Viscosity of Hydraulic Oil

By Martin Cuthbert MEng (Hons), Webtec Products Ltd.

The internal resistance to flow of a liquid is measured by a fluid's *viscosity*. More precisely absolute viscosity (μ) is defined in terms of the force between two parallel layers of fluid for a certain slip velocity between them. This is represented by Newton's equation ($\tau = \mu \frac{\partial u}{\partial y}$).

Very often a hydraulic fluid will be selected on the basis of its viscosity and the operating temperature of the system. A fluid will flow more easily the less viscous it is, since less energy is required to overcome the internal frictional forces. Any saving in energy must be balanced against an increase in leakage due to the lower fluid viscosity.

There are two measures of viscosity: absolute (also known as dynamic) and kinematic. The S.I. unit for absolute viscosity is N s m^{-2} or Pa.s. The non-S.I. unit is the *poise* (P) equivalent to 0.1 N s m^{-2} (not to be confused with the *poiseuille* (Pl), used in France, and equal to 10 poise) though the centipoise (cP) is more commonly used. In the hydraulics industry kinematic viscosity is more frequently used, where:

$$\frac{\text{dynamic viscosity}}{\text{density}}$$

The S.I. unit for kinematic viscosity (ν) is mm^2s^{-1} which corresponds to the older but still commonly used unit the centistoke (cSt).

Past measures of viscosity using arbitrary scales like Redwood No 1 seconds, Saybolt Universal Seconds (SUS), or degrees Engler should no longer be used. These units have been superseded by the empirical measures previously mentioned; conversion tables do exist but are only true at a fixed temperature.

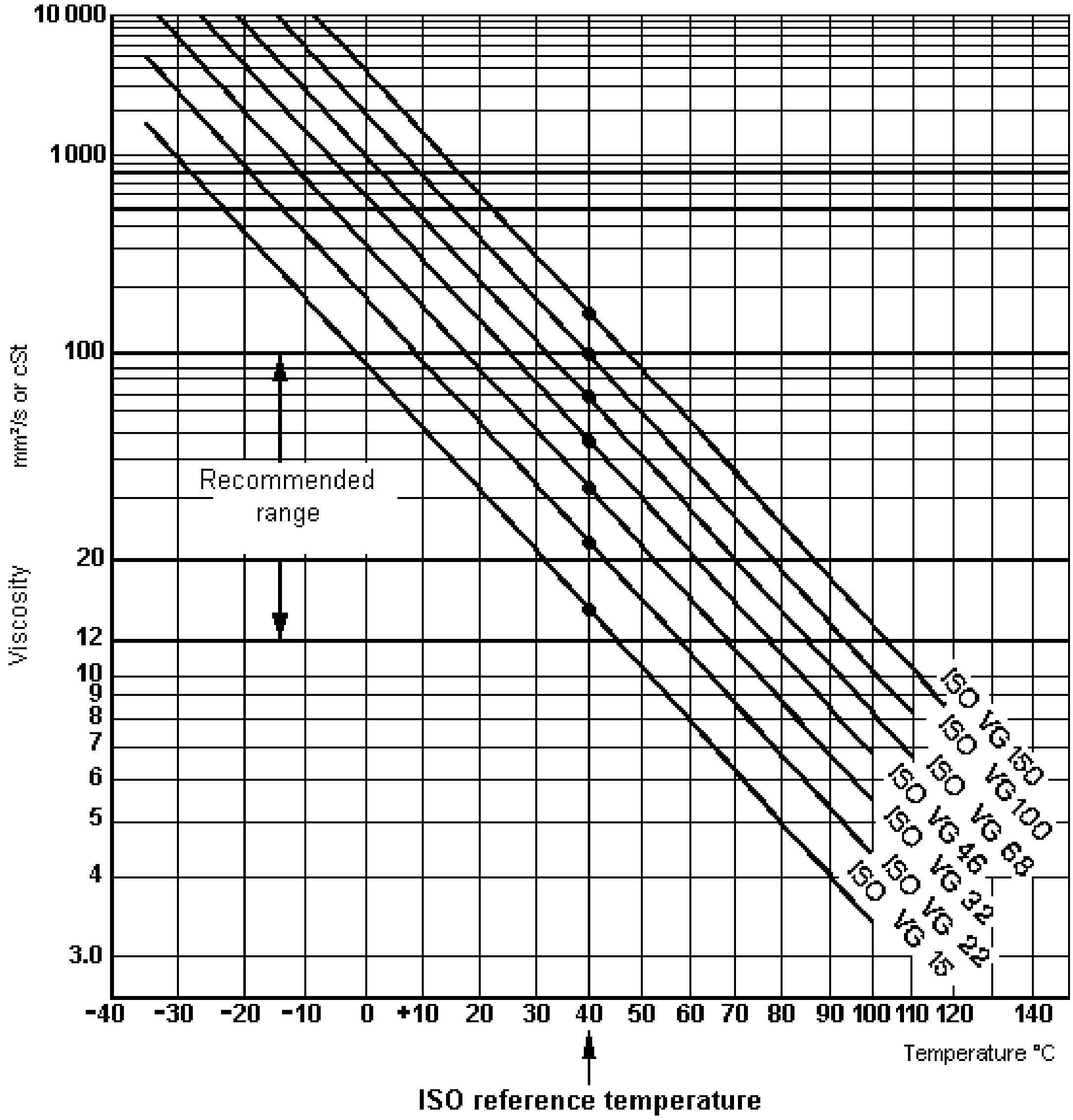
Effect of temperature on viscosity

The temperature and viscosity of hydraulic oil are inversely related; as temperature increases, viscosity decreases. In order to define the kinematic viscosity of oil, its viscosity is quoted at a set temperature (40°C for the ISO standard) and the oil is given a value according to the viscosity index (V.I.). For example an oil quoted as conforming to ISO 22 will have a viscosity of 22 mm^2s^{-1}/ cSt at 40°C.

Viscosity Index

The viscosity index is a single number representation of the viscosity temperature characteristics of a fluid. The greater the value of the V.I. the smaller the change in viscosity for a given change in temperature, and vice-versa. Oils with a V.I. of 80 or more are said to have a high V.I. value. Oils with a V.I. between 80 and 40 are said to have a medium value and those below 40 a low value. Typically mineral oils used by the fluid power industry have a high V.I. of about 100. If temperature and kinematic viscosity are plotted to give a linear relationship (using logarithmic scales) then the V.I. is a measure of the gradient of the line. As the V.I. is increased the gradient is reduced. A typical temperature-viscosity curve for ISO oils can be seen below.

Figure: Effect of Temperature on Kinematic Viscosity



Effect of pressure on viscosity

Contrary to popular belief, varying pressure can lead to significant variations in viscosity. In a closed flow circuit at a fixed temperature, a change in pressure of 40 MPa (400 bar) can lead to a change of up to 8% in viscosity. However there are problems in calculating this variation.

Density and specific volume

The density of mineral oils is typically around 870 kg m^{-3} (in comparison synthetic oils usually have a density of around 1200 kg m^{-3}). The specific gravity, the ratio of the density of the fluid to the density of water, is a dimensionless quantity typically 0.87 for mineral oils.
