THE EFFECTS OF REGULATIONS IN THE DESIGN OF HEAT PUMPS WITH LOW GWP REFRIGERANTS

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Introduction

It is a time of great turmoil for the HVAC sector: the level of the bar, in terms of environmental impact and energy efficiency, is fast raising, setting objectives more and more challenging which require all operators in the sector, such as equipment manufacturers, designers, installers and maintainers, a change of mentality and pace: responsiveness is the key to win this challenge.

The historical cycle of refrigerants and the intervention strategy

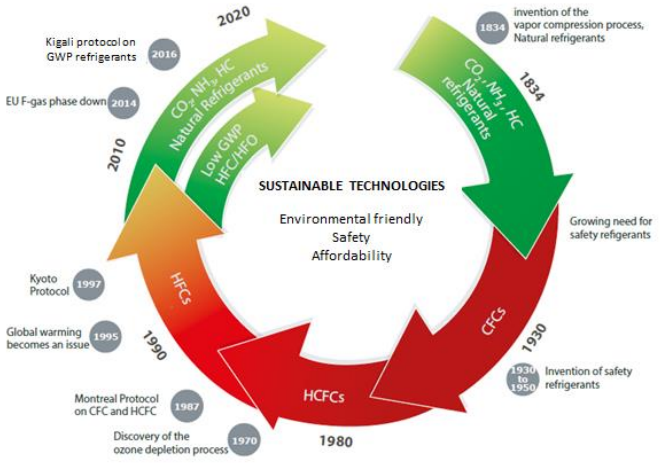


Figure 1: The historical cycle of refrigerants

The historical cycle of refrigerants shown in Figure 1, expresses the need to adopt suitable solutions for minimizing the environmental impact from HVAC technologies, using the learning curve towards refrigerants.

It all started, around 200 years ago, with flammable and toxic refrigerants to develop safe synthetic substances such as, CFCs and HCFCs which however, being characterized by high values of ODP and GWP, have been found to be harmful both to the thinning of the ozone layer and to the increase of global warming.

A great step forward was taken by developing substitute refrigerants, HFCs, all of which, although characterized by 0 ODP value, still have medium-high GWP values.

On the basis of a complete analysis of these substances, it was found that, whereas the impact due to HFC leaks in the atmosphere might not be one of the main causes of global warming, on the contrary their growing consumption, especially inside air conditioning equipments, will necessarily make HFCs the most significant contribution to global warming.

This has convinced institutions to take wide-ranging measures to contrast and limit this phenomenon:

- REDUCTION of the DIRECT IMPACT. Progressive reduction of maximum quantity of HFC and CO_2 that can be introduced into the market, through the refrigerant quota system, a mechanism for allocating limited amounts of gases to each manufacturer/importer, and the promotion of the use of low GWP refrigerants (EU Regulation n° 517/2014 better known as F-GAS Directive);
- REDUCTION of the INDIRECT IMPACT. Reduction of the consumption of primary energy linked to equipment operation through the increasing of their performance values (EcoDesign Directive).

Low GWP refrigerants: solutions and criteria of choice

In the public interest, it is necessary to provide, in the shortest period ever, “sustainable” alternatives to refrigerant fluids currently on the market (R410A and R134a), even if these solutions should represent a crossing point, applicable and valid in the short-medium term.

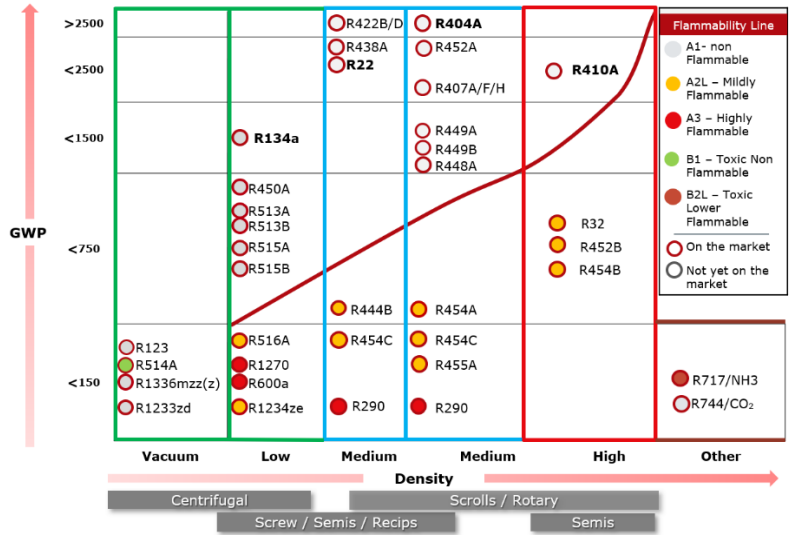


Figure 2: cataloguing of refrigerants

In Figure 2 the cataloguing of main refrigerants available on the market is represented, based on compressor type, GWP value, density and flammability/toxicity level.

In this chart the new substances to be used can be found: as can be seen from this graph, to considerably reduce the GWP value, we intersect the flammability line and we therefore need to confront refrigerants which become flammable or toxic.

But based on what strategies can we do that?

A valid method of choice of a new refrigerant is based on, as illustrated in Figure 3, three main parameters: respect of the environment, accessibility and safety. The more these parameters can be harmonized, the better the refrigerant will last on the long term.

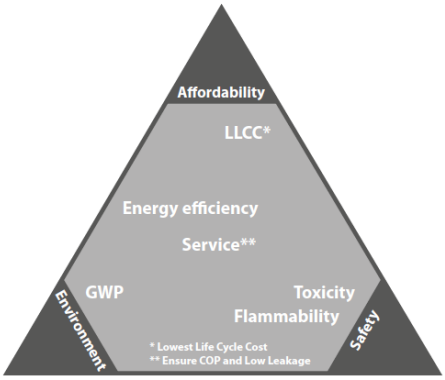


Figure 3: the triangle of refrigerant sustainability

Possible alternatives to R410A refrigerant

In Figure 4 the possible alternatives to R410A refrigerant are represented with main features and differences. They consist of mixtures of HFO and HFC, as in the case of R452B and R454B, and pure HFC as for R32.

Refrigerante	U.M.	R410A	R452B	R454B	R32
Descrizione commerciale	-	R410A	Opteon™ XL55 (DR55) Solstice®L41y	Opteon™ XL41 (DR5A)	R32
Categoria	-	MISCELA HFC	MISCELA HFO/HFC	MISCELA HFO/HFC	HFC
Composizione	-	R32 - 50% R125 - 50%	R32 - 67% HFO1234yf - 27% R125 - 7%	R32 - 68,9% HFO1234yf - 31,1%	R32
GWP_{100AR4}	kg CO_2EQ	2088	698	467	675
GWP_{100AR5}	kg CO_2EQ	1924	676	467	677
ODP	-	0	0	0	0
Classe di sicurezza	-	A1	A2L	A2L	A2L
LFL (Low Flammable Limit)*	Vol %	-	11,9	11,2	12,7
UFL (Upper Flammable Limit)**	Vol %	-	23,3	22,0	33,4
Burning velocity (velocità di propagazione della fiamma)	cm/s	-	3	3,7	6,7
Prestazioni: capacità frigorifera nominale vs R410A	-	100%	98%	96%	105%
Efficienza: EER vs R410A	-	100%	101%	100%	101%
Temperatura di scarico	°C	78	82	83	95

Figure 4: alternative to R410A refrigerant

G.I. Industrial Holding, as a result of the in-depth analysis developed on the criteria reported in “The triangle of refrigerant sustainability” (see Figure 3), has aimed to use R452B for the following reasons:

- R452B is the refrigerant whose features are most similar to R410A:
  - It has maximum condensation pressures slightly lower than R410A and about 2 bar lower than R32;
  - It features lower compressor discharge temperatures than those of R32, even 20-30°C in heat pump operation: this is why with R32 it is required to use compressors designed specifically for this fluid and which use a different lubricating oil;

- R452B is therefore compatible, unlike R32, also in heat pump operation and in 4-pipe multifunctional units, allowing the development of a whole range of units with Scroll compressors from 50kW to 1500kW;
- R452B has a GWP and a burning velocity slightly lower than R32;
- R452B is easily available on the market, being a mixture of refrigerants widely used in both the automotive and air conditioning sectors, and it is supplied by several producers. This will grant a price stability and an easily availability;
- R452B allows to produce refrigerant equipments which, at the same cooling capacity, feature identical weights and dimensions to those with R410A;
- R452B has an average seasonal energy efficiency and a cooling capacity higher than R454B, which, by contrast, has a slightly lower GWP value. At present R452B is the best compromise to reduce GWP, maintaining high energy and cost efficiencies.

Development of units with R452B: application, economical and industrial set-up aspects

This choice qualifies as a sort of “drop-in” and it has required the following activities:

- analysis and classification of units according to EN 60079-10-1:2015;
- homologation and technical-performance classification of all components with the new refrigerant;
- CE certification of new product ranges;
- adjustment of industrial set-up to the use of these refrigerants.

This has been achieved by creating a strong network of collaborations with refrigerants and components manufacturers in order to develop and validate the parts as multi-refrigerant. The choice of suppliers/partners was decisive for the achievement of this goal in terms of time and performances.

The most “delicate” theme, in substitution of R410A refrigerant, is that of the alternative refrigerants class in which they fall, all in A2L class, namely that of low flammability and non toxic refrigerants.

“Low Flammability” A2L means that these refrigerants are flammable at certain temperatures and concentrations and have a flame propagation rate lower than 10 cm/s (0,36 km/h); this concept is transposed in the Standard of refrigerants (ANSI/ASHRAE 34-2016 “Designation and Safety Classification of Refrigerants” and ISO 817: 2014 “Refrigerants - Designation and safety classification”) in turn recalled in the Applied Standard related to the safety of equipments and installations (ISO 5149:2014 “Refrigerating systems and heat pumps - Safety and environmental requirements Definitions, classification and selection criteria”; ASHRAE 15: 2016 “Safety Standard for Refrigeration Systems”). To date, however, some guidelines at the application level and **specific** standards that regulate their use and carry out necessary differentiations for practical purposes, compared to the use of refrigerants in A2 (moderate flammability) and A3 class (high flammability), are still missing.

For example, the PED Directive (Pressure Equipment Directive) does not distinguish between low flammability A2L refrigerants and moderate/high flammability refrigerants (A2/A3) because it classifies substances in only 2 groups:

- Group 1 “Dangerous” fluids: A2L (R452B, R454B, R32), A2 (R152A) and A3 refrigerants (R441A, R443A, R290);
- Group 2 “Non dangerous” fluids: R134a, R410A and R513A refrigerants.

The lack of recognition of a different level of flammability, led to a wide range of applied issues, characterized by extremely expensive implications for companies, summarized below.

The belonging of R452B to Group 1 together with a maximum admissible pressure PS > 40 bar, brings the pressure vessel (heat exchangers, liquid receivers, etc.) to a high PED category (Cat. II) in comparison to that associated to R410A (Group 2).
In Chart 1, it is clear that the same piping, if used with:

- R410A is excluded from PED (Article 4, Paragraph 3);
- R290 (propane), fluid in A3 class (high flammability/explosive) - Group 1 falls into Cat. I;
- A2L fluids such as R452B or R32 - Group 1 falls into Cat. II imposing rules, check-ups and test methods far more strict on tightness and resistance of the piping.

DESCRIZIONE	UNITÀ DI MISURA	R10A	R452B	R290 (Propano)
Fluidi gruppo		2	1	1
Infiammabilità		A1	A2L	A3
PS	bar	45	45	23
DN	mm	32	32	32
PSxDN		1440	1440	805
Cat PED		Art.4 Par.3	II	I

Chart 1: characterization of piping

So the piping used with the less dangerous fluid, being characterized by an higher PED category, requires more complex and expensive tests.

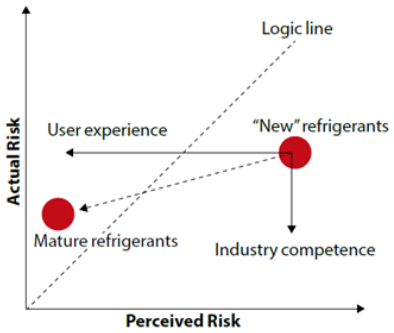
In fact, having the piping in Cat. II imposes, based on EN 14276-2 Regulation recalled in EN 378-2 Par.6.3, tightness tests for the whole and on 100% of production with a pressure of
1,43xPS = **64,3bar** (PS= 45 bar);
or
1,1xPS = **49,5bar** + 10%NDT (non destructive test on 10% of braze welding).

The problems linked to these additional tests are:

- re-solicitation to high stress from components of the circuit which have already undergone such tests;
- elimination, during the tests, of safety valves;

- impossibility, in some cases, to select parts of the circuit which operate with different PS and therefore the units must be modified by adding faucets (possible source of losses) in order to be tested;
- not all components, first of all the compressor, can be tested with pressures higher than PS without potentially compromise the operation.

In addition to these technical arguments, it should also be taken into account that there is also a psychological aspect linked with the use of these new refrigerants, well represented in Figure 5: being the diffusion of these refrigerants still recent, their risk is perceived as higher than the real one.



Picture 5: Array of real risk and perceived risk

Conclusions

The choice to opt for R452B as alternative to R410A in units with Scroll compressors has enabled us to give a fast, effective and efficient response to the market, through a "green" range of liquid Chillers, heat pumps, multifunctional units from 50kW to 1500kW.

For sure, in cooperation with cultural associations and Confindustria, it is necessary to invest on the following activities:

- works of harmonization and revision of existing standards in favour of a simplification for equipments with A2L refrigerants;
- development of specific competences from the industry world;
- Information plans, training and awareness programmes with regard to the final users.