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CONSIDERATIONS ON ADOPTING R 404A INSTEAD OF R22 ON REEFERS

MITU, D[aniela] - E[lena] & MEMET, F[eiza] S[ucuran]

Abstract: *R 22 is one of the dominant refrigerants for marine applications. This refrigerant is a HCFC chemical; its substitution in the marine sector demands efforts done to indicate the right refrigerant. On reefers (refrigerated ships), the substitutes for R 22 are R 410 A, R407 C and R 404 A, since a single ideal refrigerant is not nominated. Available literature shows that R 404 A can be used in best conditions as a substitute for R 22. Thus, in this paper is given a comparison between R 22 and R 404 A resulting alike properties. In time of crisis, the maintenance of the existing R 22 equipment provides an economic benefit. This study deals also with the retrofit aspect*

Key words: *reefers, friendly environmental refrigerant, property, equipment*

1. INTRODUCTION

Reefer transport is defined as the maritime transport of perishable cargo that asks climate control during transport in order to reduce product deterioration. Emitted CFC and HCFC refrigerants have been directly connected to the destruction of stratospheric ozone. International regulations have been adopted in order to phase out the production and consumption of the refrigerants for the protection of the stratospheric ozone layer.

All marine refrigerating systems working with R22 cannot be maintained, serviced or topped up with new refrigerant after January 1, 2010. Between January 1, 2010 and January 1, 2015, recycled HCFC may be used. After January 1, 2015, the use of HCFCs is completely banned on E.U. flagged vessels.

2. THE ENVIRONMENTAL ISSUE

The vast majority of marine refrigerating equipment is vapour compression systems that use ozone depleting substances like CFCs and HCFCs. Refrigerants like CFCs, HCFCs and HFCs are potent greenhouse gases.

2.1 About the ozone layer

The Convention signed in Vienna (1985) pointed out the need of the progressive phase-out of ozone depleting substances, contributing to the signing of the Montreal Protocol, in 1987. In the following 15 years, this Protocol was signed by several stakeholders, being quickly implemented due to the involvement of governments, industrial stakeholders, manufacturers and users of refrigerants.

The Protocol started research works in order to be found new refrigerants, the so called "green refrigerants", having no impact on the ozone layer (like HCFCs). Also, some works focused on the rediscover of forgotten refrigerants (like NH_3 and CO_2), that might be successfully used with some technical improvements.

HCFCs are mild Ozone Depleting Substances as compared to CFCs. Their ODS potential is only about 5% of that CFCs (Spatz & Soffientini, 2010).

Family of refrigerants	Main refrigerants	ODP
CFCs	CFC 11 (R 11)	1
	CFC 12 (R 12)	1
HCFCs	HCFC 22 (R 22)	0,05
HFCs	HFC 134 a (R 134 a)	0
	HFC 404 A (R 404 A)	0
	HFC 407 C (R 407 C)	0
	HFC 410A (R 410 A)	0
Natural refrigerants	NH_3 (R 717)	0
	CO_2 (R 744)	0
	Hydrocarbons	0

Tab.1. Refrigerants' impact on the ozone layer

HCFCs phase out helps ozone layer protection as well as climate change, but more than that it helps the economy. The impact of some refrigerants on the ozone layer is given in Table 1.

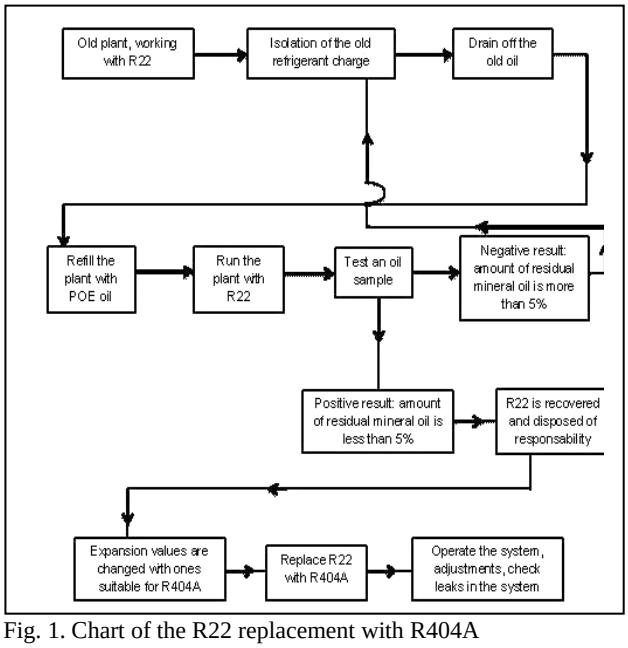

Fig. 1. Chart of the R22 replacement with R404A

2.2 Global warming

Rising global temperature measurements and their correlation with the increase in CO_2 in the atmosphere led researches to observe that human activity release gases that significantly increased the natural greenhouse effect around the Earth. This situation led to the signing of the Rio Convention, in 1992, then the Kyoto Protocol in 1997. CFCs have been replaced by HCFCs. These also have an ozone depleting and a global warming potential, but much lower. Other substitutes are HFCs. These have only a global warming potential (GWP), very close to the GWP of HCFCs, on the average. These replacements revealed a diminishing of more than 25% of global greenhouse emissions compared to 1990. The main

concerns of the marine refrigerating sector might be resumed to the reduction of the direct effect of refrigerant emissions and the reduction in the energy consumption of the refrigeration systems (Memet & Mitu, 2010). The impact of some refrigerant on the global warming is given in Table 2.

Family of refrigerants	Main refrigerants	GWP
CFCs	CFC 11 (R 11)	4750
	CFC 12 (R 12)	10890
HCFCs	HCFC 22 (R 22)	1810
HFCs	HFC 134 a (R 134 a)	1430
	HFC 404 A (R 404 A)	3900
	HFC 410A (R 410 A)	2100
Natural refrigerants	NH_3 (R 717)	< 1
	CO_2 (R 744)	1
	Hydrocarbons	20
	Water	0

Tab. 2. Refrigerants' impact on the global warming

For the two widely spread R 12 and R 22 in marine refrigeration, the time schedule of Montreal Protocol is as follows:

Refrigerants	Industrialized countries	Developing countries
CFC 12 (R 12)	Forbidden since 1996	Forbidden in 2010
CFC 22 (R 22)	Forbidden in 2020	Forbidden in 2030

Tab. 3. Regulations of the Montreal Protocol

3. KEEPING THE EXISTING EQUIPMENTS IN THE REFRIGERATING TRANSPORT

A wise option in time of crisis is keeping the existing plant and replacing R22 with a HFC refrigerant. This inexpensive solution is not available for all HFCs, but might be adopted when choosing R404A, a HFC which dominates the refrigerated transport. The replacement of R22 in this case can be followed according for the chart depicted in Figure 1.

R404A is a chlorine free mixture, able to replace HCFCs in refrigerated transportation. It is defined by the components R125/R134a/R143a (mass%: 44, 4; 52). Discussing about the most encountered HCFC retrofitting case in the refrigerated transport, meaning R22 to be changed by R404A, the comparison between thermal and energetic performances can be seen in Tables 4-8. R 404 A's vapor pressure is slightly higher than R 22 making it a potential choice for retrofitting existing equipment; the thermodynamic cycle efficiency is similar in both cases. Specific refrigerated capacity and specific mechanical work have comparable values, making also the retrofitting possible. Heat transfer analysis shows slightly lower performances for R 404 A (Spatz &Soffientini, 2010).

Evaporating temperature -35^{0}C; Condensing temperature -35^{0}C	R 22	R 404A
Discharge pressure (bar)	14,07	16,78
Discharge temp (^{0}C)	197,0	123,5
Cooling capacity (KJ/m^3)	619	705
% of R-22	100	114
COP	1,27	1,27
Compression ratio	11,4	10,7
Temperature glide (^{0}C)	0	0,5
Flow rate	5,67	7,57
Mineral oil	Yes	No
POE	Yes	Yes

Tab. 4. Comparative performances in refrigeration

t_o	Specific refrigerated capacity		Specific mechanical work	
	R22	R404A	R22	R404A
-40	652	550	382	358
-30	1000	803	518	450
-20	1550	1249	614	545
-10	2500	2002	709	654

Tab. 5. Thermal properties of R22 an R404A, for different evaporating temperatures

t_0 ^{o}C	t_c ^{o}C	Deviation, %
-10	50	16,2
-20	45	14,2
-30	40	11,3
-40	35	10,6

Tab. 6. Deviation of specific energy consumption – comparison between R22 and R404A

Mass flux (Kg/ m^{2}s)	80	180	280	380	480
R 22	4000	5800	7300	8000	9700
R 404 A	3840	4600	5900	6300	7000

Tab. 7. Average evaporation coefficient for a tube diameter of 8 mm and an evaporation temperature of 267 K

Mass flux(Kg/ m^{2}s)	80	180	280	380	480
R 22	1000	1800	2500	2900	3800
R 404 A	980	1200	1800	2500	3000

Tab. 8. Average condensation coefficient for a tube diameter of 8 mm and a condensation temperature of 317K

4. CONCLUSION

Refrigerated transport is an essential activity for our society. International regulations determined this sector to action in order to replace R 22, a spread hydro chlorofluorocarbon (HCFC) from the specific equipments. Presented comparison indicates thermodynamic similarity between R 22 and R 404 A.

Keeping the existing equipments in the refrigerating transport is a cheap solution in time of crisis, available for R 404 A, but not for all HFCs. It was given steps to be followed for the replacement of R 22 with R 404 A.

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