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COMPARISON OF THERMOPHYSICAL PROPERTIES OF HFC 125, 32 and 143a

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INTRODUCTION

The Montreal Protocol has regulated the production and use of fully halogenated refrigerants which take place in the ozone layer destruction process.

CFC-115 and consequently CFC-502 (azeotropic mixture of HCFC-22 and CFC-115) is one of these compounds. Several binary and ternary mixtures (azeotropic or near azeotropic) have already been proposed to replace CFC-502 in commercial refrigeration and especially supermarkets. All these mixtures are based on new HFC 125, 32 and/or 143a.

The objective of this work is to provide properties of these important pure refrigerants which can be used for prediction of the properties of the new mixtures.

PHYSICAL PROPERTIES

Main physical properties of the new HFC's are reported in table I.

Vapor pressure

The comparison of saturation pressures over a large temperature range is shown in figure 1. Values have been compiled from /1/ for HFC-32 from /2/ for HFC-125 and from /3/ for HFC-143a.

It shows that HFC-125, HFC-32 and HFC-143a exhibit higher saturation pressures than CFC-502 even for as low saturation temperature as - 40°C, larger values being observed with HFC-32. HFC-125, 32 and/or 143a will generally generate blends with high saturation pressures

This is certainly an advantage in the case of a leakage in the refrigeration system, in order to avoid introduction of humidity and air in the system.

But this should result in a few "hardware" changes in regulation devices and compressors technologies.

At higher temperatures, the higher pressures of HFC-32 and 125 blends will also necessitate materials of extra thickness for pipes and vessels normally used in refrigeration.

For instance at 50°C, the following condensing pressures are developped :

. 25,3 bars for HFC-125
. 31,4 bars for HFC-32
. 23,0 bars for HFC-143a

(to be compared to 21,0 bars for CFC-502).

HFC-125 and HFC-32 have pressures higher than 25 bars which is generally the maximum pressure accepted.

Saturated liquid density

Comparison of saturated liquid density over a large temperature range is shown in figure 2. Values have been compiled from /1/ for HFC-32 from /2/ for HFC-125 and from /3/ for HFC-143a.
It shows that both HFC-32 and HFC-143a exhibit smaller saturation liquid density (23 to 28 % comparing to CFC-502).

Consequently for HFC-32 and HFC-143a blends :

- given storage containers will hold lower mass of HFC-32 and/or HFC-143a mixtures than CFC-502.

- receivers will have to be redesigned

- transfer pumps, regulation devices and transfer lines will have to be recalibrated.

Among the 3 studied substitutes, HFC-125 offers the better match to refrigerant 502 density.

Water solubility in refrigerant

Values are reported in table I these values have been measured by the dew point method /4/ ; because of the presence of hydrogen atoms in their structure, the new refrigerants are slightly more hygroscopic than CFC-12 ; this is also the case for CFC-502.

During transfer of the fluid from the storage container into the charging boards and the systems, HFC's mixtures will have a greater tendency to pick-up humidity from the air.

However, solubility of water in HFC's is very small comparable to CFC-502 ; this is compatible with the constraints of refrigeration and air conditioning industry, if sufficient care is taken during handling of these refrigerants.

TRANSPORT PROPERTIES

Table II summarizes main transport properties of the new refrigerants.

HFC-125 has the lowest surface tension (36 % less than CFC-502); as a result, it can be expected a greater "wetting power" which is favorable for evaporation process and deals better heat transfers.

Although higher, the surface tension of HFC-32 and HFC-143a are still acceptable, of the same order of magnitude as the one of HCFC-22 for instance.

For both HFC-32 and HFC-143a specific heat of saturated liquid is higher than the one of CFC-502 (45 % in the case of HFC-32, 5 % for HFC-143a) denoting a greater need of frigory to cool down the hot liquid refrigerant when passing through the expansion device.

Figure 3 gives a comparison of liquid viscosity of the new HFC's over a wide range of temperature. These values have been compiled from /6/ for HFC-32, from/7/ for HFC-143a and from /2/ for HFC-125 ; liquid viscosities of all refrigerants are lower than those of CFC-502, with much lower values for HFC-143a (33 to 37 percent decrease) ; loss of pressure will be lower in the case of HFC-143a mixtures that will permit to reach lower temperatures at the evaporator.

Figure 4 represents variation of liquid thermal conductivity of refrigerants (from /8/ for HFC-32, /9/ for HFC-143a and /2/ for HFC-125).

Except for HFC-125 which has lower values, liquid thermal conductivities of new refrigerants are higher than those of CFC-502 over the whole range of temperature.

(from 145 % to 195 % increase for HFC-32
from 20 % to 32 % increase for HFC-143a)

Heat exchanges will be more rapid and more efficient for HFC-32 and HFC-143a mixtures.

BEHAVIOR WITH ELASTOMERS

Investigations were made according NFT 46 013 standard on NBR, Hypalon(R) and Neoprene(R) for 15 days at 25°C with pure refrigerants. Results are reported in table III.

Swelling and tensile strength tests show that HFC-32, 125 and 143a, unlike CFC-502, have generally little or no effects on these elastomers.

MISCIBILITY WITH LUBRICANTS

Screening investigation was made in a glass tube fitted with a valve for introducing the refrigerant ; the tube was slowly cooled from + 25°C to - 30°C until the refrigerant comes out of the oily phase.

Results are reported in table IV.

For the new HFC, both mineral oil and alkylbenzene oils present a very poor miscibility at low temperature. Except for 143a with low concentrations in lubricant, all HFCs have very good miscibility with ester tested (Neopentyl type). This is very promissing for the future because all the know how accumulated now on these new synthetic lubricants and HFC-134a will be extrapolated to these new HFC mixtures.

CONCLUSION

HFCs-32, 125 and 143a have very similar thermophysical and chemical properties than CFC-502.

One can expect that the use of mixtures based on these new HFCs will only require few adaptations of the systems, for both retrofit and new installations uses.

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Figure 1 : *VAPOR PRESSURE*

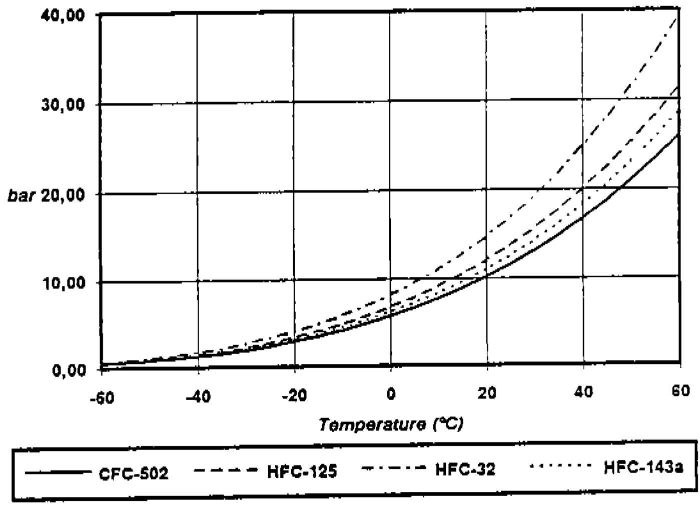

Figure 2 : *SATURATED LIQUID DENSITY*

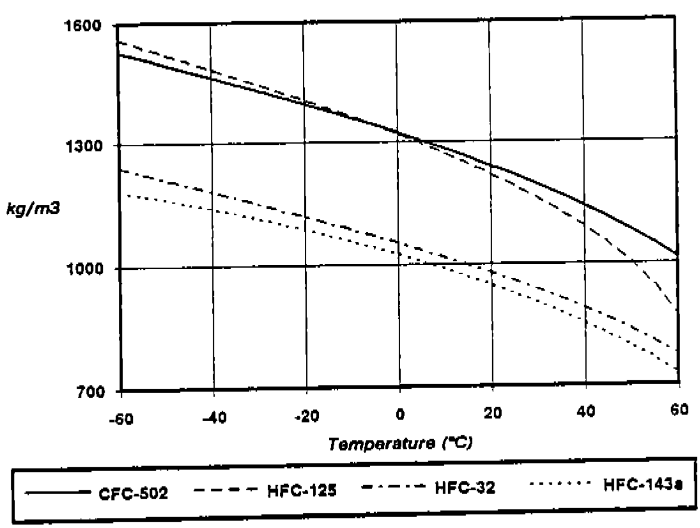

Figure 3 :

LIQUID VISCOSITY

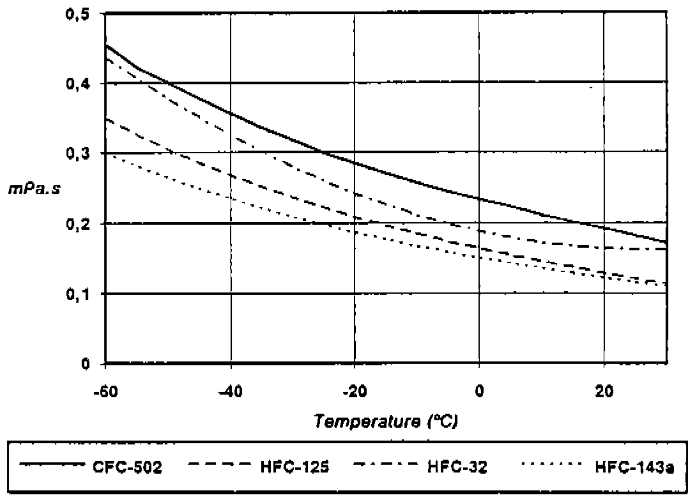

Figure 4 :

LIQUID THERMAL CONDUCTIVITY

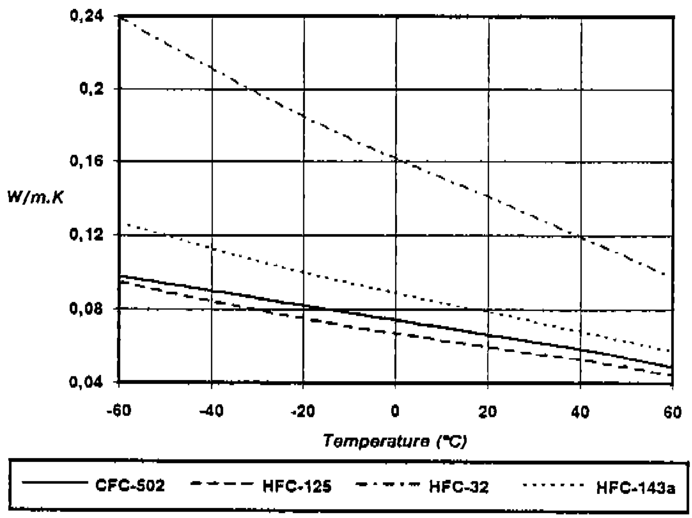

Table I :

COMPARISON OF PHYSICAL PROPERTIES

	CFC-502	HFC-125	HFC-32	HFC-143a
Chemical formula	Azeo 22/115	CHF2-CF3	CH2F2	CH3-CF3
Molecular weight	111.6	120 .0	52.0	84.0
Boiling point (°C)	-45.4	-48.1	-51.7	-47.4
Critical temperature (°C)	82.1	66.3	78.4	72.85
Critical pressure (bar)	40.7	35.2	58.1	37.87
Critical density (kg/m3)	566	572	429	455
Water solubility in refrigerant (%weight) at 25°C	0.056	0.055	na	0.051
Flammability limits in air (%vol)	none	none	12.7 to 33.4	7.1 to 16.1
ODP	0.33	0	0	0
GWP	4.01	0.84	0.13	1.2

na : not available

Table II :

COMPARISON OF TRANSPORT PROPERTIES

	CFC-502	HFC-125	HFC-32	HFC-143a
Thermal conductivity at 25°C (W.m-1.K-1)				
-Liquid	0.0645	0.058	0.1355	0.0763
-Vapor under 1.013bar	0.0117	0.0109	0.011	0.0116
Viscosity at 25°C (mPa.s)				
-Liquid	0.19	0.1214	0.1628	0.1164
-Vapor under 1.013 bar	0.0134	0.0139	0.0141	0.0132
Surface tension at 25°C (mN.m-1)	5.9	3.8	7.0	6.7
Specific Heat (kJ.kg-1.K-1)				
-Liquid at -50°C	1.25	1.04	1.76	1.31
-Vapor under 1.013 bar at 25°C	0.703	0.798	0.825	0.932

Table III:

BEHAVIOR OF NEW HFC REFRIGERANTS WITH ELASTOMERS

Elastomer	Refrigerant	% VARIATION AFTER CONTACT WITH HFC AND AFTER DRYING. length L	thickness e	mass m	extraction	hardness (shore)	tensile strength: elongation at break	tear strength
NEOPRENE (polychloroprene)	CFC - 502	-1.5	0	-2.7	3.5	15.6	-7.1	-6.2
	HFC -143a	0.9	0	0.7	0.1	0.6	-1.6	-6.7
	HFC - 125	0.9	4	0.8	0.08	-0.2	-8.7	-7.9
	HFC - 32	1.2	1	1.3	na	na	na	na
NITRILE (NBR)	CFC - 502	3.7	1.1	3.3	<10	-16.5	-24.9	-30.1
	HFC -143a	1.1	1.1	0.3	3.9	4.3	-9.8	-19.2
	HFC - 125	0.1	0.1	2.7	4.4	0.4	-19.4	-22.8
	HFC - 32	3.1	1.6	2.8	na	na	na	na
HYPALON (polyethylene chlorosulfone)	CFC - 502	1.5	0	5.4	1.33	-19.5	-15.9	-53
	HFC - 125	0.6	1.1	1.6	0.46	-14.9	-5	-21.2

Table IV :

MISCIBILITY OF REFRIGERANT/LUBRICANT MIXTURES (DEMIXTION TEMPERATURE)

	NAPHTENIC MINERAL OIL iso 32 80%oil/20%ref.	NAPHTENIC MINERAL OIL iso 32 5%oil/95%ref.	POLYESTER OIL iso 22 80%oil/20%ref.	POLYESTER OIL iso 22 5%oil/95%ref.	ALKYLBENZENE OIL iso 64 80%oil/20%ref.	ALKYLBENZENE OIL iso 64 5%oil/95%ref.
CFC-502	+6°C	-10°C	na	na	<-30°C	-20°C
HFC-143a	+10°C	(-)	-27°C	(-)	+10°C	(-)
HFC-125	+5°C	(-)	<-30°C	<-30°C	+5°C	(-)
HFC-32	+20°C	(-)	<-30°C	-10°C	(-)	(-)

(-) : not miscible
na : not available