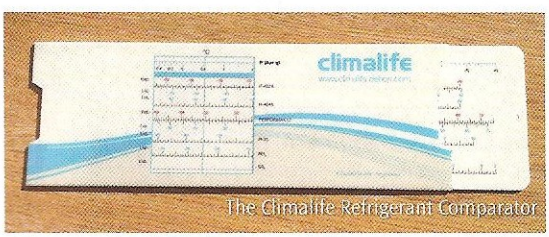
As of 1st January 2012, IDS Refrigeration has changed its logo to Climalife. IDS Refrigeration has remained as the legal entity but as part of the Dehon group strategy, all Climalife subsidiaries throughout the world will promote their products and services under the trademark of Climalife.

Allan Harper, Managing Director of Climalife UK said: "Whilst we will still offer the same quality service, a common visual identity, product specification sheets and labelling will be of benefit to our customers as well as access to the latest technical information and legislation updates."

As well as stocking the Honeywell's Genetron Performax LT refrigerant, Climalife UK stocks the Isceon direct replacement range of refrigerants from DuPont.

At the show, Climalife launched the new Climalife Refrigerant Comparator, suitable for all of the most commonly used refrigerants currently available. This pressure/temperature relationship comparator enables temperatures to be checked at saturation, including liquid and vapour states for non-azeotropic fluids and in relation to the pressure taken in an installation.

Editor's opinion *There are plenty of well documented case studies to show that an Isceon direct replacement for R22 is much cheaper and easier to carry out than a full system replacement.*



The Climalife Refrigerant Comparator

ACRIB NEWS UPDATE

The race is on...

Up to fifteen young hopefuls will be competing for the SkillFRIDGE crown in semi-finals taking place at Bridgwater College, Somerset on the 16th May and Gateshead College, Tyne and Wear on the 30th May. This elimination round will involve a range of exercises to test their electrical knowledge and practical skills based upon a refrigeration circuit installation and use,

SummitSkills is committed to delivering a competition this year which will raise the profile of refrigeration skills and qualifications as part of a suite of building services engineering competitions covering electrical, pipework, plumbing and RAC. All of the competitors will gain recognition for their skills, injecting dynamism and excitement into their training. The events are also designed to boost the reputation of employers committed to training their technicians and colleges who are offering outstanding service to their students.

More sponsorship needed

ACRIB supports these important events as a sponsor, as do ACRIB members BRA, IOR and B&ES. But there is always more help needed and any companies who want to raise their profile in the training world should contact Michael Reeves at SummitSkills for more information about cash and in-kind sponsorship packages.

Visitors from industry and local schools or colleges are encouraged to attend and support the competition days and there is space for exhibiting as well. Each is a full day with competition activity starting at 10am and concluding with an award presentation to the winners around 6.30pm. If you want to find out more about how these competition days work and hear from past competitors and winners see the showreel on the website http://www.skillmande.org.uk/skillfridge

Good luck to all of the young engineers preparing for the forthcoming SKILLFridge semi-finals.

WorldSkills UK

There is also exciting news about a new venue for the national skills competition finals as well. Following on from the success of last year's Word Skills event in London which attracted high profile visitors, international media coverage and many thousands of young visitors, the UK will be hosting a WordSkills UK Show at the NEC in Birmingham on 15-17 November 2012. The show is expected to showcase around 45 different skills competitions, with over 500 competitors participating. The show is part of a national commitment to encourage vocational training and apprenticeship take up. More information can be found at http://worldskillsuk.apprenticeships.org.uk/the-skills-show

There will be even more opportunities to promote RAC careers at this show through exhibition space, hands on have-a-go activities, or sponsorship.

INDUSTRY ISSUES

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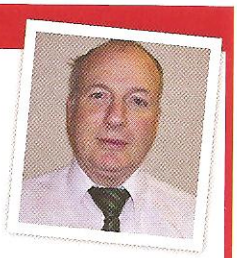
AIR CONDITIONING SYSTEMS



What could possibly replace R410A, asks Jim Rusling, Training Manager for Mitsubishi Electric.

Alternative refrigerants for room air conditioning

From certain sectors there has been pressure to convert to using low GWP (Global Warming Potential) refrigerants such as ammonia, HCs and carbon dioxide. Several of the voices appear to hold vested interests in alternative refrigerants so a profit motive as well as genuine environmental concerns may be at work. Another important sector pushing for the removal of HFC refrigerants is supermarkets. They have historically been very bad at containing their refrigerants so a move to lower GWP refrigerants might seem a logical step.

Whatever refrigerant is used, it will not work efficiently if the plant in which it runs is not leak tight, so even an "environmentally benign" refrigerant could be consuming more power and therefore generating more CO_2 at power stations. The generally accepted figure for the ratio of direct (global warming due to leakage) to indirect (global warming due to power consumption) is 15% to 85%. This means that plant efficiency is a very important factor in assessing environmental impact and that GWP becomes less important and ultimately irrelevant as leakage rates are reduced.

So what about alternative refrigerants for room air conditioning?

Ammonia is probably a non-starter because of toxicity and material compatibility problems.

HCs can be used and can deliver good efficiencies, but if there is a leak or a fire flammability can be an issue.

CO_2 is interesting. I am not expert in CO_2 applications and would appreciate comments (via the editor) from any one with CO_2 experience. I see advantages in terms of its low GWP, non-flammability and low toxicity. However, it works at higher pressures with higher leakage rates, requiring thicker walled pipe with associated cost implications. It offers lower COP's and is an asphyxiant. Additional engineering training is vital.

Ammonia, HCs and CO_2 will have applications for which they will be very suitable. However, room air conditioning is different to much of the R&AC sector. Leakage rates are at the lower end of the scale (still always room for improvement) so efficiency is increasingly more important than the GWP of the refrigerant in use.

If I look in my crystal ball at room air conditioning in 10 years' time I'd guess the following answers:

- Will room AC use CO_2? Yes, some but not much.
- Will room AC use HCs? Yes, some but not much – more than CO_2.
- Will leakage rates be less? Yes definitely.
- Will COPs and efficiency be improved? Yes definitely (but I don't know how)
- Will HFC use have diminished? Yes, a little in room AC but much more in the rest of the sector.

Where will it all end?

A review of the future of refrigerants by Ray Gluckman, Climate Change Director, SKM Enviros.

During the last 20 years we have seen two major changes in the types of refrigerants used for refrigeration and air-conditioning applications, driven by legislation to protect the ozone layer. In the 1990s we moved away from CFCs – and we saw an increasing reliance on pure HCFCs such as R22 and HCFC blends such as R408A. Then we had to stop using HCFCs, with HFCs taking over as mainstream refrigerants in many parts of the RAC market. Currently HFC 404A is a dominant refrigerant in many commercial and industrial refrigeration applications and HFC 410A is dominant for small air-conditioning and heat pumps. HFCs 134a and 407C are also quite widely used.

It is becoming increasingly clear that we will soon face a third major change linked to growing concerns over climate change. The high global warming potential (GWP) of HFC refrigerants makes them a target in international efforts to reduce emissions of greenhouse gases (GHGs). Table 1 shows the GWPs of a range of refrigerants, based on the IPCC 4th Assessment Report – the widely used HFCs have GWPs between 1500 and 4000 times higher than the GWP of CO_2. Limiting emissions of these powerful GHGs is a logical and correct objective of policy makers. It is also the objective of many RAC system suppliers and end users.

Table 1: GWPs of various refrigerants

Refrigerant	GWP
R507	3,985
R404A	3,922
R422D	2,729
R410A	2,088
R407F	1,825
R407C	1,774
R134a	1,430
R1234yf	5
R290 (propane)	5
R744 (CO2)	1
R717 (ammonia)	0

Current Regulations in EU

What is the best route to take to limit emissions? The current EU F-Gas Regulation takes the "leakage reduction" approach – allowing the use of all HFC refrigerants in stationary RAC systems, but trying to improve design and maintenance to minimise leakage. The EU MAC Directive (which affects Mobile Air-Conditioning for cars and vans) takes the "refrigerant ban" approach – making it illegal to use HFC 134a (the current worldwide standard refrigerant for MAC) on new vehicle types.

Whilst the F-Gas Regulation has had some success in reducing leakage from many RAC markets, the overall emissions remain fairly constant because the market is growing, especially in the air-conditioning and heat pump sectors. There is strong pressure on policy makers in Brussels to enhance the current leakage reduction approach and to enforce the use of lower GWP refrigerants throughout RAC markets in the EU.

Possible new regulations in EU

The European Commission is in the process of making recommendations about a revised F-Gas Regulation. It is likely that they will make proposals towards the end of 2012 and that these will be the basis of a new Regulation that may come into force in 2013. The new Regulation is likely to use one or both of the following approaches:

a) A phase down of the amount of HFCs that can be supplied into the EU market. This might involve an initial step down in supply between 2015 and 2018 and a series of cuts until the supply reaches a minimum level from around 2030. The minimum level might be around 10% to 20% of current supply. It must be stressed that the proposals are for a phase down rather than a phase out – with a small residual consumption being allowed for applications that cannot use alternatives.

b) A ban on specific applications of high GWP HFCs. This might be similar to the MAC Directive that specifies an application and a maximum allowable refrigerant GWP.

The phase down approach is simpler to implement as it avoids the need to specify particular applications and to decide appropriate GWP thresholds and ban dates. The market will have the freedom to meet the phase down level in a flexible way – which should imply the lowest cost.

How will the market respond to a phase down?

We are seeing rapid changes in the refrigerants market that will help RAC end users select new equipment with much lower GWPs. Some good technologies are available and cost effective now, while others are likely to emerge over the next five years. CO_2 is seeing rapid growth, particularly in the supermarket sector. The MAC sector has opted for a brand new refrigerant, HFO 1234yf, which has a GWP of only 5, but is mildly flammable. Assuming appropriate safety codes are developed, it is likely that HFOs will be used in stationary RAC applications in the future, although there is currently insufficient production to satisfy MACs, so there is little availability for the stationary markets.

The best choice of refrigerant will always be highly dependent on system size and application. In Figure 1 there is a qualitative representation of the relative cost effectiveness of different refrigerants in different sized systems. The "x-axis" shows five different sizes, ranging from <1 kg of refrigerant on the left (e.g. domestic refrigerators), to >250 kg on the right (large industrial systems). The "y-axis" represents the relative "total owning cost" of a system – including capital cost and the total energy and maintenance costs over the life of a plant. The figure clearly shows that the most cost effective refrigerant options vary considerably with system size:

Very small systems (<1 kg) such as domestic refrigerators and small retail displays and vending machines are well suited to hydrocarbons (HCs), especially in sizes below 0.15 kg. HCs are the dominant refrigerant for domestic refrigerators and freezers in Europe and have been used widely in small retail systems. In a few years time it is possible that HFO 1234yf may also become a cost effective option in this market.

Very large systems (>250 kg) such as blast freezers and public cold stores are well suited to ammonia. This combines high energy efficiency with zero GWP – and the refrigerant itself is low cost. CO_2 can be considered in some very large systems, especially if heat recovery is a useful spin-off benefit. HFCs are rarely used in such large applications and HFOs are likely to prove too expensive in such large quantities. The high flammability of HCs makes them unattractive in very large installations except in special circumstances e.g. refrigerant used in a petrochemical plant.

Small systems (2 to 10kg) such as split system air-conditioning are currently the most difficult market to find a cost effective low GWP solution. Ammonia and HCs are not easy to use in small "distributed" applications (i.e. with separate evaporator and condensing unit joined by site constructed pipework) due to toxicity or flammability. CO_2 is an option, but currently costs are high and component availability is low. In the longer term HFOs and HFO/HFC blends may fill this gap – but we need to wait several years before they are commercially available. In this market HFCs remain the most cost effective option.

Medium systems (10 to 50 kg) such as large condensing unit systems or small industrial plants are also problematic. HFCs are currently the lowest cost option in this size range. Ammonia is not appropriate and CO_2 becomes less cost effective as size goes down. Again we will perhaps need to rely on HFOs and HFO/HFC blends when they become commercially available in a few years' time.

Large systems (50 to 250kg) such as supermarket pack systems or medium sized industrial plants -this range represents the transition from medium to very large. Both ammonia and CO_2 are strong contenders (e.g. ammonia in an industrial application and CO_2 in a supermarket system). HFCs are cost competitive, especially at the smaller end of this size range.

Important note – Figure 1 applies to small hermetically sealed systems and distributed systems. The comparison would be different if applied to chillers located in a plant room with no public access.

Some guidelines for buying new systems

It is not always easy to make the correct choice as the market is seeing such rapid change. Some simple rules to follow are:

- For very small hermetically sealed systems consider using HCs.
- For large and very large systems consider using ammonia or CO_2.
- In the small and medium ranges HFCs are likely to remain a key choice in the short term, although this is likely to change within the next 5 years.
- If you need to select an HFC ensure that (a) you avoid the very high GWP HFCs such as R404A and R507 and (b) that the plant is designed to have a very low leakage level.
- For all new plants ensure that you carefully consider energy efficiency. The largest part of the carbon footprint of an RAC system is the "indirect" emission from electricity used. The best time to improve efficiency is when a new plant is being purchased.
- Consider using a secondary coolant system, in order to minimise the charge of refrigerant and length of refrigerant pipework. But in this case, take great care to minimise any reduction in energy efficiency due to extra pumps, heat-exchanger temperature drops or inappropriate choice of evaporating temperature. The use of CO_2 as a volatile secondary coolant is an interesting option for such a system.

Fig. 1: Size and total owning cost diagram (distributed refrigeration systems)