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

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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).