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The refrigerant's future: The phase down of HFCs and its consequences (Saint Petersburg, Russia, November 2013)

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The International Institute of Refrigeration (IIR) is an independent intergovernmental science and technology based organization which promotes knowledge of refrigeration and associated technologies that improve quality of life in a cost-effective and environmentally sustainable manner including:

- Food quality and safety from farm to consumer;
- Comfort in homes and commercial buildings;
- Health products and services;
- Low temperature technology and liquefied gas technology;
- Energy efficiency;
- Use of non-ozone-depleting and low global warming refrigerants in a safe manner.

Founded in 1908 with the head office in Paris, the IIR comprises 60 member countries (both developed and developing) including of course Russia, 500 experts and 600 corporate and private members: private companies (refrigeration equipment, public services, food and pharmaceutical sectors…), consultants, academics, students…

The information services provided are the refrigeration portal with almost 100 000 references, the publication of Journals, Books, Informatory Notes, and Statements, the organisation of Conferences and Working Parties…

Increasing energy and environmental challenges

1. Increasing needs of refrigeration

Temperature is a key variable in physics, chemistry and biology. It characterizes the state of matter (liquid, solid, gas) and is vital for all living beings (pathogens as well as humans).

Refrigeration is everywhere:

- Cryogenics (petrochemical refining, steel industry, space industry, nuclear fusion…);
- Medicine and health products (cryosurgery, anaesthesia, scanners, vaccines…);
- Air conditioning (buildings, data centres…);
- Food industry and the cold chain;
- Energy sector (including heat pumps, LNG, hydrogen…);
- Environment (including carbon capture and storage), public works, leisure activities…

Moreover, because of the role refrigeration plays in providing safe food and drugs as well as avoiding post-harvest losses (3 times more losses in developing countries than in developed countries due to the lack of refrigerating equipment); and because of the role air conditioning plays for human health and well-being along with information technologies, there is an increasing need for refrigeration, including air conditioning. There will be an increase in the global population, particularly in Africa and South Asia where these needs are already major ones. This population will double in urban areas of developing countries by 2050, increasing the need for a cold chain and westernized models.

Accordingly, there will be two consequences:

- Refrigeration, including air conditioning, represents about 15% of global electricity consumption and even more than 20% in countries like the USA. The current increase has indirect consequences on global warming because of electricity production with fossil fuels. The price of electricity will increase because of increasing costs of new energy sources and there could be an increasing lack of power infrastructure.

Reducing energy consumption of refrigerating systems is necessary.

This consumption is linked to the refrigerant used in the system.

- Vapor-compression systems will remain predominant in the medium term and thus we will need more refrigerants.

2. The refrigerants issue

According to the Montreal Protocol, production and consumption of Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs) in developed countries are or will be phased out by 1996 and 2020 for CFCs and HCFCs respectively, and by 2010 and 2030 in developing countries.

They are depleting the ozone layer. They also are potent greenhouses gas, about 1000 to 10 000 times compared to carbon dioxide (CO_2).

Since the global warming potential (GWP) of CFCs is about 5 times the GWP of HCFCs, the replacement of CFCs by HCFCs was good, both for the ozone layer and climate change. Thanks to the Montreal Protocol, the ozone layer will recover within a few decades and the phase-out of CFCs firstly decreased CO_2 equivalent emissions. However, the production and consumption of HCFCs increases; they are progressively replaced by Hydrofluorocarbons which do not deplete the ozone layer but generally are as potent greenhouse gas-

es as HCFCs. Both currently represent less than 2% of CO_2 equivalent emissions. Due to increasing needs for refrigeration equipment, they would represent about 7% in 2050, which is not negligible. They are included in the Rio Convention on climate change as well as CO_2 and people would like to reduce their HFCs emissions used mainly in refrigeration and air conditioning (80%) and in foams (10%); their use seems thus limited to certain sectors and the manufacturers are few. It seems to be much easier to phase-down HFCs emissions than CO_2 emissions even if CO_2 is the main greenhouse gas.

The phase-out of CFCs and HCFCs is a success due to manufacturers' interest which could provide new refrigerants, creating a new market, with new patents. It could be the same with the currently used HFCs which could now be replaced by low GWP HFCs, including hydrofluoroolefins (HFOs). HFOs manufacturers were pleased with the accelerated phase-out of HCFCs and since 2009, would be pleased with a phase-down of HFCs provided that the amounts were weighted according to their GWP. In addition, their lifetime within the atmosphere is much lower than the lifetime of CO_2: in a short term perspective, phasing down HFCs is more efficient than phasing down CO_2 emissions. Hence there are negotiations at an international level.

International negotiations

1. The discussions in United Nations (UN) conferences

There are two parallel processes: Montreal Protocol conferences trying each year to improve its achievements and UN climate change conferences, trying each year to find an agreement and a process to reduce greenhouse gas emissions and to help developing countries adopt adequate technologies. Each Conference has its own secretariat within the United Nations Environmental Programme (UNEP). Financing resources for developing countries are different. Country representatives are often different in these parallel processes.

Following a study exaggerating the threat to the climate by HFCs published in 2009, North America (USA, Canada, Mexico) on one side, Micronesia and various islands on the other side, simultaneously proposed each year, starting in 2009, similar amendments to the Montreal Protocol in order to phase down HFCs. For instance, the 2013 American amendment proposal is the following:

The baseline is the average of the production and consumption of HFCs and of 85% of HCFCs for developed countries (90% of HCFCs for developing countries) weighted by the GWP; the objective is 15% of the baseline for HFCs in 2033 in developed countries (2043 for developing countries); the first step would be –10% in 2016 for developed countries and +0% in 2018 for developing countries. HFOs are not included in that proposal, considering that HFOs are different than HFCs, even if it was the contrary in the previous years. HFCs production and consumption would be phased down with the tools of the Montreal Protocol (people and procedures of the Protocol).

Progressively, most countries supported the will to phase down HFCs within the Montreal Protocol, with various motivations: the European Union and other West European countries (Norway, Switzerland) would like to do the same in their region for environmental reasons and it would be better for them not to be alone; poor developing countries, particularly African countries, and island countries, which do not produce refrigerants and refrigerating equipment and would be the victims of global warming.

Some others do not agree since the beginning: «emerging» countries, of which India is the «leader», followed by China and Brazil, which probably could agree with some compensations: they would like to protect their refrigeration and refrigerants industry; Gulf countries and some other Middle East countries, which were always reluctant to measures against global warming and currently do not find clear solutions for air conditioning in hot climates; some Latin American countries which regularly criticize US lack of involvement against global warming; countries in transition such as Russia do not currently have a clear position.

Twice a year debates took place during UN Conferences on the ozone layer. However, no decision could be taken since it required an agreement of all the parties involved in the Montreal Protocol (e. g. all the UN countries). During yearly Conferences on climate change, the subject was a small one among many others and was only officially mentioned in 2012, when the subject became a «hot» political subject.

The debates were essentially technical with the participation of industry representatives from major countries and of environmental non-governmental organizations. Since 2012 they have progressively become political. A new initiative of Hillary Clinton on short-lived substances compared to CO_2 (especially including HFCs) took place in 2012, followed by a declaration in the conclusion of Rio+20 in June 2012, adopted by 191 countries. In 2013, the presidents of the USA and of China declared an agreement to phase down HFCs, followed by a joint declaration of the US President and of the India Prime Minister.

A declaration of the G20 took place also in Saint Petersburg in September 2013.

Despite these declarations, some countries, including India, still refuse to create an official forum of discussion on the amendments to the Montreal Protocol and on the possibility to phase down HFCs within this Protocol (situation after the yearly UN conference on the ozone layer, which took place end of October 2013).

2. The European Union case

At the beginning of the century, some countries, in Northern Europe

(Denmark…) imposed taxes and bans on HFCs in order to reduce greenhouse gas emissions. In 2007, the European Union decided to implement two measures:

• A mobile air conditioning directive (MAC directive) progressively banning refrigerants with a GWP higher than 150 in cars. At the time, the main refrigerant used in cars was the R134a, which GWP is about 1300. The only possibilities of a refrigerant replacement were R152a, a slightly flammable refrigerant, CO_2, which was already experimented but not used and the promising unsaturated HFCs (HFOs) which still did not exist. The first deadline was the ban on refrigerants with a GWP higher than 150 for new series of cars in 2013.

• The fluorinated gas (F-gas) regulation which imposed training and certifications for people having to manipulate F-gases and certifications for companies using them, as well as obligations of annual reports on the refrigerant uses. Afterwards, this regulation had to be adapted by each European

country in its own regulation. Some were just implemented this year. The regulation had to be reviewed in 2012.

In parallel, the European Union decided to phase out HCFCs earlier than the Montreal Protocol requested: in 2015, when it will be impossible to charge equipment with HCFCs, including recycled ones.

The review process of the F-gas regulation started in 2010. Very rapidly, taking into account the fact that the current F-gas regulation could only stabilize emissions (which is already a good result), the Commission proposed to phase down production and consumption of HFCS, similarly to the North American proposal. The Commission officially submitted its proposal to the member states and the European Parliament in November 2012 and presented it to all the Parties of the Montreal Protocol as an example to be followed.

The Commission's proposal is the following (summary):

• Refrigerated transport will be included in the new F-gas Regulation;

• The duration of the availability of the controls will depend on the GWP of each refrigerants;

• Training and certification obligations should be reviewed and are also recommended for natural refrigerants;

• Freeze in 2015 then progressive reduction of CO_2 equivalent HFC consumption: 93% in 2017, 63% in 2020, 45% in 2023, 31% in 2026, 24% in 2029, 21% in 2030;

(This phase-down is similar to that proposed by North America).

• HFCs with a GWP higher than 150 should be banned for small hermetic systems in 2015;

• HFCs with a GWP higher than 2500 should be banned in 2017 and those with a GWP higher than 150 should be banned in 2020 in commercial refrigeration;

• HFCs with a GWP higher than 150 should be forbidden in air-conditioning systems in 2020;

• Pre-charged equipment imports should be banned in 2015.

• This proposal was then amended by the Commission of Environment of the European Parliament:

— The final step should be 16% in spite of 21% in 2030;

— Shorter delays to phase out high GWP refrigerants in various applications;

— A tax of 10€/t of CO_2 eq. on the market should be imposed.

These proposals shall now be negotiated between the European Council, the Commission and the Parliament.

The aim is to reach an agreement at the beginning of 2014 before the European Parliament elections in order to implement it in 2014.

Environmental Non-Governmental Organizations and Green Parties (particularly active in the Parliament) would like to strengthen the regulation, as well as some Northern European countries. Southern countries are less ambitious or would like to implement national taxes on HFCs for environmental and budgetary reasons: Spain will implement a tax, 20€ per ton of CO_2 equivalent, similar to the Danish tax in 2014; France is trying to create a tax at a European or national level… European companies agree with a phase down of HFCs but would like less ambitious final goals than the Commission and no bans or taxes, only quotas of HFCs for manufacturers and importers.

Concerning the implementation of the MAC directive, most car manufacturers decided to use R1234yf, an HFO produced by DuPont and Honeywell for new series of cars. However, Daimler Benz did not implement the regulation, considering that R1234yf being mildly flammable is not acceptable and that their preferred refrigerant, CO_2, still requires more technical developments.

A future phase down of HFCs

1. The time schedule

There will be no progress in international discussions on a phase down of HFCs without progress in international discussions on climate change. Despite general political commitments, India in any case will refuse any decision without a general framework provided by the UN Convention on Climate Change (UNCC). 2015, the first key date was set as the deadline for an international agreement on measures concerning climate change to start in 2020. A UN Conference will be organized in Paris at the end of 2015. People hope it will be possible to have a general commitment on greenhouse gases including HFCs which could be phased down under the Montreal Protocol methods possibly starting before 2020.

Consequently it is very likely that the phase down time schedule proposed by North America will be delayed. At least the deadline for developed countries would be delayed until 2040 and the deadline for developing countries until 2050, instead of 2033 and 2043 respectively, with a starting point delayed at the end of the decade. The European Union and other European countries such as Norway or Switzerland could start and end before, as they did for the phase out of CFCs and HCFCs: about 5 years before the deadlines of the developed countries. This time, taking into account the little progress made on climate negotiations, the European «advance» could be almost 10 years. Is it an advantage?

Countries in transition such as Russia would have the same time schedule as developing countries. Another possibility could be the absence of any agreement but only voluntary commitments. However the results could be similar since major refrigeration equipment producers including Chinese manufacturers are ready or almost ready to change and would push their governments. As soon as these manufacturers will have changed their core production in their plants, old refrigerants will be rare and more costly. Being years in advance can be a problem; being the last one to change is also generally a problem.

In any case, every country should start to prepare a phase down since many issues to be considered would take several years to be solved: implementation of technologies as well as safety regulation issues. Each country will have to define a strategy sector by sector.

The maturity of each sector is different. In some, such as domestic refrigeration, technically proven and widely available commercial solutions have existed for a long time; in others such as commercial refrigeration, solutions are progressively being implemented; in others, such as air conditioning, we are only at a technical and commercial starting point while many issues remain to be solved. Currently developing countries have to propose and implement HCFCs phase out plans. The perspective of a future phase down of HFCs must be taken into account in choosing a strategy for the phase out of HCFCs in order to avoid permanently changing the technologies with related costs: CFCs then HCFCs then HFCs then others…

2. Future technical solutions and safety consequences

A first and obvious solution is to try to implement technologies without any refrigerant in order to solve all the current problems and possible future regulations. However, for the moment other technologies are only niche technologies which are generally more costly with limited refrigeration capacities or limited efficiency. Technical developments and sometimes real scientific breakthroughs can be necessary. The most promising ones in a mid-term perspective are:

• Absorption and adsorption technologies, particularly if they are linked with new energy sources, such as solar energy, waste lost energy….More and more countries are interested in this, in Southern Europe, Africa, Asia and Australasia particularly.

• Magnetic refrigeration: following scientific results in developing new magneto-caloric materials for a dozen of years, various prototypes were developed in Europe, Eastern Asia and North America. First domestic equipment using magnetic refrigeration might be commercialized next year in Western Europe.

• Cryogenics: liquid nitrogen or solid CO_2 could be disseminated in the place to be refrigerated. In Europe and the USA industrial trials in refrigerated transport have been carried out for silent night time deliveries made in town centers.

• Other technologies, such as thermoelectric cooling, have not progressed significantly during the past years.

A second possibility is to reduce leakage: progress margins exist as a result of important variability within similar equipment working under similar conditions. This is the aim of the current F-gas regulation in Europe, which already has a significant impact. Training, which will take some time, is the biggest obstacle. However, reducing leakage has clear advantages in terms of savings and safety when using harmful refrigerants (See below).

Apart from training and certifications, reducing the refrigerant charge is also a way to reduce the quantity of emissions if leakage. This also concerns both safety and the reduction of greenhouse gas emissions. Consequently, research and development focus on all refrigerants, on secondary fluids (which allow both a refrigeration charge reduction and a containment of harmful refrigerants) as well as mini and micro channels within the refrigerating equipment.

Last but not least, choosing a low-GWP refrigerant is the most frequently discussed solution. It is also necessary on a mid-term perspective if we want to reduce and not only stabilize emissions. The definition of a low-GWP refrigerant (which limit of a GWP?) could be a delicate issue, at least at an international level.

Hence, the proposal to only organize a phase down of HFCs based on CO_2 equivalent emissions is the most pragmatic way to obtain an agreement: we can then have a sector by sector approach, taking into account the different properties of refrigerants which depend on the various applications. We also need a differentiated regional approach, since for instance the average external temperature has an influence on the energy efficiency of the refrigerant.

Some HFCs already have a relatively low GWP compared to the current HFCs used, for instance R32. Others have a very low GWP, similar to CO_2: the HFOs. Refrigerant manufacturers are now developing various mixtures HFCs-HFOs-Hydrocarbons, as they previously developed mixtures of CFCs and HCFCS. These mixtures are adapted to various applications used in optimizing energy efficiency with the GWP of refrigerant and flammability issues.

Natural refrigerants, which are more and more considered in the perspective of a phase down of HFCs also exist. Ammonia which has been used successfully for more than 100 years, is one of the best refrigerants but is also toxic. CO_2 was abandoned in the XXe century and then newly developed during the 90s in Northern Europe: it is now developing fast, especially in commercial refrigeration in Europe and Japan and is progressively used in higher temperatures thanks to technological improvements. Hydrocarbons are very efficient refrigerants but highly flammable. They are progressively used in smaller refrigeration and sometimes in air conditioning equipment both in developed countries and in developing countries particularly in China.

Key elements to be taken into account when choosing a low-GWP refrigerant:

• Energy efficiency and life cycle performance of the whole system; worldwide and local industrial strategies as well as prices and availability of various refrigerants followed by investment and working costs;

• Safety issues which will be the most challenging in the next few years since most low-GWP refrigerants are mildly (most low-GWP HFCs) or highly flammable (hydrocarbons), toxic (ammonia) or working with high pressures (CO_2).

There are several strategic issues. First, there is a will to create new standards at an international level (ISO particularly) especially with the creation of a new class (A2L) of mildly flammable refrigerants, containing R32 and HFOs. It would facilitate the adoption of these refrigerants in various applications. Secondly, regional and national regulations concerning safety are relatively old and based on previous technologies in a different context where suitable solutions with high GWP refrigerants were possible. They certainly have to be reviewed. A comparison within the various national regulations is of great interest. Some countries have recently started to review these regulations: hydrocarbons in the USA, ammonia in France…

Conclusion

1. A phase down of HFCs will take place very soon in Europe and in the future most likely everywhere in the world, even if the ways countries will implement it are often unknown and will certainly vary country by country. We need to prepare it now.

2. Training engineers and technicians worldwide in a rapidly developing and changing sector is necessary. Improving and developing new technologies requires increasing research in universities and companies.

3. Belonging to a worldwide scientific and technical network in order to know the true information, the best practices, the various regulations, the newest innovations and evolutions (technologies are moving fast), is necessary. This is the role of the IIR.