The Voice of European Air-Conditioning, Refrigeration and Heat Pumps Contractors

Low GWP Refrigerants

Guidance on use and basic competence requirements for contractors

June 2011

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HFCs can be used in all refrigeration, air conditioning and heat pump (RACHP) applications. However due to their high global warming potential (GWP), HFCs have environmental implications in the event of refrigerant emissions into the atmosphere. Whereas RACHP contractors use every available solution with complete neutrality towards equipment and refrigerants, this paper considers alternatives to HFC, with a dual aim:

- Set the general AREA position on **use of low GWP refrigerants** in RAC installations: for what type of equipment are they best suited, under which conditions & requirements etc
- Set basic **competence requirements** for RACHP contractors dealing with low GWP refrigerants

Recent and future legislation will probably encourage a greater use of natural refrigerants Ammonia, Hydrocarbons (HCs), Carbon Dioxide (CO_2) and the synthetic refrigerant HFOs in certain applications. Ammonia, CO_2 and HCs are well known refrigerants which have pro and cons, while HFO is a new refrigerant for which little data is available from a practical point of view, as it will be widely used by all carmakers (EU Directive 2006/40/EC on mobile air conditioning).

The table below shows the respective properties of the low GWP refrigerants under consideration

	HFC	Natural			HFO
Refrigerant		HCs	Ammonia	CO_2	1234yf
GWP (100 years)	✗✗ R134a 1300 – R410A 1900	✔ 3 - 5	✔✔ 0	✔✔ 1	✔ 4
Toxicity	✔✔	✔✔	✗✗	✔	✔✔
Flammability	✔✔	✗✗	✗	✔✔	✗
Materials	✔	✔	✗	✔	✔
Pressure	✔	✔	✔	✗✗[1]	✔
Availability	✔✔	✔	✔	✔	✗✗
Familiarity	✔✔	✔	✔	✗	✗

Very poor ✗✗ **Poor** ✗ **Good** ✔ **Very Good** ✔✔ *Source: F-gas support Information Sheet - RAC7 alternatives*

HFCs vs. alternatives in refrigeration & air-conditioning equipment[2]

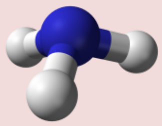
There are no easy answers to the question "*which refrigerant is most efficient?*", as no refrigerant represents the ideal solution in all cases and for every equipment – each cooling application has to be looked at in its own merits and a professional choice must be made taking into account many more factors than simply GWP. In view of the Total Equivalent Warming Impact (TEWI)[3] of greenhouse gases, energy efficiency is the most relevant criterion to assess the suitability of a refrigerant in R&AC systems. Applying this criterion to RAC equipments according to their size reveals that:

- *On small systems*, HCs tend to be more energy efficient
- *On large systems*, CO_2 or ammonia are generally more energy efficient
- *In between these scales*, each equipment should be analysed on a case by case basis

[1] It should be noted that CO_2 has been categorised "very poor" in terms of pressure because the RAC industry will need to learn to cope with using a fluid at 120 bar, which is much higher than the current peak pressures of around 20 bar. However, the high pressure does deliver some desirable characteristics such as smaller pipe diameters and less compressor swept volume.

[2] AREA Position Paper dated 30th June 2009

[3] Method which assesses direct and indirect greenhouse emissions connected only with the use-phase and disposal



Ammonia - R717

Applications for NH_3

- Industrial Refrigeration
- Large Chiller applications

The operating pressures of ammonia are comparable with those of other refrigerants. Ammonia's ability to absorb larger amounts of heat per volume makes it possible to use smaller pipes and smaller components compared to other refrigeration systems while delivering the same amount of refrigeration.

As a refrigerant, ammonia offers three distinct advantages over other commonly used refrigerants. First, ammonia is an environmentally compatible refrigerant because it has an ozone depletion potential (ODP) of zero and a global warming potential (GWP) of zero. Second, because of its superior thermodynamic properties, ammonia as a refrigerant requires less energy than other refrigerants when used in large industrial systems. Third, ammonia refrigeration has a proven safety record, in part because of the refrigerant's physical properties (not the least of which is its well-recognizable and easily-detectable smell), compliance with voluntary industry standards and an industry of well-trained operators[4].

From a purely economic point of view and without unnecessary regulatory burdens, ammonia should find broader applications as a refrigerant than it currently enjoys. Ammonia's use in the HVAC&R industry should be expanded as regulatory and code officials become informed of its relative safety. Applications for ammonia-based refrigeration systems include thermal storage systems, HVAC chillers, process cooling and air conditioning, district cooling systems, supermarkets, convenience stores, air conditioning for the International Space Station and Biosphere II, and increasing output efficiencies for power generation facilities.[5]

As regards materials, one should note that copper, brass and bronze cannot be used with ammonia – metal choices are mild steels, stainless steels and nickel.

Limitations on the use of ammonia are generally due to national legislation. For this reason industrial and large applications, where limitation and controls are periodically under observation, are more suitable for ammonia. However, further implementation of ammonia use can be foreseen in smaller applications (domestic and commercial) under certain safety conditions.

Basic competence requirements for RAC contractors dealing with NH_3

Basic competence requirements are detailed in the Leonardo da Vinci project **AREA Refrigeration Craftsman**[6]. However, particular attention should be given to safety issues and technical differences with HFC:

Safety Issues:

- Tables of toxicity (breath, eyes, skin)
- First Aid
- First Intervention
- Wear the correct personal protective equipment (PPE)
- Miscibility with water and compatibility with other materials

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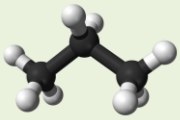
[4] Ammonia: the Natural Refrigerant of Choice (An IIAR Green Paper)
[5] Ammonia as a Refrigerant position paper ASHRAE 2006
[6] See AREA portfolio of qualifications and skills needed to work in the field of refrigeration and air conditioning with excellent craftsmanship, which was established on the basis of the Leonardo da Vinci Project EUR/02/C/F/NT- 84604 / EC Agreement N° 2002-4549/001-001LE2X

Main technical differences from HFC:

- Generally ammonia compressors are of open-drive design due to the incompatibility of copper and NH_3.
- No compatibility with copper or zinc, so these materials must be avoided.
- Differences in oil return to the compressor must be considered in ammonia refrigeration systems.
- Oils used in ammonia refrigeration systems are insoluble in NH_3 while oil solubility is absolutely essential with the halocarbons in order to facilitate oil return.
- Need for pressure vessels



Hydrocarbons

Applications for HCs[7]

Hydrocarbons normally used are R290 (propane) and R600a (isobutene):

- Domestic Refrigeration as fridges (R600a)
- Commercial Refrigeration as Bottle Coolers (R290)
- Heat Pumps and Air conditioning (growing in numbers)

Refrigerants R290 and R600a are possible alternatives to other refrigerants with high GWP in small hermetic systems, like factory-made commercial refrigerators and freezers. They have also been in use in refrigeration plants in the past, and are still used in some industrial plants. R290, in particular, is a possible refrigerant for such an application with good energy efficiency, but special care has to be taken regarding flammability.

So having in mind the safety aspects of hydrocarbons which make them very different to handle from an installation, maintenance and commissioning point of view, one could generally say that:

- R600a applications could be alternatives to HFC R134a
- R290 application could be alternatives to HCFC R22

It must also be pointed out that each country has its own set of regulations that need to be followed regarding hydrocarbon applications, so specific limits could exist.

Under EU standard EN 378 the following applications and the refrigerant charges are recommended:

- Systems with a charge size of 0.15 kg or less may be installed in any size of room
- For systems with a charge size of more than 0.15 kg, the room size should be such that a sudden loss of refrigerant shall not raise the mean concentration in the room above the practical limit of 0.008 kg/m^3

Basic competence requirements for RAC contractors dealing with HCs

Basic competence requirements are detailed in the Leonardo da Vinci project **AREA Refrigeration Craftsman**. However, particular attention should be given to safety issues and technical specificities, such as tools to be used for hydrocarbons.

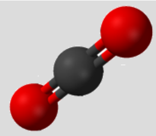
Safety Issues:

- What not to do when handling hydrocarbons (no smoke, fire...)
- First intervention in case of fire
- Safety code of practice A2-A3 of the British Institute of Refrigeration (IoR)[8]

[7] Danfoss Practical Application of Refrigerant R290 Propane(and R600a isobutane) in Small Hermetic Systems
[8] See http://www.ior.org.uk/ior_publication.php?pubid=WBEW5TW4AG

Technical Issues:

- Avoid any contact with sparks and fire
- Use only ultrasonic welding, Lokring connections or suitable compression fittings
- Compressor protectors: overload, Clickson must be used on all sealed types
- Thermostats position in fridges to avoid ignition in case of leak
- Welding is not permitted
- All electronic control components should be explosive proof



Carbon Dioxide - R744

Applications for CO_2

Evaluations carried out on CO_2 in recent years have shown that it is efficient and worthy of use. The main advantages are a very low environmental impact, non-flammability and non-toxicity. The disadvantage is high pressure at low temperatures: CO_2 reaches its critical point at 31.1 °C with 73.8 bars. Below is a list of applications, their characteristics and the benefits of using CO_2.

Sub-critical (in industrial applications):

- CO_2 as primary refrigerant in cascade with ammonia or other refrigerants: *first stage, low temperature and low pressures*
- CO_2 as secondary refrigerant: *small diameters and sizes of the components*

Trans-critical:

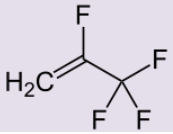
- Hot water Heat Pump applications: *the application matches the supercritical temperature glide in the CO_2 gas cooler providing good efficiencies inside a compact system*
- Auto A/C applications: *refrigerant leaks are frequent on automotive applications, so the direct effect of emission could be greater than the indirect effect.*
- Supermarkets: *Where ambient temperature permits*

Basic competence requirements for RAC contractors dealing with CO_2

Although CO_2 is classified as a safe refrigerant, not toxic and not flammable, some precautions must be taken.

Basic competence requirements are detailed in the Leonardo da Vinci project **AREA Refrigeration Craftsman**. Additional safety issues should be taken into account due to the high pressures in running conditions in both trans-critical and sub-critical systems (the refrigerant could easily reach 100 bar and above).

Like HFC, CO_2 vapour is heavier than air, so a leak in unventilated rooms would cause oxygen to be dispersed from the floor level upwards. This, together with the fact that CO2 has no smell, increases the resulting risk of casualties by suffocation.



HFOs

Applications for HFOs

Carmakers around the world are seeking a globally compliant replacement for R134a refrigerant, the use of which is prohibited under the MAC Directive. A near drop-in replacement solution has been developed: HFO-1234yf (Hydro-Fluoro-Olefin, 2,2,2,3 Tetrafluoroprop-1-ene) enables carmakers to meet EU low GWP requirements.

These new fluids have potential in small commercial and residential applications where a medium pressure refrigerant can be efficiently employed and where low GWP is needed or desired. HFOs could allow use of current technologies minimizing conversion cost for the industry.[9] HFOs and new blends of HFO–HFC (with reduced GWP 300-600, not flammable) may be available for applications that currently use R134a, R404A, and R410A.

Basic competence requirements for RAC contractors dealing with HFOs

HFOs are mildly flammable. Basic competence requirements are detailed in the Leonardo da Vinci project **AREA Refrigeration Craftsman**. However, particular attention should be given to safety and technical issues (tools used for flammable refrigerants – see section on hydrocarbons).

[9] Honeywell - 14th EU Conference Milan June 2011

Summary Table : Applications - Low GWP Refrigerants

The table below describes the combination applications/refrigerants which provide good results from energy efficiency and environmental aspects, also considering safety issues
(more applications for HFOs and HFO blends will probably be developed with full commercialisation of the products)

Application	Refrigerant
Industrial Refrigeration	
All kind of Industrial Ref.	Ammonia
Cascade systems	Carbon Dioxide + Ammonia
Secondary fluids	Carbon Dioxide
Commercial Refrigeration	
Cabinets	Hydrocarbons
Bottle coolers	Hydrocarbons
Supermarkets	Carbon Dioxide
Domestic Refrigeration	
freezers	Hydrocarbons
Air Conditioning	
Heat Pumps Hot Water	Carbon Dioxide Trans-critical
Large Chillers	Ammonia
Small Monobloc Air Conditioning	Hydrocarbons
Automotive	Carbone Dioxide or HFO1234yf

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About AREA

AREA (www.area-eur.be) is the European organisation of refrigeration, air-conditioning and heat pump (RACHP) contractors. Established in 1988, AREA voices the interests of 21 national members from 19 European countries, representing more than 9,000 companies across Europe (mainly small to medium sized enterprises), employing some 125,000 people and with an annual turnover approaching €20 billion.

AREA members are the designers of RACHP systems, which they design, install, service and maintain. For this purpose, RACHP contractors use every available solution with complete neutrality towards equipment and refrigerants, with the sole aim of ensuring the highest level of reliability, energy efficiency and cost-effectiveness.