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Characteristics of Some New Generation Refrigerants with Low GWP

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Abstract

In the present study, a comparison was considered about some characteristics of new generation low GWP value gases most of which are at the trial stage. Hydrofluoro-olefin (HFO) based mixed gases having low GWP value were investigated as alternatives to different four refrigerants used commonly in refrigerating and air conditioning equipments. In the study, R450A, R513A, R1234yf and R1234ze(E) gases were used instead of R134a; DR-33, L40, DR-7 and R448A were used instead of R404A; DR-5 and R447A were used instead of R410A; and N20 and R444B refrigerants were used as alternatives to R22. Refrigerants were compared within their own groups in terms of liquid density and viscosity properties.

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Keywords: HFO; GWP; refrigerants

1. Introduction

Many factors are considered in refrigerating fluid selection. Removal of chloride and fluoride containing gases is aimed with Montreal Protocol due to ozone depletion potential (ODP). Usage of some refrigerating fluids is limited with Kyoto Protocol [1] due to their contribution to sera gas formation. However, owing to some regulations and limitations in the recent years, tendency to refrigerants having low global warming potential (GWP) has increased. Along with EU F-gas regulation, usage of gases lower than 150 GWP value has become mandatory for the vehicle air conditioning systems [2]. Obligation of low GWP value refrigerating fluid using has increased new gas search for different systems (refrigeration, air conditioning, cryogenic, etc.). In addition to low GWP value, enabling of the desired capacity with lower gas charge is important in terms of environmental effect. Despite of the production of low GWP gases for different systems, most of them are at the trial stage. Major manufacturers collaborate in this matter.

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The phase out process for the CFC and HCFC gases has been started due to the adverse effect of those refrigerants on the ozone layer and global warming. It is not sufficient to use gases having low GWP and ODP of zero value for decreasing sera gases. At the same time, in the selection of refrigerating fluid, refrigerants with thermodynamic properties such as high vaporizing temperature and high gas density should be preferred for capacity improving and low energy consumption. Otherwise, an increase in sera gas amount can be caused indirectly as a result of high energy consumption.

Considering the studies in which utilization of refrigerating fluid with low GWP value instead of available refrigerants, Mota-Babiloni et al. [3] theoretically investigated the efficiency values of HFO based new gases such as L40, DR-7 and R448A for the different refrigeration systems. They have stated that according to the simple transition, DR-7 has a COP value 10% higher than R404A for the evaporation and condensing temperature values of -10°C and 40°C, respectively [3]. One of the major candidates is R1234yf as a substitute for R134a used in the automotive industry [4]. Among HFO derivative gases, it is the refrigerant commercialized first and still in use. Therefore, most of the studies on gases with HFO have focused on R1234yf and R1234ze [5-10].

In the present study, properties of new generation refrigerating fluid mixtures with hydrofluoro-olefin bases, and their environmental effects were compared. Suggestions were made according to the usage purpose.

2. Environmental impacts

2.1. ODP

The greatest environmental effect-is the destruction of the ozone layer by the chemical gases. Decrease or removal of this layer which functions as a filter against harmful ultra violet rays can damage life on earth profoundly. After the exploration of the damage caused on the ozone layer by chlorine based gases, removal of this type of gases has been planned with Montreal Protocol. ODP of R11 gas, which is in CFC group, has been accepted as 1 and used as a reference value. ODP of R22 gas, which is in HCFC group, is 0.055 [11].

2.2. GWP

Another environmental impact is high GWP value which is used to measure greenhouse effect of a gas based on its radiative properties relative to CO_2 in a given time frame.

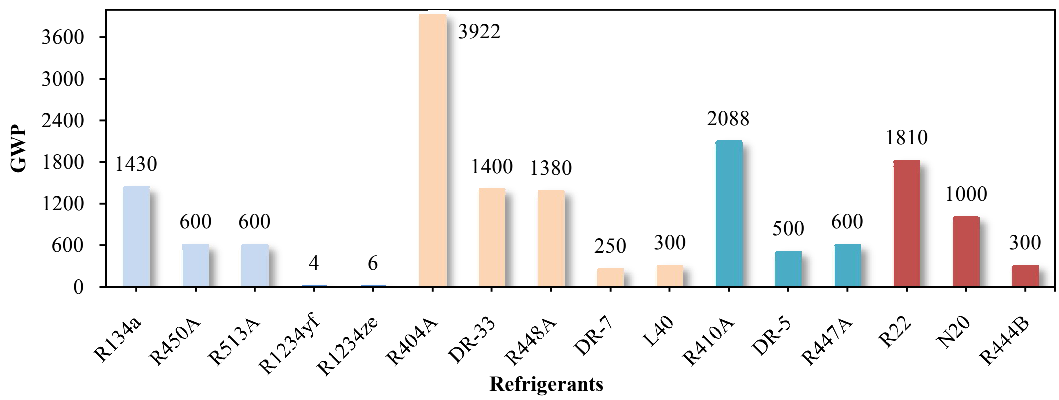

Fig.1. GWP values for the refrigerants.

The GWP of CO_2 is 1 [12]. Refrigerants having high GWP are not preferred since they stimulate sera gas formation and increase global warmth [13]. The GWP depends on the infrared radiation absorption of the refrigerant, gas lifetime in the atmosphere, and the selected time frame. Thus, the same gas can have different GWP for different time frames with 100 years normally used as the standard time frame [12]. Comparison of GWP values of the refrigerants used in this study is shown in Figure 1 which illustrates the comparison of four main refrigerating fluids and the fluids that could be used instead of them. In Figure 1, it is clear that 58% decrease of GWP can occur by using R513A instead of R134a.

3. Refrigerants

In this study, refrigerants widely used in vapor compression refrigeration systems were investigated. Although each gas is used for different processes, R134a gas is used in small capacity refrigerators and chiller equipment generally, R404A is used in cool-store equipment, R410A is used in air conditioning equipment (cooling and heating), and R22 is used in both refrigerating and air conditioning devices. The properties of four main refrigerating fluids according to different application fields and the alternative refrigerants with low GWP values are given in Table 1. Some properties were determined by Refprop [14]. When critical temperatures and pressures of main refrigerant and alternative gases are reviewed, it is clear that the values are similar. It is seen that some of the candidate gases are mildly flammable according to ASHRAE safety class [15, 16]. This property will be limiting for usage in some applications.

Table 1. Physical properties of the investigated refrigerants

	Composition	Mass%**	ASHRAE safety class	Boiling T (°C)	Critical T (°C)	Critical P (MPa)	Glide
R134a	R134a	100	A1	-26.07	101.06	4.06	0.0
R450A	R134a/R1234yf/R1234ze	42/18/40	A1*	-25.6	100.18	3.74	0.1
R513A	R134a/R1234yf	44/56	A1*	-27.9	97.51	3.67	-0.3
R1234yf	R1234yf	100	A2L	-29.45	94.70	3.38	0.0
R1234ze(E)	R1234ze	100	A2L	-18.97	109.36	3.63	-0.2
R404A	R-125/R-134a/R-143a	44/4/52	A1	-46.50	72.12	3.73	0.8
DR-33	R-32/R-125/R-134a/R-1234yf	24/25/26/25	A1*		85.02	4.48	
R448A	R-32/R-125/R-134a/R-1234yf	25/25/20/30	A1*	-38.50	84.62	4.47	5.2
DR-7	R-32/R-1234yf	36/64	A2L*	-37.90	89.17	4.55	5.1
L40	R-32/R-152a/R-1234yf/R-1234ze(E)	40/10/20/30	A2L*	-22.00	89.89	4.84	19.5
R410A	R-32/R-125	50/50	A1	-51.40	71.34	4.90	0.1
DR-5	R-32/R-1234yf	72.5/27.5	A2L*	-45.40	83.11	5.40	3.9
R447A	R-32/R-1234ze(E)	73/27	A2L*		80.45	5.35	
R22	R22	100	A1	-40.81	96.14	4.99	0.0
N20	R-32/R-125/R-134a/R-1234yf/R-1234ze(E)	12.5/12.5/31.5/13.5/30	A1*	-31.70	91.87	4.19	5.9
R444B	R-32/R-152a/R-1234ze(E)	45/20/35	A2L*	-36.70	90.56	5.07	7.60

*A2L: Mildly Flammable, A1:Non-flammable, * estimated, ** [17].*

4. Results

P-h diagrams shown in Figure 2 were plotted with respect to thermodynamic properties in Refprop program. As it is clear in Figure 2a, where R134a gas is compared with the alternatives, specific refrigerating effect of R134a for the same phase change temperature is higher than that of other gases. The refrigerants observed as most close to R134a are R450A and R1234ze(E).

With the same perspective, it can be stated that L40 and DR-7 in Figure 2b are much better than R404A. It is obvious that R448A and DR-33 refrigerants having better specific refrigerating effect in comparison to R404A have almost similar characteristics. In Figure 2c, comparison of R410 with DR-5 and R447A gases are considered, and it is evident that specific refrigerating effects of low GWP refrigerants are higher than that of R410A. The investigation of R22, R444B and N20 in Figure 2d presents that specific refrigerating effect of R444B is higher than that of R22. In the same plot, it can be stated that N20 having low GWP has similar properties as R22. Cooling capacity of the refrigerating fluid with high specific refrigerating effect can be high as well [18].

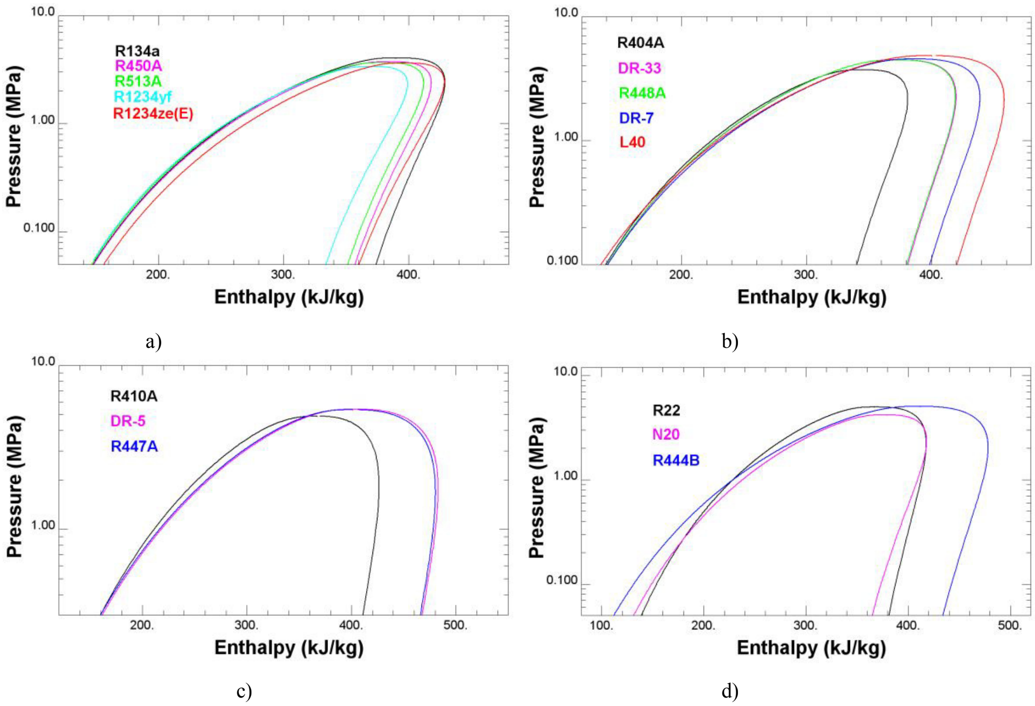

Fig. 2. Pressure-enthalpy diagram of the refrigerating fluids a) R134a and its alternatives b) R404A and its alternatives c) R410A and its alternatives d) R22 and its alternatives

It is seen that critical point temperatures of R134a and its alternatives are very close to each other. R410A has a lower critical point temperature than that of its alternatives.

Another factor affecting the cooling capacity is the mass flow rate of the refrigerant which circulates in the system. The reduction in liquid density will significantly decrease the amount of refrigerating fluid charge [17]. The change of fluid density with temperature is depicted in Figure 3. R1234yf and R513A refrigerants with less need for fluid charge and with lower liquid density can meet cooling capacity compared to R134a. The liquid density values of alternative refrigerants for R134a are also lower.

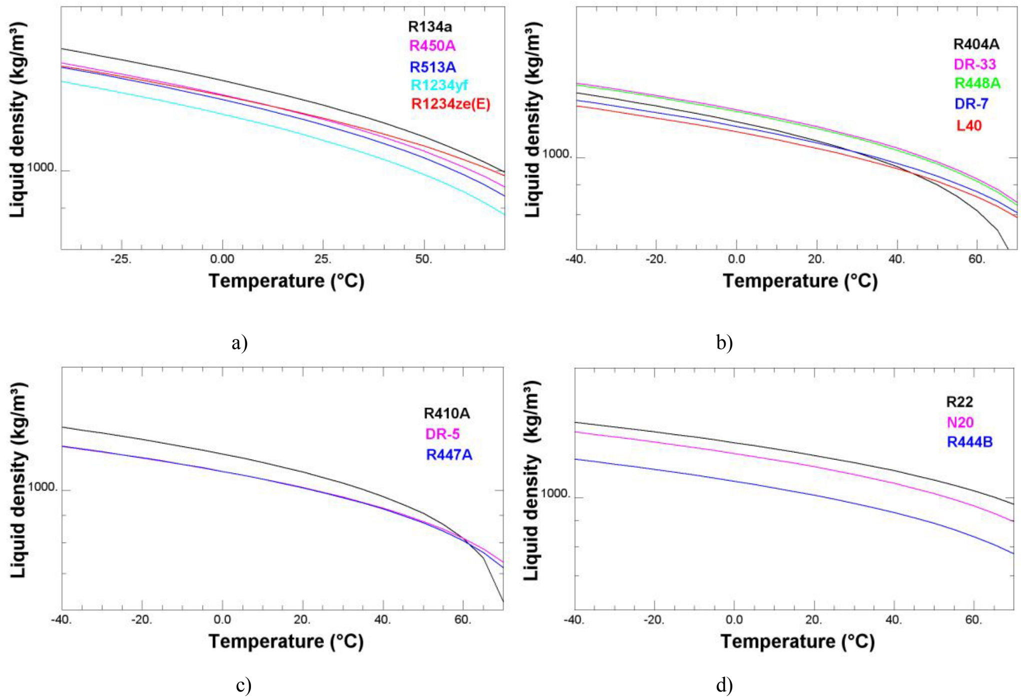

Fig. 3. Variation of liquid density with temperature for the refrigerating fluids a) R134a and its alternatives b) R404A and its alternatives c) R410A and its alternatives d) R22 and its alternatives

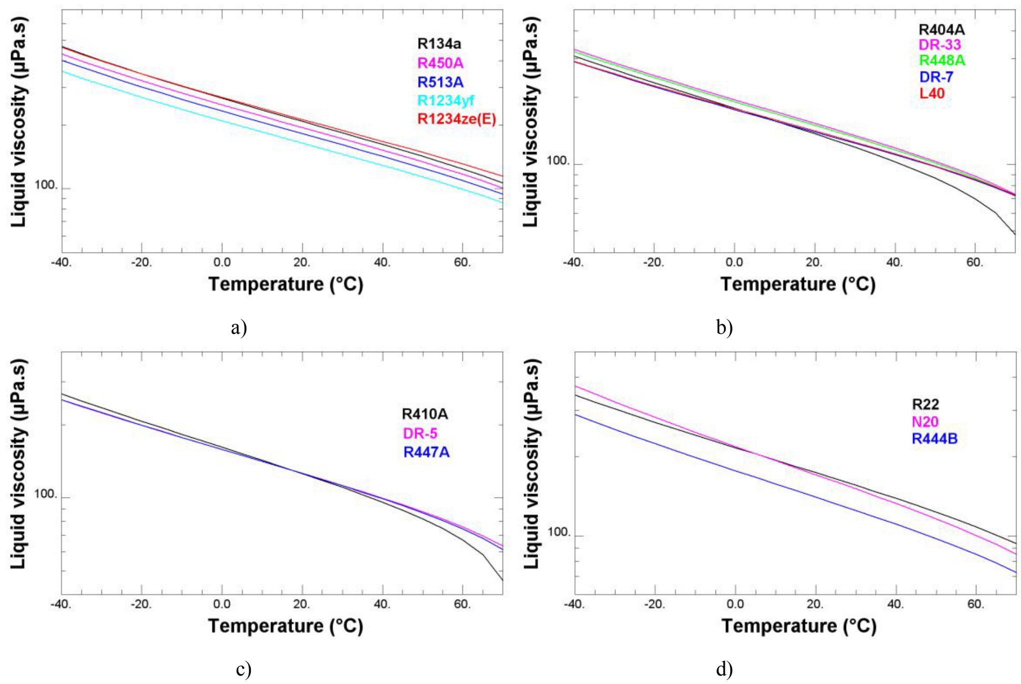

Fig. 4. Variation of liquid viscosity with temperature for the refrigerating fluids a) R134a and its alternatives b) R404A and its alternatives c) R410A and its alternatives d) R22 and its alternatives

Another variable which is one of the transport characteristics of refrigerating fluids is liquid viscosity. Low viscosity means low friction and the system can consume less energy. The variation of viscosity with temperature is demonstrated in Figure 4 for the investigated refrigerants. It is seen in Fig. 4a that liquid viscosity of R1234yf, R513A and R450A is lower than that of R134a. Based on this result, new refrigerants with low GWP have lower friction in comparison to R134a. Figs. 4 (b,c) indicate that liquid viscosity values of the refrigerants those can be used as alternatives to R404A and R410A are very close to each other. In Fig.4d, R444B with low GWP value is distinguished with lower liquid viscosity compared to R22.

5. Conclusion

In the selection of refrigerating fluids, in addition to low GWP consideration, gases with better energy characteristics should be preferred because of their limiting characteristics. The study represents that all new alternative gases are better regarding their lower GWP values. Although they have some differences in terms of energy parameters, it can be stated that R1234yf, L40, DR-5 and R444B refrigerants can be good alternatives to R134a, R404A, R410A and R22, respectively. Since there is no system to take place of vapor compression refrigeration cycles in the medium term, proper gas search should be conducted and test of gases commercially provided to the market should be carried out.

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