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Revised Viscosities of Saturated Liquid Halocarbon Refrigerants from 273 to 353 K

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This paper presents revised saturated liquid viscosities for 15 halocarbon refrigerants, that is, R11, R12, R22, R13B1, R152a, R113, R123, R123a, R143a, R114, R134a, R141b, R142b, R225ca, and R225cb, reported in our previous papers [1, 2], in which the vapor buoyancy correction for the sealed capillary viscometer was not applied. The maximum corrections amount to from 1.2% for R225cb to 17.4% for R143a. The erroneous data in our previous papers should be considered obsolete except for the low-vapor density refrigerants R11, R123, R123a, R113, R141b, R225ca, and R225cb, for which the maximum correction is 2.4%.

KEY WORDS: halocarbons; refrigerants; saturated liquid; vapor buoyancy effect; viscosity.

1. INTRODUCTION

We previously obtained saturated liquid viscosities for 15 halocarbon refrigerants using a sealed capillary viscometer [1, 2]. Ripple and Defibaugh [3] pointed out subsequently that our viscosity values for R143a were 3 to 8% higher than their data, with the largest deviations corresponding to the highest measured temperatures, and the deviations were attributable to the missing vapor buoyancy correction in the working equation for our capillary viscometer. In addition, they showed that our viscosity values of R143a and R152a agreed with their values within the mutual uncertainty of 3% when corrected for the buoyancy effect. In more detail, Laesecke et al. [4] have suggested that agreement with the viscosity data of Okubo et al. [5] within experimental uncertainty was achieved

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when our data for R134a were corrected for the buoyancy effect. This paper presents revised saturated liquid viscosities for 15 halocarbon refrigerants, that is, R11, R12, R22, R13B1, R152a, R113, R123, R123a, R143a, R114, R134a, R141b, R142b, R225ca, and R225cb, reported in our previous paper [1, 2], in which the vapor buoyancy correction for the sealed capillary viscometer was not applied.

2. REVISED DATA

By adding the vapor buoyancy effect, the revised viscosity η can be evaluated from the following working equation, in which the gravitational force driving the flow is proportional to $(\rho_1 - \rho_v)$ instead of ρ_1 as in our previous equation [1].

$$\eta = C(\rho_1 - \rho_v)\, t \tag{1}$$

where C is the viscometer constant, ρ_1 and ρ_v are the densities of the saturated liquid and vapor, respectively, and t is the efflux time. The corrected viscosity values in this paper were obtained by multiplying our original viscosity values [1, 2] by a factor of $(\rho_1 - \rho_v)/\rho_1$.

Table I presents the revised viscosity values for 15 halocarbon refrigerants. The saturated vapor densities ρ_v were taken from the sources which shown in Table I. The estimated error of the revised viscosity values should be larger than 0.5% as quoted in the previous paper [1], considering the

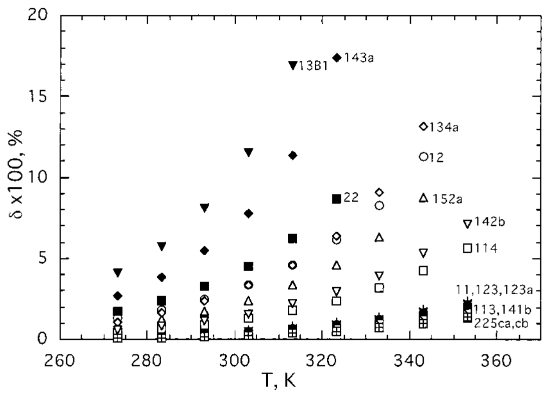

Fig. 1. Correction for vapor buoyancy effect on by our original data [1, 2]. $\delta = \eta_{\text{original}}/\eta_{\text{revised}} - 1$. (●) R11; (○) R12; (■) R22; (▼) R13B1; (△) R152a; (▲) R113; (×) R123; (+) R123a; (◆) R143a; (□) R114; (◇) R134a; (□) R141b; (▽) R142b; (□) R225ca; (⊞) R225cb.

Table I. Viscosity of Halocarbon Refrigerants

T (K)	η (mPa · s)				
	R11	R12	R22	R13B1	R152a
273.15	0.5328	0.2531	0.2092	0.1893	0.2120
283.15	0.4750	0.2276	0.1877	0.1684	0.1891
293.15	0.4259	0.2049	0.1685	0.1490	0.1691
303.15	0.3844	0.1848	0.1511	0.1308	0.1514
313.15	0.3482	0.1663	0.1350	0.1131	0.1354
323.15	0.3161	0.1494	0.1201		0.1210
333.15	0.2886	0.1336			0.1077
343.15	0.2635	0.1186			0.0953
353.15	0.2406				
Ref. No. for vapor density	[6]	[6]	[6]	[6]	[7]
	R113	R123	R123a	R143a	R114
273.15	0.9362	0.5651	0.5962	0.1579	0.4739
283.15	0.8047	0.4982	0.5246	0.1390	0.4166
293.15	0.7019	0.4420	0.4651	0.1220	0.3680
303.15	0.6158	0.3948	0.4146	0.1068	0.3265
313.15	0.5446	0.3545	0.3708	0.0926	0.2903
323.15	0.4842	0.3194	0.3334	0.0788	0.2590
333.15	0.4324	0.2882	0.3007		0.2313
343.15	0.3879	0.2606	0.2716		0.2061
353.15	0.3484	0.2359	0.2453		0.1836
Ref. No. for vapor density	[6]	[7]	[8]	[7]	[6]
	R134a	R141b	R142b	R225ca	R225cb
273.15	0.2698	0.5461	0.2967	0.8118	0.8383
283.15	0.2372	0.4819	0.2648	0.7037	0.7281
293.15	0.2090	0.4288	0.2375	0.6161	0.6382
303.15	0.1843	0.3839	0.2136	0.5434	0.5640
313.15	0.1623	0.3454	0.1922	0.4824	0.5013
323.15	0.1424	0.3123	0.1730	0.4306	0.4482
333.15	0.1242	0.2832	0.1557	0.3859	0.4025
343.15	0.1069	0.2578	0.1396	0.3466	0.3626
353.15		0.2346	0.1245	0.3122	0.3272
Ref. No. for vapor density	[4]	[7]	[7]	[7]	[7]

neglect of the vapor density of the calibration liquid, chloroform, measured between 304.73 and 334.41 K. Laesecke et al. [4] showed that the maximum contribution in the error is $\pm 0.4\%$ at its normal boiling point, 334.41 K. The maximum corrections for the vapor buoyancy effect amount to from 1.2% for R225cb to 17.4% for R143a as shown in Fig. 1. As pointed out by Ripple and Defibaugh [3] and Laesecke et al. [4], the revised values for R143a, R152a, and R134a, containing large deviations from our original data, agree with their data within the experimental uncertainties.

3. CONCLUSIONS

Our original viscosity data have been quoted in correlations, predictions [9–11], and comparisons of data [12–18] for viscosity. The erroneous data in our previous papers, however, should be considered obsolete except for the low-vapor density refrigerants of R11, R123, R123a, R113, R141b, R225ca, and R225cb for which the maximum correction is 2.4%.

REFERENCES

1. A. Kumagai and S. Takahashi, *Int. J. Thermophys.* **12**:105 (1991).
2. A. Kumagai and S. Takahashi, *Int. J. Thermophys.* **14**:339 (1993).
3. D. Ripple and D. Defibaugh, *J. Chem. Eng. Data* **42**:360 (1997).
4. A. Laesecke, T. O. D. Lüddecke, R. F. Hafer, and D. J. Morris, *Int. J. Thermophys.* **20**:401 (1999).
5. T. Okubo, T. Hasuo, and A. Nagashima, *Int. J. Thermophys.* **13**:931 (1992).
6. Japanese Association of Refrigeration, *Reitoki-binran Kisohen* (1981) (in Japanese).
7. Japanese Association of Refrigeration, *JAR Thermodynamic Tables, Vol. 1, HFCs and HCFCs, Ver. 1.0* (1994).
8. M. Takahashi, C. Yokoyama, and S. Takahashi, *Proc. 11th Japan. Symp. Thermophys.* (Tokyo, 1990), p. 115.
9. M. L. Huber and J. F. Ely, *Fluid Phase Equil.* **80**:239 (1992).
10. G. Latini and F. Polonara, *Proc. 3rd Asian Conf. Thermophys.* (Beijing, 1992), p. 432.
11. S. Khan and K. Srinivasan, *Int. J. Thermophys.* **17**:361 (1996).
12. C. Oliveira, M. Papadaki, and W. A. Wakeham, *Proc. 3rd Asian Conf. Thermophys.* (Beijing, 1992), p. 32.
13. D. E. Diller, A. S. Aragon, and A. Laesecke, *Fluid Phase Equil.* **88**:251 (1993).
14. C. M. B. P. Oliveira and W. A. Wakeham, *Int. J. Thermophys.* **14**:33 (1993).
15. R. Krauss, J. Luettmer-Strathmann, J. V. Sengers, and K. Stephan, *Int. J. Thermophys.* **14**:951 (1993).
16. M. J. Assael, J. H. Dymond, and S. K. Polimatidou, *Int. J. Thermophys.* **15**:591 (1994).
17. L. Han, M. Zhu, X. Li, and D. Luo, *J. Chem. Eng. Data* **40**:650 (1995).
18. M. J. Assael, L. Karagiannidis, and S. K. Polimatidou, *Int. J. Thermophys.* **16**:133 (1995).