

Discussion

At 100 F and atmospheric pressure the oil has a viscosity about 84 times that of the gasoline, but at 50,000 psi they differ by 2600 times and the difference is increasing rapidly with increasing pressure. This clearly points up why atmospheric pressure viscosity of fluids is often misleading as a means of judging the behavior of fluids in high pressure metal working applications. At 80,000 psi the viscosity of the gasoline at either temperature is still considerably less than that of the oil at atmospheric pressure. In fact at 80,000 psi the viscosity of the gasoline at 100 F is about the same as that of the oil at atmospheric pressure and 210 F. This is independent of the partial solidification problem that exists with the oil at the pressures above 50,000 psi.

It is commonly thought that the viscosity of fluids is an exponential function of pressure, and that the knowledge of the pressure-viscosity coefficient, $\frac{1}{\mu} \frac{d\mu}{dp}$, at atmospheric pressure is sufficient to describe the viscous behavior of the fluid under pressure. It is clear from Fig. 2 that this may be acceptable for the oil at 100 F but can clearly be misleading in each other case reported here. The error encountered by this method would be very large indeed for the gasoline.

Although there are many viscosity correlations available few are very satisfactory over a wide range of pressures and temperatures. The correlational method developed by Roelands [8] is reasonably satisfactory for the fluids investigated. In the simplest form it is

$$\frac{\log \eta + 1.200}{\log \eta_r + 1.200} = \left(\frac{311}{t + 211} \right)^S \left(1 + \frac{p}{28,440} \right)^Z$$

where the three constants η_r , S , Z are shown in Table 1 for the three fluids investigated. η_r is the reference viscosity which in this case is the viscosity in centipoises at atmospheric pressure and 100 F. S is the viscosity-temperature slope and the Z is the viscosity-pressure slope. η is the viscosity in centipoise at any other temperature t in degrees Fahrenheit and pressure p in psi. Roelands' correlation is least correct for low viscosity fluids and therefore the maximum error for these fluids will be for the gasoline. For that fluid the correlation will predict viscosities which are low by about a factor of two at 80,000 psi. Because of the state-of-the-art in high pressure metal working this is probably not a serious error and the benefits gained from being able to predict high pressure viscosity of fluids outweigh this error.

Summary

A high pressure viscometer suitable for determining the high pressure viscosity behavior of fluids used in high pressure metal

Table 1

Fluid	η_r [cp]	S	Z
leaded gasoline	0.34	0.58	0.60
50/50 mixture	1.68	0.85	0.65
oil	29	1.14	0.63

working has been reported and the properties of three typical high pressure metal working fluids have been reported. Because of the past success in using leaded gasoline as the working fluid, these

data suggest that the rather small increase of viscosity of this fluid with pressure and the lack of partial solidification may be the reasons for its desirable performance.

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DISCUSSION

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The author presents a lucid technique for the measurement of viscosity of liquids over a range of pressures and temperatures. A number of questions arise on the results presented.

How was it determined that the paraffin oil began to solidify at a pressure of 50,000 psi, as contrasted with a gradual increase in viscosity?

We have sometimes found differences in the behavior of gasoline fresh from the tanks of a service station and after having remained in a gasoline safety can for a week or more. Has any difference in viscosity been found for fresh and "old" gasoline?

Would a major difference be expected in pressure-viscosity data for paraffinic oil from different sources; e.g., from Pennsylvania, California, or Oklahoma.

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