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VISCOSITIES FOR R22 ALTERNATIVES AND THEIR MIXTURES WITH A LUBRICANT OIL

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ABSTRACT

Viscosities for pure liquid refrigerants HFC32, HFC125, HFC134a, and HFC143a, as well as their mixtures with a synthetic polyolester lubricant oil, have been measured. Measurements for the refrigerant/lubricant mixtures were made over a temperature range from 20 to 80°C and a range of oil mass fractions from 0.5 to 1. A modified capillary tube method was used for all measurements. The accuracy of measured viscosities is estimated to be ±1.2% and ±1.8% for pure refrigerants and for refrigerant/oil mixtures, respectively. Correlations for calculating the viscosity of saturated liquid refrigerants were developed. A method has also been proposed to calculate viscosities of refrigerant/oil mixtures on the basis of pure component data alone.

INTRODUCTION

The fluorocarbons HFC32, HFC125, HFC134a, and HFC143a are currently under consideration as components of mixtures to replace the refrigerant HCFC22. The successful application of these mixtures as working fluids for refrigerating and air-conditioning systems requires reliable viscosity data over a range of operating conditions. Viscosities for the alternative refrigerant mixtures with lubricant oils are especially important for the design of refrigeration compressors. In this paper, we present new viscosity measurements for pure HFC32, HFC125, HFC134a, and HFC143a, as well as their mixtures with a synthetic polyolester lubricant oil. Comparisons are given for the viscosity of pure refrigerants with data available from literature. The viscosity measurements for refrigerant/lubricant mixtures have been correlated using pure component data only.

EXPERIMENTAL PROCEDURE

The viscosity of pure refrigerants and their mixtures with oil was measured using the modified capillary tube method. A detailed description of the viscometer and the experimental procedure used for pure refrigerants, as well as experimental viscosity data for several pure refrigerants are given elsewhere [1].

For refrigerant/oil mixtures, a capillary tube with a diameter of 0.152 mm and a length of approximately 60 mm was used. All measurements were done using a single capillary tube but different values of the pressure drop corresponding to $Re < 10$. The temperature in these experiments was measured to within ±0.01 K using mercury thermometers, and pressure was measured to within ± 1 kPa with a digital pressure transducer. The samples of refrigerant/lubricant mixtures were prepared separately in a special cell and then were charged into viscometer. The final mixture composition was defined using experimental temperature-pressure-composition data.

The viscosity values were calculated by taking into account corrections for capillary end effects, thermal expansion of the capillary tube, and a kinetic-energy factor. The sum of these corrections did not exceed 0.4% of the measured viscosity. Also, the following assumptions were made: the fluid expands in the capillary tube; the fluid is compressed inside the pump during the experiment due to a decrease in the pressure difference associated with the decrease in the height of the mercury; some energy dissipates to create the kinetic energy of the fluid flow. As a consequence, an average value for the pressure drop, a density change due to the pressure change, and a change in the mass flow due to the pressure change have been employed. Uncertainties in the viscosity data for pure refrigerants and refrigerant/lubricant mixtures did not exceed $\pm 1.2\%$ and $\pm 1.8\%$, respectively.

VISCOSITIES OF PURE REFRIGERANTS

Viscosity data near the vapor-liquid saturation line for pure HFC32, HFC125, HFC134a, and HFC143a are shown in Figure 1. The temperature dependence of the measured viscosities is given by

$$\mu = a_0 + a_1 t + a_2 t^2 + a_3 t^3, \tag{1}$$

where μ is the viscosity in μPa·s and t is the temperature in ^{o}C. The coefficients in this equation are given in Table 1 for all pure refrigerants and for the synthetic polyolester lubricant oil.

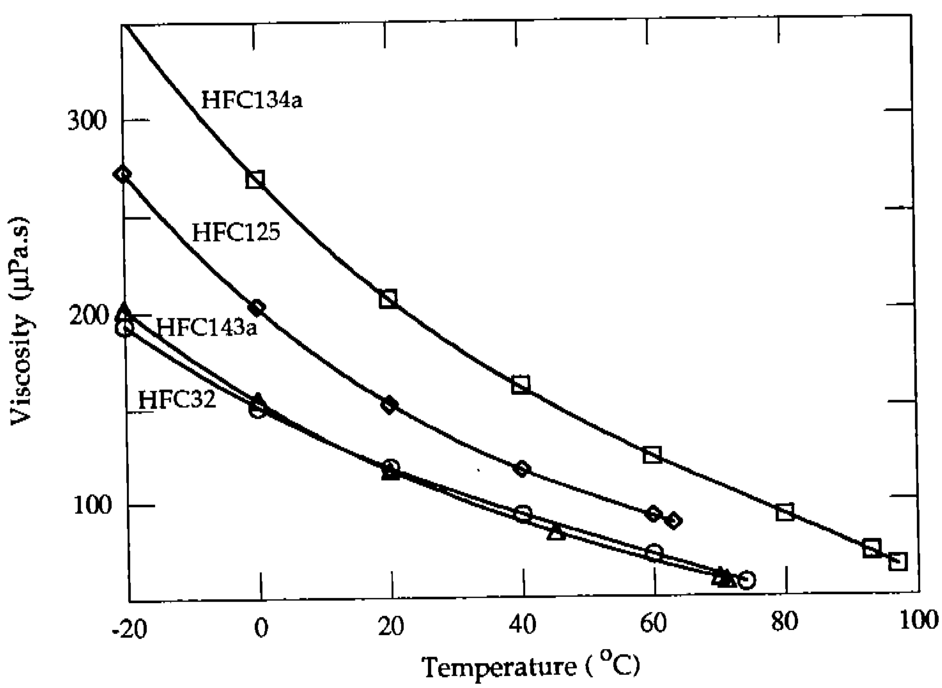

Fig. 1. Viscosities of pure refrigerants as a function of temperature (the solid curves represent the values calculated from the equation 1).

A comparison of the saturated liquid viscosities for HFC32 obtained in this work with the results of Phillips and Murphy [2] shows deviations greater than 20%. It should be noted, however, that viscosity data from [2] for the other refrigerants, such as HCFC11, HCFC12, HCFC22, and HFC152a, also differ by 10-20%

from more recent data [3]. The deviations between our data for saturated liquid HFC125 and the results obtained by Wilson et al. [4] do not exceed 10%. Comparison with the results of Shankland for HFC125 [5] show greater deviations. For HFC134a, comparisons were made with the experimental results of Shankland et al. [6], Heide and Lippold [7], Kumagai and Takahashi [8], and the generalized correlation presented by Krauss et al. [9] based on all published data. Our measurements differ by less than 2% from this correlation except in a small region near the critical point. The results of Kumagai and Takahashi [8] for saturated liquid viscosities of HFC143a are higher than our experimental data by 10-15%.

Table 1. The coefficients of viscosity correlation (1).

Fluid	a_0	a_1	a_2	a_3
HFC32	151.0	-1.847	$1.281 \cdot 10^{-2}$	$-6.83 \cdot 10^{-5}$
HFC125	202.4	-2.954	$2.474 \cdot 10^{-2}$	$-1.04 \cdot 10^{-4}$
HFC134a	269.2	-3.624	$2.711 \cdot 10^{-2}$	$-1.18 \cdot 10^{-4}$
HFC143a	154.1	-2.102	$1.390 \cdot 10^{-2}$	$-4.66 \cdot 10^{-4}$
Oil	$144.1 \cdot 10^{3}$	$-5.836 \cdot 10^{3}$	$8.958 \cdot 10^{1}$	$-4.77 \cdot 10^{-1}$

VISCOSITIES OF REFRIGERANT/LUBRICANT MIXTURES

The synthetic polyolester oil used in these experiments has the following physical properties: molecular mass of 550 kg/kmol; density at 40°C of 968.7 kg/m^3, and kinematic viscosity at 40°C of $24.4 \cdot 10^{-6}$ m^2/s. The viscosity measurements for refrigerant/oil mixtures are given in Tables 2-5. The viscosity of HFC134a/oil mixtures as a function of oil mass fraction is shown in Figure 2, and for HFC32/oil mixture viscosities as a function of temperature in Figure 3.

Table 2. Experimental viscosity data for HFC32/oil mixtures (x is the mass fraction of oil).

t = 20°C		t = 50°C		t = 75°C	
x	μ (mPa.s)	x	μ (mPa.s)	x	μ (mPa.s)
0.440	1.400	0.448	0.840	0.465	0.549
0.500	1.612	0.490	0.949	0.520	0.633
0.592	2.05	0.505	0.984	0.597	0.702
0.720	4.03	0.598	1.238	0.701	1.154
0.801	6.73	0.707	1.923	0.810	1.961
0.869	11.97	0.795	2.99	0.863	3.06
0.922	19.94	0.852	4.18	0.940	4.86
		0.930	7.92		

Table 3. Experimental viscosity data for HFC125/oil mixtures (x is the mass fraction of oil).

t = 20°C		t = 50°C	
x	μ (mPa.s)	x	μ (mPa.s)
0.462	2.34	0.501	1.310
0.541	3.48	0.585	2.03
0.597	5.26	0.644	2.67
0.729	12.03	0.733	4.06
0.790	16.11	0.818	6.39
0.914	34.4	0.825	6.56
		0.920	10.51

Table 4. Experimental viscosity data for HFC134a/oil mixtures (x is the mass fraction of oil).

t = 20°C		t = 50°C		t = 80°C	
x	μ (mPa.s)	x	μ (mPa.s)	x	μ (mPa.s)
0.515	4.05	0.517	1.590	0.511	0.868
0.625	7.37	0.589	2.31	0.650	1.660
0.730	13.2	0.666	2.95	0.750	2.44
0.814	21.4	0.670	3.10	0.790	2.76
0.858	26.3	0.765	5.03	0.895	4.29
0.910	36.9	0.841	7.15	0.915	4.56
		0.902	9.76		

Table 5. Experimental viscosity data for HFC143a/oil mixtures (x is the mass fraction of oil).

t = 20°C		t = 45°C		t = 70°C	
x	μ (mPa.s)	x	μ (mPa.s)	x	μ (mPa.s)
0.514	3.05	0.537	1.601	0.552	0.890
0.599	5.03	0.612	2.52	0.627	1.282
0.640	6.74	0.651	2.94	0.668	1.721
0.762	13.41	0.770	6.09	0.781	2.93
0.828	21.6	0.833	8.62	0.839	3.75
0.896	31.8	0.904	12.85	0.910	5.30
0.935	41.7	0.939	15.55	0.944	6.31

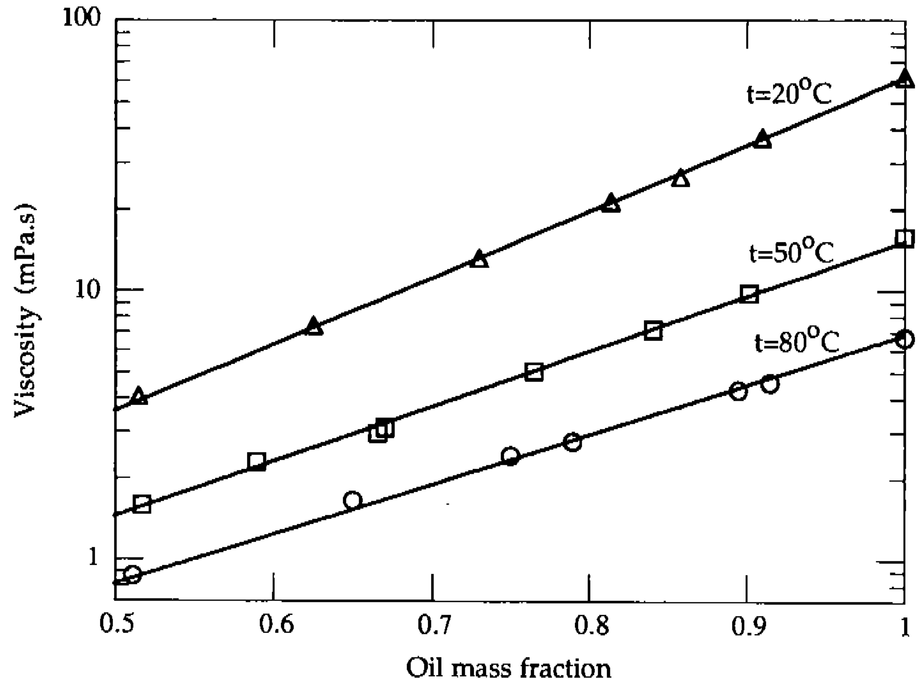

Fig. 2. Viscosity of HFC134a/oil mixtures as a function of mass oil fraction (the solid curves represent the values calculated from the equation 2).

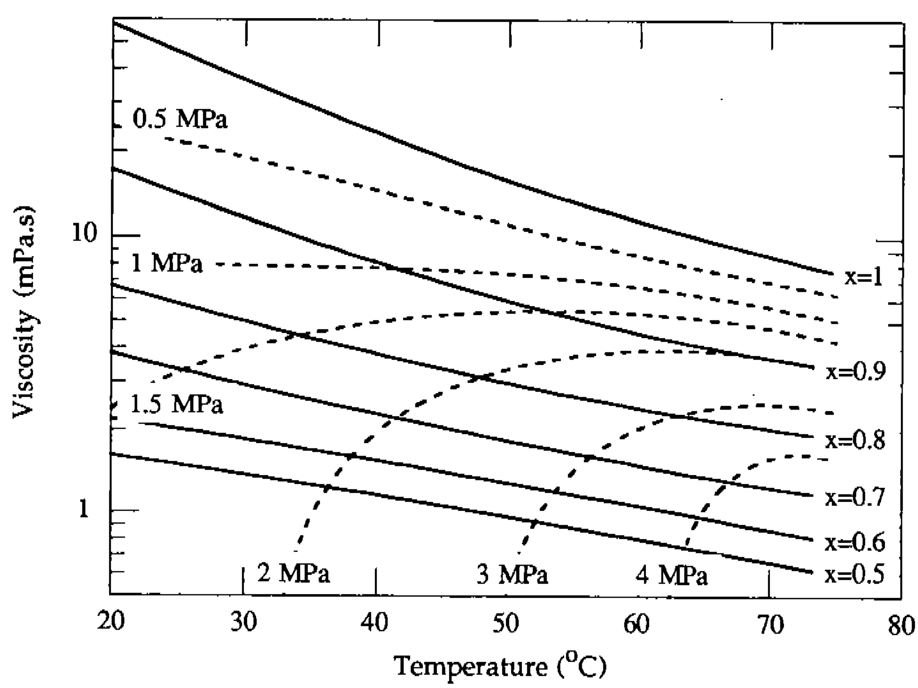

Fig. 3. Viscosity of HFC32/oil mixtures as a function of temperature (the solid curves represent constant composition, the dashed lines represent the isobars)

The viscosity data satisfy the following relation:

$$\mu = \mu_R \; exp\,[(ln\,\mu_O - ln\,\mu_R)\,x]\,, \tag{2}$$

where μ_R and μ_O are the viscosities of pure refrigerant and pure oil, respectively, given by equation (1); x is the oil mass fraction. The deviations between experimental and calculated viscosities do not exceed 7% for all mixtures under investigation, except for HFC32/oil mixture, where the deviations are greater than 50%. The higher deviations for this mixture are probably due to the high polarity of HFC32.

CONCLUSIONS

New viscosity data for pure HFC32, HFC125, HFC134a, and HFC143a, and for their mixtures with a synthetic polyolester lubricant oil have been presented. These data are critical information for the design of refrigeration compressors. Correlations for calculating viscosities of pure components as a function of temperature were developed. A method for calculating viscosities of refrigerant/oil mixtures on the basis of pure-component data alone has also been proposed.

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