The opportunities and challenges of R152a. Part 1.

In a way, R152a is the “unlucky” refrigerant that is often overlooked in favor to other refrigerants. It was considered as potential refrigerant during the transition from ozone depleting refrigerants in the 1990ties, and it was again considered as a replacement to R134a in mobile air conditioning systems a decade ago. Both times another refrigerant has been prioritized over the R152a. Why it happened and what makes R152a so special to renew the interest to it from time to time?

General considerations on R152a

The process of refrigerant selection is a constant tradeoff between a numbers of criteria. The preferences depend on the application, existing regulations and, often, the priorities given to one criterion or another. These days, when environmental properties of refrigerants are given high priority, some favor long term environmental benefits by selecting natural refrigerants and dealing with their eventual drawbacks in form of elevated flammability, toxicity or pressure levelsa. On the ontrary, some technicians prefer the available HFC/HFO alternatives in favor of their ease of implementation and thus agree to deal with their eventual environmental effects for the future. In this respect R152a falls in between of these categories as being both flammable and synthetic refrigerant which is therefore not chosen by many. For the very same reason R152a could potentially be a good compromise between these selection criteria.

R152a, 1,1-Difluoroethane, is refrigerant with rather low GWP value of 138 (AR5). Its applicability has been actively studied in the beginning of 1990ties as it was considered to be a potential replacement to R12 in medium temperature air conditioning systems. As we now know, R152a has lost to R134a and the latter become one of the most used refrigerants nowadays. Simultaneously, R134a has become the most abundant HFC gas in the atmosphere [1].

Due to the high GWP value of R134a, that it is nearly 10 times as high than R152a, it is now essential to replace it with lower GWP analogs. Interestingly enough, this issue has been pointed out prior to R134a wide adoption, when, for example, it was stated that “the global warming issue when discussing substitute fluids for CFCs was first stressed … … mainly when discussing HFC134a vs. HFC152a as a substitute for CFC12 in refrigerators. Because the GWP of HFC152a is one order of magnitude less and as it is also expected to have lower energy consumption than HFC134a, the fluid HFC152a with its lower global warming potential was favored by the Environmental Protection Agency. It was stated that, similar to the process which led to the Montreal Protocol on ozone-depleting substances via the Vienna Convention, a climate convention could lead to a global warming regulation, which, besides CO_2 and other greenhouse gases, could also affect HFC fluids, which are not under the control of the Montreal Protocol” [2]. Now, more than 20 years later we are still during the discussions of possibility to achieve global agreement of HFC reduction.

The interest to R152a renewed a decade ago when it was considered as a replacement to R134a in mobile air-conditioning applications. But again, another refrigerant has been selected as it allowed simpler transition without significant system modifications.

The question we ask us is what makes R152a to appear in the discussion every time when the potential refrigerant is searched for, and what stops it from being selected?

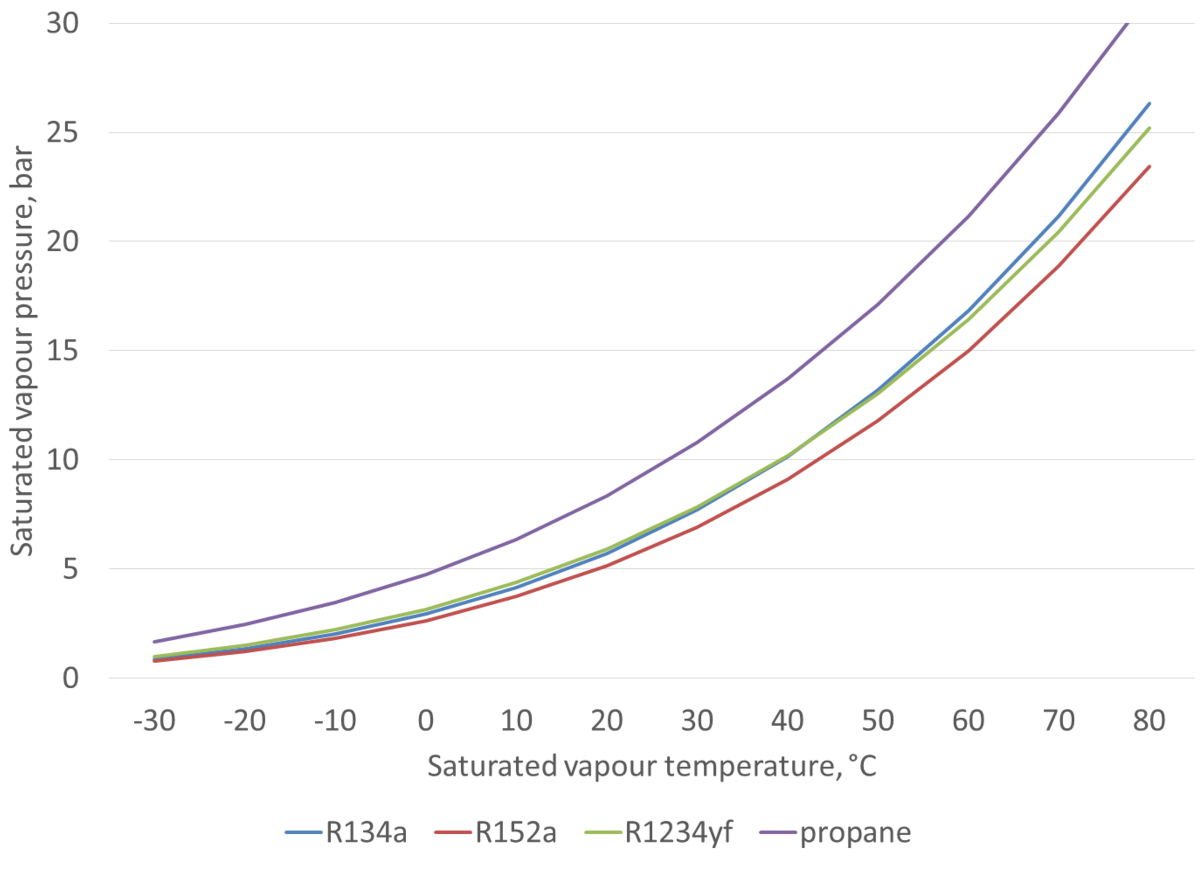
Thermodynamic properties of R152a

Looking at thermodynamic properties of R152a and some of the alternative refrigerants, we can see that R152a is the refrigerant with the lowest pressure compared to R134a, R1234yf and propane (R290) (see Figure 1 and Table 1). The difference between R152a and R134a is small and it is possible to say that R152a is likely to be alternative to R134a in medium temperature systems, where it mostly used these days.

R152a is more flammable than nonflammable R134a and mildly flammable R1234yf as it consists of a greater number of hydrogen atoms. Propane has double as many hydrogen atoms and therefore more flammable than R152a.

Normal boiling point of R152a is slightly higher than that of other alternatives, including R134a. But the difference between R152a and R134a is minor. That allows R152a to be used in the applications where R134a is used today. The critical temperature is higher as well, giving the possibility to use R152a in heat pump cycles with higher condensing temperatures.

The GWP of R152a is low. However, being fluorinated greenhouse gase, it is subject to the F-Gas regulation requirements.



Figur 1 - Saturated vapour pressure of R152a and analogous refrigerants

Tabell 1 - Main properties of R152a and analogous refrigerants

Refrigerant	**R134a**	**R1234yf**	**R152a**	**R290**
Chemical formula	$C_2H_2F_4$	$C_3H_2F_4$	$C_2H_4F_2$	C_3H_8
P_{crit} (Mpa)	4,06	3,38	4,52	4,25
T_{crit} (°C)	101,1	94,7	113,3	96,7

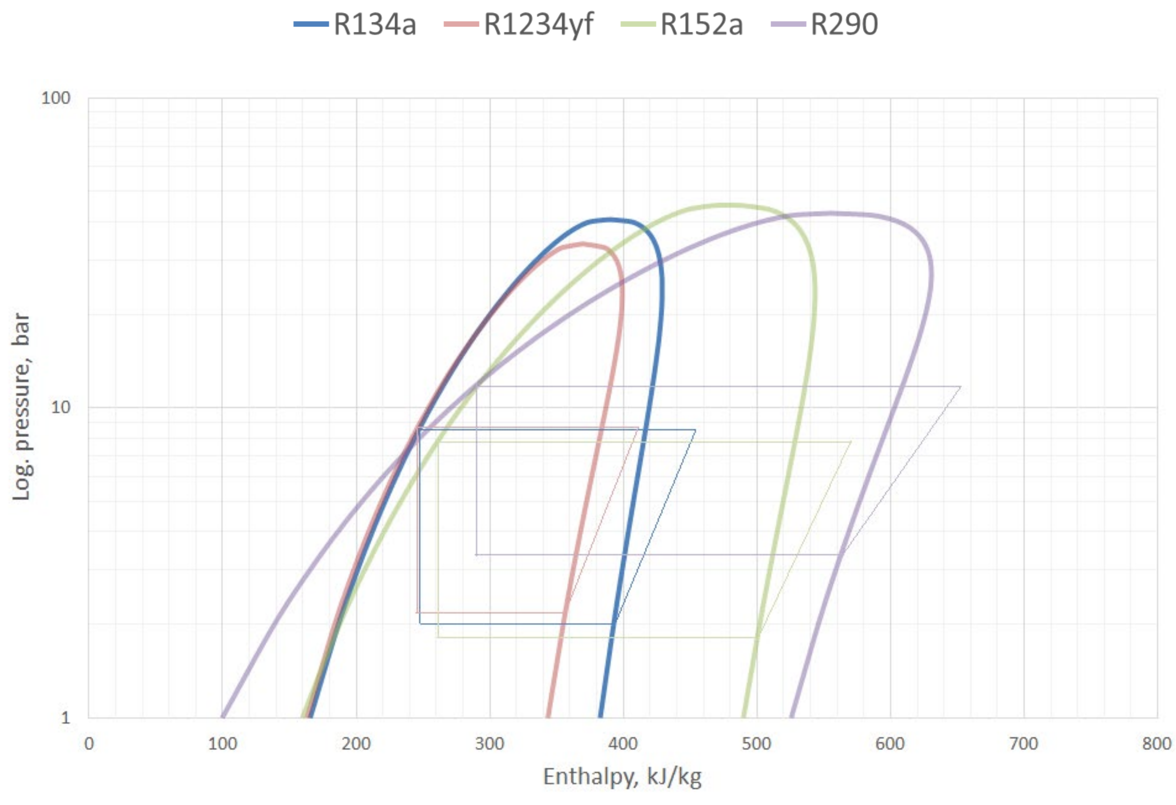
NBP (°C)	-26,1	-29,5	-24,0	-42,1
ASHRAE Safety group	A1	A2L	A2	A3
GWP (AR5)	1300	<1	138	3

Refrigeration cycle performance

R152a is further compared in simple refrigeration cycle with conditions of evaporating temperature of -10 ˚C, condensing temperature of 35 ˚C, and assumptions of no subcooling and superheat and 70% isentropic efficiency.

It can be seen (Figure 2, Table 2) that R152a is characterized by higher than R134a latent heat of vaporization (and therefore higher cooling effect). The refrigerant vapor mass density is, however, significantly lower. All in all, R152a has slightly lower volumetric cooling capacity and, therefore, will require slightly bigger compressor to cover similar cooling demand. The difference in mass densities will result that R152a mass flow is significantly reduced, compared to R134a. The reduced massflow also leads to pressure drop reduction in evaporator, that is confirmed by limited experimental studies [3].

Similar considerations apply to other presented refrigerants.



Figur 2 - Basic refrigeration cycle examples at T evap = -10 ˚C, T cond = 35 ˚C, no SH and SC, compressor isentropic efficiency 0.7

Tabell 2 – Basic refrigeration cycle properties at T evap = -10 ˚C, T cond = 35 ˚C, no SH and SC, compressor isentropic efficiency 0.7

Refrigerant	**R134a**	**R1234yf**	**R152a**	**R290**
P_{evap}, bar	2,01	2,22	1,82	3,45
P_{cond}, bar	8,87	8,95	7,94	12,18

PR, -	4,42	4,04	4,37	3,53
$\rho_{sat,v}$, kg/m³	10,0	12,6	5,9	7,6
q, kJ/kg	143,7	109,1	238,1	270,8
q_v, kJ/m³	1442,5	1369,9	1393,5	2066,9
COP	3,25	3,07	3,39	3,21
COP, % to R134a	-	-5,5%	4,3%	-1,4%

The COP of R152a in the presented cycle is the highest, and theoretically is 4,3% higher for a given cycle. The increase of the COP of R152a in comparison to R134a is also supported by a number of limited experimental studies. In a recent experimental study of R134a vapor refrigeration system, that has been retrofitted to R152a, the results shown the COP improvement of up to 13,2% (11,7% without IHX) when using R152a instead of R134a, despite the reduction of cooling capacity of about 10%. Other observations include lowering of refrigerant mass flow that can be up to 41,5% lower with R152a than R134a, and a slight increase of compressor discharge temperature of around 5 K, which will result in higher compressor thermal losses. During the study it was concluded that R152a can be successfully used for a drop-in replacement of R134a [4]. Another experimental study of R152a to replace R134a in a domestic refrigerator confirm the energy consumption benefits of R152a that has shown COP values 4,7% better than R134a on average [5]. It should be noted, that the amount of the experimental studies of R152a is very limited, especially if compared the amounts published for its analogs.

First impressions

From thermodynamic point of view R152a is suitable replacement to R134a and provides greater energy efficiency. Its major drawback is, however, its flammability. It is classified as A2 flammability class and therefore considered as more flammable than, for instance, R1234yf. Its good thermodynamic properties and low GWP are sometimes utilized in refrigerant mixtures, as for instance in refrigerant R444B, which is the mixture of R152a, R32 and R1234ze(E) which is developed to replace R22.

The safety and flammability of R152a is an interesting topic in itself and therefore will be a focus of our publication in the next Kyla.

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References

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