Computation of Some Physical Properties of Lubricating Oils at High Pressures

I. Density

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From a survey of available data on the density of fluid lubricants as a function of pressure and temperature, the following empirical equation has been derived:

$$\rho=\rho_0(1+ap-bp^2)_t.$$

ρ is the density at a given pressure (gage) p and temperature t; ρ_0 is the corresponding density at atmospheric pressure. The constants a and b are evaluated over a temperature range extending from 20° to 220°F and the density equation is valid over a pressure range of 50,000 lb./in.^{2}. While the equation was derived from data on mineral oils it has been found to hold equally well for animal, vegetable, and fish oils. The variation of density with pressure is independent of the nature of the oil.

…der to compute the thermodynamic char-…ristics of an oil at high pressure it is …sary that the specific volume or density be …as a function of temperature and pressure. …ever, in problems of lubrication design it is …necessary to convert from the dynamic to …nematic coefficient of viscosity, and vice …and in order to do this at high pressures …densities must be known over the range of …re involved. It is the purpose of this paper …ent a practical means for calculating …over a pressure range up to 50,000 lb./in.^{2} …mperatures between 20 and 220°F. These …of pressure and temperature are those …nly encountered in many problems of …tion in the fields of engineering and …physics, and although data could be …ed readily at higher pressures, provided …he temperature was also raised so that the …ld remain fluid, the investigation would …ome one of academic interest rather than …ical importance.

…ties of five petroleum lubricants have …sured by Hyde[1] at 104°F over a pressure …f 25,000 lb./in.^{2}. Similar data were ob-…n four petroleum oils by Dow[2] at 77°F, …and 167°F at pressures up to 50,000 … Dow and Fenske[3] obtained data on an oil at 104°F and 167°F at pressures up to 50,000 lb./in.^{2}, and then fractionated the oil into narrow-boiling cuts and obtained data on ten of these cuts.

The striking result of all these investigations is the fact that, within the range of experimental error, all of the oils have the same compressibility. Thus the oils studied in Europe by Hyde, who used the moving piston type of apparatus to make his measurements, showed the same behavior in this respect as the oils studied in this country by Dow who used the sylphon apparatus. Furthermore, the work of Dow included extreme types of oils such as a typical Pennsylvania oil which is noted for its high paraffinicity and low temperature coefficient of viscosity, and a typical Gulf Coast oil which is characterized by the fact that it contains large amounts of naphthenic and aromatic types of molecules and has a relatively high temperature coefficient of viscosity. The work of Dow and Fenske, moreover, shows that the generality in regard to compressibility may be extended to narrow-boiling fractions which vary considerably in boiling point and molecular weight. This insensitivity of compressibility, within the range of experimental error, among the wide variety of oils studied is strikingly different from other properties that have been studied under pressure, as, for example, viscosity.[4]

From an experimental standpoint, therefore,

[1] Hyde, Proc. Roy. Soc. **A97**, 240 (1920).
[2] Dow, J. Wash. Acad. Sci. **24**, 516 (1934).
[3] Dow and M. R. Fenske, Ind. and Eng. Chem. **27**, …
[4] R. B. Dow, J. App. Phys. **8**, 367 (1937).