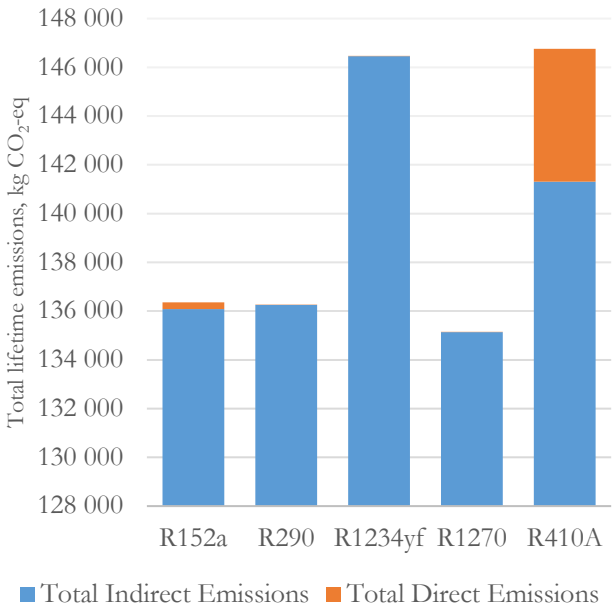
The opportunities and challenges of R152a. Part 2.

R152a is an example of a non-ozone depleting (or zero ODP) synthetic refrigerant with good thermodynamic properties. In the previous Kyla we have discussed the R152a from perspective of its thermodynamic properties and its performance in comparison to R134a and other alternatives. It was shown that it is a very energy efficient refrigerant and often outperforms other analogous alternatives in similar applications. In this article we will have a second look on the R152a from the perspective of its environmental properties and its flammability.

Environmental properties of R152a

It can be said that R152a is a very promising refrigerant from an environmental point of view: In addition to its low GWP value(138), it presents a high performance in refrigeration and air conditioning systems, and often outperforms other low GWP alternatives. Thus, all combined, the R152a total contribution to global warming used on a HVAC system is generally low. For instance, in a life cycle climate performance (LCCP) analysis of an air/water residential HP system with 30 kW rated heating capacity R152a showed to be one of the most environmentally friendly refrigerants in three different European locations [1] (Figur 1).



Figur 1 - Total lifetime CO_2-equivalent emissions associated with heat pump operation, colder climate example (Helsinki) [1]

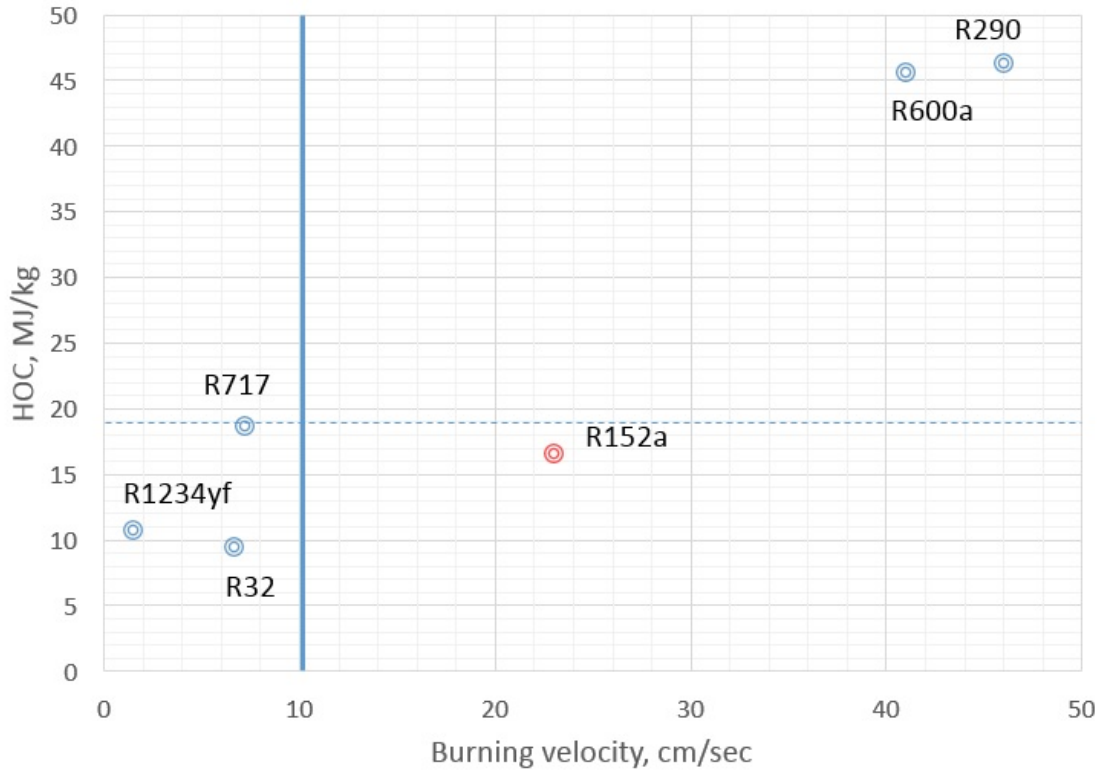
Safety of R152a

R152a has comparable toxicity to R134a as well as other synthetic refrigerants commonly used. However, the major negative safety aspect with R152a is its flammability. Tabell 1 lists some flammability properties of a number of known pure flammable refrigerants. Main parameters listed are lower flammability limit (LFL, minimum concentration of refrigerant that is capable of propagating a flame within a homogeneous mixture of refrigerant and air), heat of combustion (HOC), and burning velocity (BV, the maximum velocity at which a laminar flame propagates in a normal direction relative to the unburned gas ahead of it).

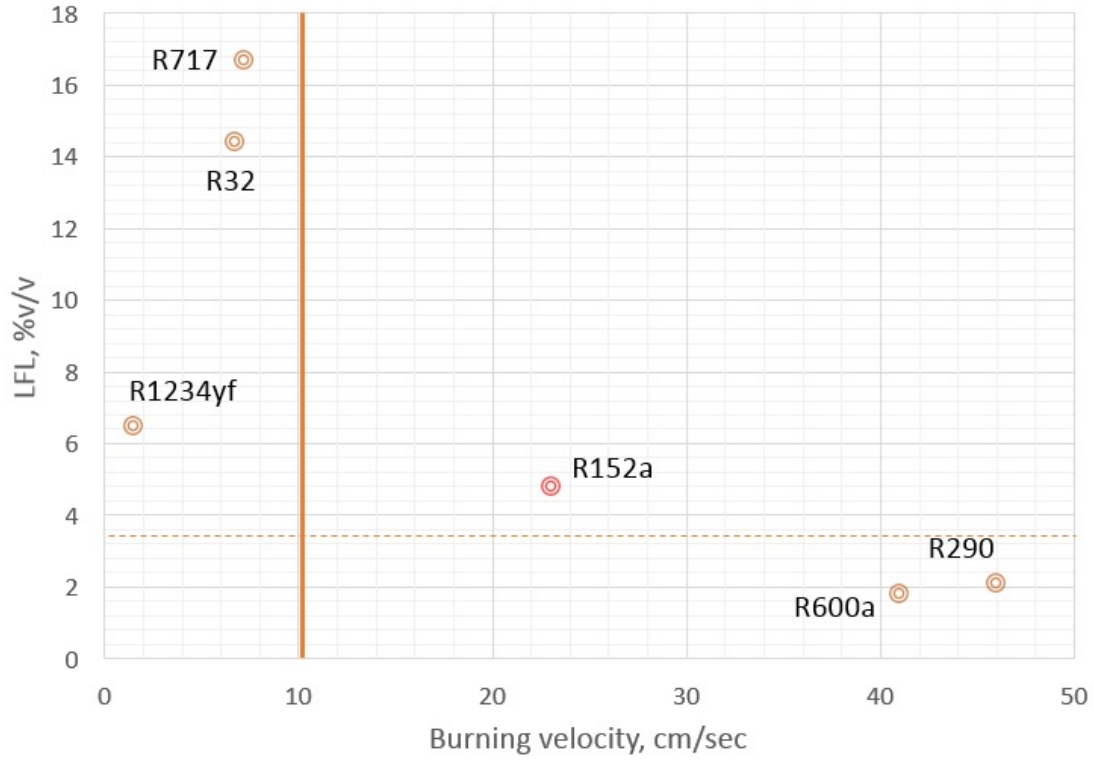
Please refer to our previous publication for more information on these flammability metrics [5] These values are visualized in the Figur 2 and Figur 3. It can be seen that the presented values are somewhat in between of more flammable hydrocarbons and less flammable A2L gases.

Tabell 1 – Flammability properties of R152a in comparison to other pure flammable refrigerants

Refrigerant	LFL, (% v/v)	BV, (cm/s)	HOC, (MJ/kg)	Safety Group
R1234yf	6,5	1,5	10,7	A2L
R32	14,4	6,7	9,4	A2L
R143a	8,2	7,1	10,3	A2L
R717	16,7	7,2	18,6	B2L
R152a	**4,8**	**23**	**16,5**	**A2**
R600a	1,8	41	45,6	A3
R290	2,1	46	46,3	A3



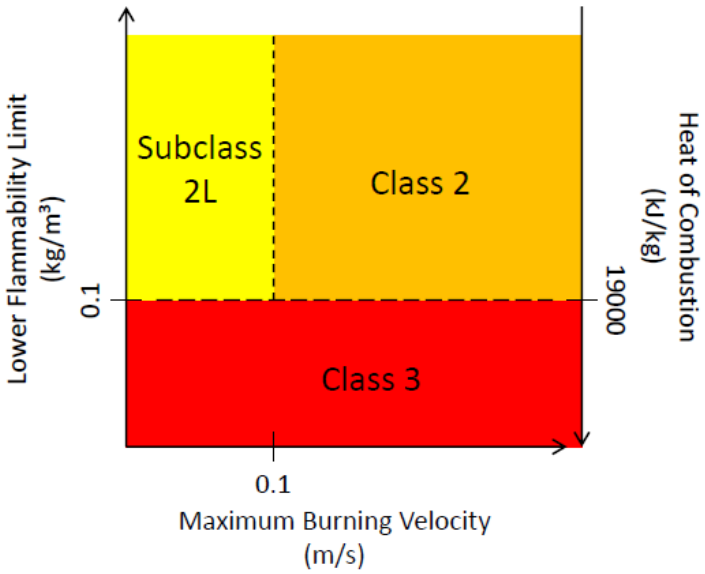
Figur 2 – Heat of combustion (HOC) of R152a in comparison to other pure flammable refrigerants



Figur 3 – Lower flammability limit (LFL) of R152a in comparison to other pure flammable refrigerants

A2L and A2 class boundary

According to the ASHRAE refrigerant classification, a refrigerant is considered to be flammable if it shows flame propagation when tested in air at 60°C and 101,3 kPa. If flammable, the refrigerants are subdivided into several flammability classes: higher flammability 3 class if has a LFL≤3,5% by volume or has a HOC that is ≥19 MJ/kg, otherwise a refrigerant is Class 2 “lower flammability”, with a 2L subclass valid for those Class 2 refrigerants, which have a maximum burning velocity of ≤10 cm/sec (Figur 4).



Figur 4 - Safety classification of flammable refrigerants [2]

The burning velocity threshold of 10 cm/s was chosen to identify substances with flammability similar to or lower than ammonia. Although ammonia has 7.2 cm/s burning velocity, it was considered that some measurement tolerance was necessary [3]. According to the BV limit, R152a is lower flammability refrigerant because its burning velocity is 23 cm/s and therefore it is not applicable to the 2L subclass criterion.

The short term situation can be worse for R152a. Recently, there have been reports of significantly different flammability characteristics for refrigerants with burning velocities in the range of 0 and 10 cm / s. This has resulted in proposals to reduce burning velocity boundary to 7 cm/s or 5 cm/s, where the 7 cm/s is related to the burning velocity of ammonia and the 5 cm/s is related to both the report of a rapid increase in minimum ignition energy at and below 5 cm/s burning velocity and the elimination of the possibility of a static discharge from a human as a possible ignition source [4].

Effects of humidity on flammability

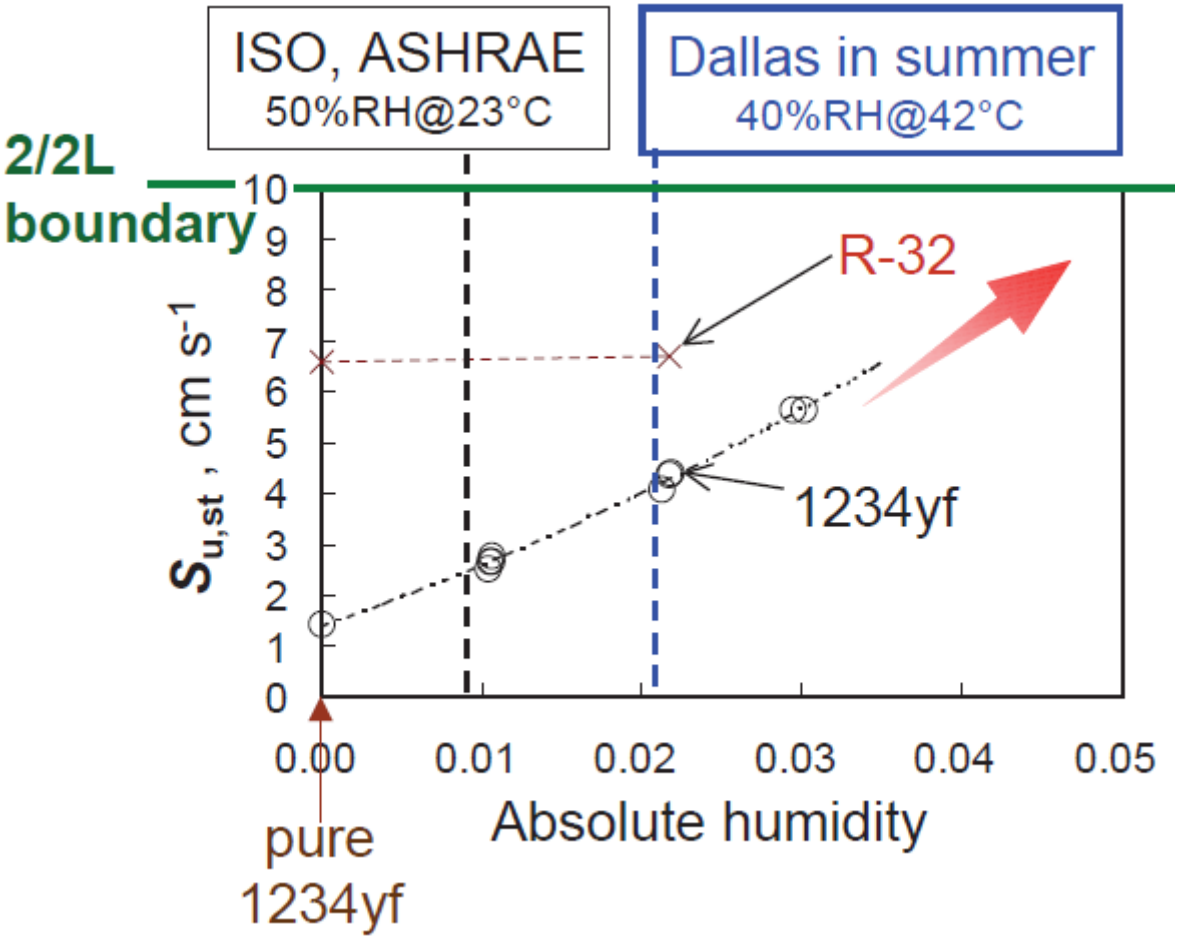
R152a is definitely a flammable refrigerant. So do all the other refrigerants in the Tabell 1. The difference between all these refrigerants in the probability of the fire and severity of the fire, when it occurs (which are quantified by a number of different metrics, including, but not limiting to, LFL, BV and HOC). Regardless of the chosen refrigerant careful consideration should be taken when using them in refrigeration equipment. This imply deeper understanding of flammability of the refrigerants and its behavior when applied to refrigeration systems. The research in this field is ongoing and we will come back to this topic in the future publications.

An example of the recent findings is the effect of the humidity on flammability. Dampened paper and woods are difficult to burn so flammability measurement in dry air may appear conservative. However, the combustion reaction of carbon is much faster when moisture is present. The reason is that the combustion of carbon decomposes water molecules to generate hydrogen and OH radical which transfer combustion energy and react rapidly.

If the number of fluorine atoms is more than that of hydrogen atoms in HFC compounds the generation of OH radicals is blocked by fluorine and the reaction rate is lower. However, if water molecules are available, the combustion of carbon becomes faster and results in a higher burning

velocity. In addition, the combustion products can undergo a hydrolysis reaction causing a higher heat of combustion [3].

HFCs with an unsaturated bond (HFO) have noticeable tendency of this effect. As shown in Figur 5, BV of R1234yf with dry air is only 1.5 cm/s, but in wet air it can reach 5.9 cm/s, while in the case of R32 the burning velocity do not change significantly at varying humidity. This finding suggests that in humid conditions R1234yf is more likely to ignite than R32 (due to lower LFL), and, when ignited, have comparable severity of flame (due to comparable BV and greater HOC).



Figur 5 – Effect of humidity on burning velocity of R234yf and R32 [3]

Using the example above we would like to highlight the importance of understanding the flammability characteristics of a substance "beyond the 2 or 2L". It is important not to limit understanding of potential safety concerns of flammable refrigerants to several discrete safety classes. A greater number of flammability characteristics are used to describe the flammability of a substance. Therefore, the design of safe refrigeration equipment should take into account all the available data. As many other flammable refrigerants are used these days, it seems therefore possible to use R152a in a limited amount of systems, where its flammability has been taken into account.

To sum up, R152a is a great refrigerant that is likely to be used in the future due to its favorable thermodynamic properties and low contribution to global warming. However, its major drawback is its flammability. With active research in the area of flammability it is likely to see this refrigerant to be used in the specially designed systems (but not as a retrofit refrigerant in existing systems).

Följ gärna våra publikationer och få vårt digitala nyhetsbrev. Anmäl dig genom att följa länken bit.ly/kth_ett.

References

[1] P. Makhnatch and R. Khodabandeh, "The Influence of Climate Conditions on Life Cycle Climate Performance of Low GWP Refrigerant Based Heat Pumps," ASHRAE Annual conference, 2014.

[2] P. Johnson, ASHRAE 2012 Annual Meeting Seminar 11.

[3] O. Kataoka, Safety considerations when working with 2L flammability class refrigerants, London, 2013.

[4] ASHRAE, Research Topic Acceptance Request: Defining the 2 / 2L Flammability Boundary in Standard 34, 2016.

[5] P. Makhnatch, R. Khodabandeh och B. Palm, ”Något om Köldmediers brännbarhet,” *KYLA+ Värmepumpar,* nr 04, Jun 2015.