A Note on Viscosity as a Function of Volume and Temperature of Oils

R. B. Dow, *Research Laboratory of Physics, Harvard University*

(Received April 17, 1935)

The viscosity-volume data of Kleinschmidt and Dow have been examined at various pressures and temperatures for lard, sperm and Pennsylvania medium oil. The viscosity-volume isotherms at 25°, 40° and 75°C are not identical for any of the oils studied, indicating that viscosity cannot be a function of the specific volume alone. The viscosity-volume curve for lard oil at 25° departs from the one at 75° by an amount sufficient to change the viscosity by a factor of 2.3 at a volume of 0.99, and by a factor of 3.2 at a volume of 0.93. Similar curves for Pennsylvania medium oil at the same temperatures are even more relatively displaced; the discrepancy in viscosity varies from a factor of 3.8 at a volume of 0.99 to 7.6 at 0.94. The three oils do not obey Batschinski's equation at atmospheric and higher pressures up to 4000 kg/cm².

Comparatively little is known of the physical properties of lubricating oils at high hydrostatic pressures. Among the non-thermodynamic properties of lubricants at high pressures, viscosity has been most extensively studied because of its significance for thick film lubrication. The experiments of Hyde[1] and, more recently, those of Hersey and Shore,[2] and Kleinschmidt,[3] have shown that the coefficient of viscosity of a mineral oil at ordinary temperatures increases by a factor of about 20 with an initial increase of pressure of 1000 kg/cm,[2] this increase being several times greater than that observed for pure liquids[4] or mixtures of liquids[5] through the same range of pressure. With the recent study of some of the thermodynamic properties of similar oils,[6] sufficient data are available for an examination of the viscosity of oils as a function of volume.

In addition to the practical usefulness of viscosity-volume data taken at various pressures and temperatures, there is theoretical interest in the functional relation between viscosity and volume. Consequently, this communication presents the viscosity-volume-temperature relations for three lubricating oils and includes a discussion of the theoretical relationship.

Data

Table I contains the log relative viscosities and volumes at various pressures and temperatures for lard, sperm and Pennsylvania medium oil, respectively, the data being taken from the papers of Kleinschmidt[3] and Dow.[6] The density of each oil at atmospheric pressure and 40°C is given in order that the specific volumes may be computed directly from the table of volumes by division. The log relative viscosities are expressed as $\log_{10} t/t_0$, t being the time of fall of a weight in a viscometer at a certain pressure and tempera-

Table I. *Relative viscosity and volume.*

Pressure kg/cm²	$\log_{10}$ Relative viscosity 25°	40°	75°	Volume 25°	40°	75°
			Lard oil $\rho_{40}=0.9009$ g/cm³			
1	0	$\bar{1}.770$	$\bar{1}.370$	0.9902	1.0000	1.0190
100	0.079	.845		.9844	.9936	
250	.183	.938	.500	.9763	.9850	1.0051
500	.345	0.082	.628	.9647	.9721	.9921
750	.499	.220	.742	.9550	.9615	.9800
1000	.642	.351	.855	.9461	.9523	.9697
1500	.920	.607	0.070	.9299	.9366	.9522
2000		.835	.262		.9229	.9374
2500		1.052	.441		.9111	.9240
3000			.615			.9120
4000			.962			.8927
			Sperm oil $\rho_{40}=0.8945$ g/cm³			
1	0	$\bar{1}.720$	$\bar{1}.256$	0.9894	1.0000	1.0227
100	0.079	.792	.374	.9835	.9934	
200	.150			.9781	.9876	1.0099
300	.220	.920		.9730	.9818	
400	.289	.981		.9685	.9768	
500		0.040	.531		.9722	.9925
750		.181	.649		.9618	.9794
1000		.318	.757		.9525	.9684
1500			.959		.9437	.9510
2000			0.149			.9368
2500			.327			.9241
3000			.481			.9127
4000			.792			.8926
			Pennsylvania oil $\rho_{40}=0.8524$ g/cm³			
1	0	$\bar{1}.660$	$\bar{1}.020$*	0.9901	1.0000	1.0178
100	0.119	.761		.9839	.9934	
250	.280	.904	.235*	.9752	.9841	1.0040
500	.536	0.131	.420*	.9632	.9711	.9908
750	.777	.346	.594*	.9529	.9599	.9786
1000	1.008	.551	.760*	.9440	.9504	.9672
1500		.955	0.070		.9340	.9485
2000		1.341	.369		.9196	.9330
2500			.661			.9196
3000			.953			.9082
4000			1.511			.8891

* Extrapolated.

---

1 J. H. Hyde, Proc. Roy. Soc. **A97**, 240 (1920).
2 M. D. Hersey and H. Shore, Mech. Eng. **50**, 221 (1928).
3 R. V. Kleinschmidt, Trans. A.S.M.E. APM-50-4 (1928).
4 P. W. Bridgman, Proc. Am. Acad. **61**, 57 (1926).
5 R. B. Dow, Physics **6**, 71 (1935).
6 R. B. Dow, J. Wash. Acad. Sci. **24**, 516 (1934).