LONG TERM SOLUTION FOR COMMERCIAL REFRIGERATION AND RESIDENTIAL COMFORT WITH LOW GWP REFRIGERANTS

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SCROLL COMPRESSORS WITH REFRIGERANTS OF GWP BELOW 150 LONG TERM SOLUTION FOR COMMERCIAL REFRIGERATION AND RESIDENTIAL COMFORT

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Abstract

The F-Gas regulation is in force within the European Union as of 1st January 2015. It is enforcing the phasing out of the current high GWP refrigerants either by limiting the GWP threshold for certain equipment or indirectly by limiting the availability in the market of the refrigerants presenting high GWP due to the phase down scenario. The reduction will be achieved by many changes affecting the commercial refrigeration, air conditioning and heat pump systems.

Long-term scenario shows that the average GWP value of the refrigerants shall fall below 400. Therefore, it is considered by many experts that the refrigerants with GWP below 150 will be the long-term solution for many refrigerating applications. In this range propane (R290), R455A and R454C are medium pressure refrigerants and are some of the potential alternatives to replace R407C in heat pump and R404A in refrigeration. This paper gives an overview of Scroll performance with these refrigerants. Moreover, a brief introduction of the compressor changes required when using these refrigerants based on the last revision of the safety standards is given.

Legislation is Driving the Changes

The European F-gas regulation (EU 517/2014) bans refrigerants having a GWP higher than 2500 in stationary applications. The regulation has introduced some GWP bans by application. For example, refrigerants with a GWP over 150 will not be allowed in multipack systems for commercial refrigeration, with an exemption for medium temperature when a secondary fluid is used. On top of the bans, the regulation introduced a phase-down of refrigerant consumption targeting a 79 % of reduction in equivalent CO2 by 2030. Based on simulation the average GWP used in all refrigeration systems should be lower than 400 to meet the phase down scenario. This will probably put pressure on refrigerants having a GWP higher than 400 after 2030. Experts are therefore looking for sustainable solutions and are considering refrigerants with a GWP below 150 as a future proof and long-term solution.

On top of F-gas regulation, there is a simultaneous global push towards higher efficiency to minimize the indirect carbon emissions from power plants. The minimum efficiency requirements will increase in the coming years both for comfort and commercial refrigeration. Low GWP and higher efficiency are the challenges of next year to meet legislative requirements.

Refrigerants Candidates With GWP Below 150

Among the refrigerants landscape, the available refrigerants with a GWP below 150 are principally R744, R290, R455A, R454C, R457A, R1234yf and R1234ze. In this section, the focus will be on medium pressure refrigerants: R290, R455A and R454C.
Table 1 reports some properties of these candidates as well as for R404A and R407C for comparison. R455A and R454C are classified mildly flammable (A2L) while R290 is highly flammable (A3). Therefore, a further effort during the design of the product, its life, maintenance and dismantling is required to make the product safer when using these new refrigerants.

	Unit	**R404A**	**R407C**	**R454C**	**R455A**	**R290**
Composition		R143a + R125 + R134a	R134a + R125 + R32	R1234yf + R32	R1234yf + R32 + R744	-
GWP (IPCC 4th Ed.)	-	3922	1770	148	148	3
Critical Temp.	(°C)	72.1	86.1	82.4	82.8	96.7
Critical Pressure	(bar)	37.3	46.2	39.5	43.8	42.6
Liq. Density (30°C)	(kg/m3)	1020	1115	962	999	484
Temp. Glide (30°C)	(K)	0.4	5.4	7.3	10.6	-
Safety Class		A1	A1	A2L	A2L	A3

Table 1: Refrigerants Properties

R454C and R455A are non-azeotropic blends presenting a high temperature glide during phase change. As reported in the table, for example at 30°C, R454C has 7.3 K and R455A has 10.6 K temperature glide. Consequently, the system design and the heat exchangers should be optimized to benefit from the effect of the temperature glide.

Scroll Performance for Refrigeration
Figure 1 shows the performance of a scroll compressor with a displacement of 11.7 m³/h tested at -10/45°C (MT) and -25/40°C (LT) conditions. R290 and R454C cooling capacity is about 15 % less than R404A, while it is 10 % lower for R455A.
Figure 2 reports the COP of the scroll compressor tested at MT and LT. R290 shows +10 % and -3 % respectively at MT and LT compared to R404A. While R454C and R455A have a COP +5 % higher than R404A.

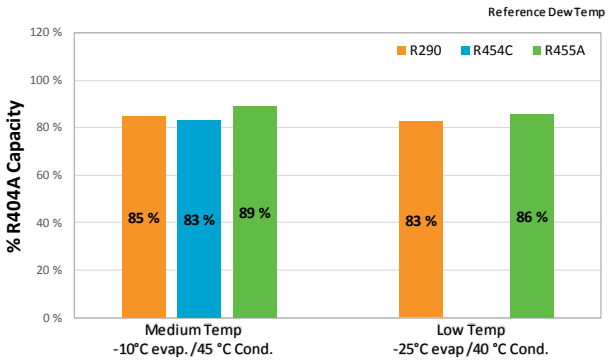

Figure 1

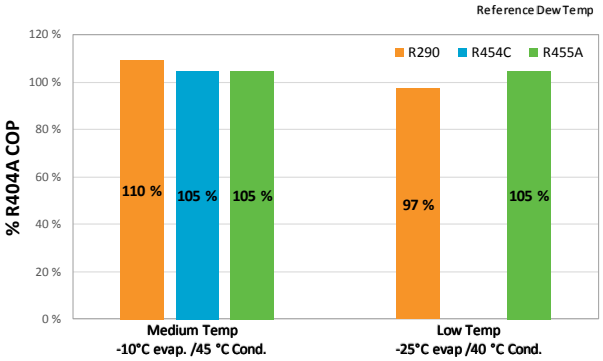

Figure 2

Figure 3 compares the performances at the mid-point: R455A and R454C gain respectively 7 % and 4 % capacity compared to dew-point (figure 2). However, the COP decrease for R455A by 4% and R454C by 2%.

Figure 4 shows the discharge temperature variation of these refrigerants compared to R404A. R290 discharge temperature is + 4 K at MT, R454C and R455A are respectively +8 K and +12 K. While at LT, the discharge temperature variation is more than 10 K. As consequence, the operating envelope is slightly limited with R290 and even more so with R454C and R455A.

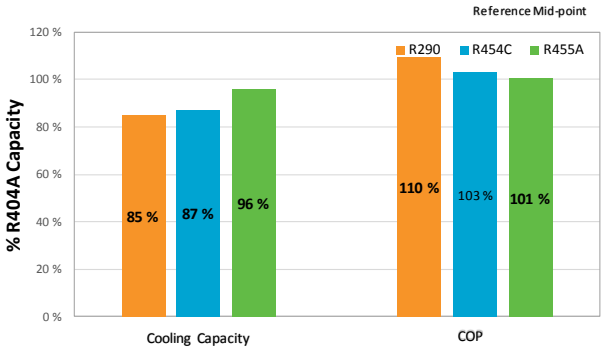

Figure 3

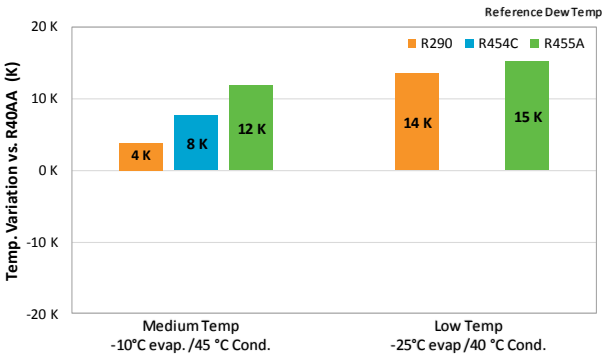

Figure 4

Scroll Performance for Heating

Figure 5 shows the performances at heat pump rating conditions compared to R407C. R290 and R454C have about 8 % less heating capacity and R455A is similar to R407C. While the COP is 1 to 2 % higher for R454C and R455A, it is 7 % higher for R290.
When considering the performance at mid-point (figure 6), R290 heating capacity drops by another 5% compared to R407C. R454C capacity decreases by 1% and R455A increases by 3% . There is a slight change of the COP within 2%.

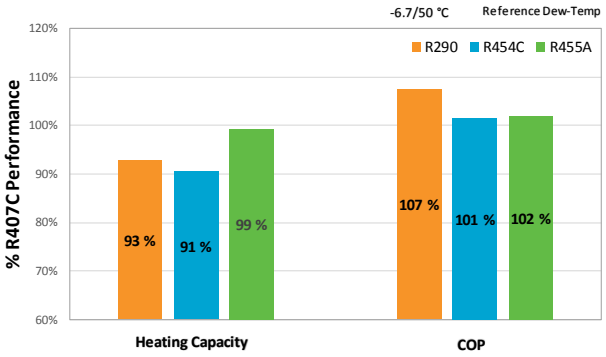

Figure 5

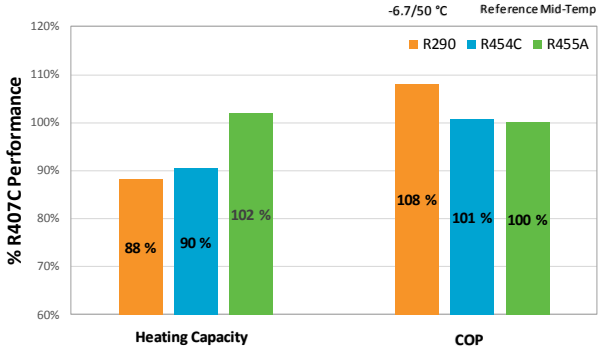

Figure 6

The discharge temperature represented in figure 7 is lower for all refrigerants compared to R407C. The low discharge temperature allows the extension of the operating envelope at low evaporating temperature.

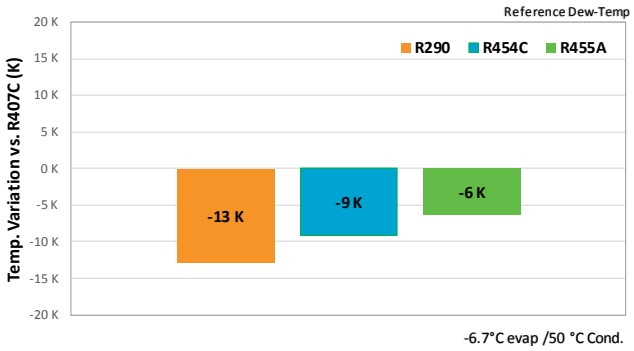

Figure 7

Impact of flammability on Scroll Compressor

When using flammable refrigerants, it is important to avoid leaks of the refrigerant which can create a flammable atmosphere once mixed with ambient air. In case of leaks, the electrical components must not be source of ignition.

The IEC60335-2-89 standard for commercial refrigeration systems is under revision to allow a higher charge for flammable refrigerant and to assess the risk consequent to using flammable refrigerants. Today's published standard does not differentiate between A2L and A3 refrigerants. In case of using electrical components source of ignition, they must be protected in accordance to IEC60079-15.

On the other hand, the IEC60335-2-40 standard revision for air conditioning and heat pump equipment is in an advanced phase and expected to be published early 2018. The standard will address the safety requirements of the electric components for both A2L and A3.

Scroll compressors are hermetically sealed and unlikely to be source of leaks. From this point of view, the choice of a hermetic compressor used with flammable refrigerants is appropriate. The electrical connections of the scroll compressor designed for commercial refrigeration and

heat pump are not source of ignition. This makes the compressor safe in case of leaks from the refrigerating system.

The pressure equipment directive (2014/68/EU) is more stringent when using flammable fluid. In this case, the PED category of the scroll compressor increases by one level. Therefore, additional requirements for quality system and production process need to be put in place.

Conclusion

Legislation is pushing the GWP of refrigerants to a low level, but at the same time requiring higher efficiency. The GWP threshold limit will vary by application. R290, R454C and R455A refrigerants have a GWP below 150 and could be considered as good candidates for the long-term.

R455A matches R404A and R407C capacity, whereas R290 and R454C are lower. All these refrigerants have a higher or comparable COP vs. today HFCs. The temperature glide of R454C and R455A will certainly require the review of the design of the heat exchanger to take advantage for improving the refrigerating system efficiency.

The discharge temperature of these refrigerants is lower than R407C which allows to extend today's application envelope. It is slightly higher compared to R404A and therefore limits the operating envelope, especially at low evaporating temperature.

The scroll compressor is not a source of ignition and could be considered as a safe component even when it is used in an explosive environment. More and more electronics, such as controllers and drivers, are part of the compressor package, major attention must be given to them as they could be a source of ignition

The scroll compressor falls in a higher PED category when using flammable refrigerants. Consequently, the manufacturing process is more restrictive.