

# Viscosity Index

This calculated system is used in the oil industry and quantifies the rate of change of viscosity with temperature.

**AN INCREASE IN TEMPERATURE** or a decrease in pressure weakens the intermolecular bonds in a fluid, leading to a reduction in its viscosity. This means that for all liquids as the temperature increases, the liquid's viscosity decreases. A fluid's viscosity should always be quoted at a specified temperature and pressure. If the pressure is omitted, it is understood to be atmospheric. Viscosity Index (VI) attempts to quantify the rate of change of viscosity with temperature.

Although viscosity can be plotted directly against temperature, there is no fundamental mathematical relationship that will completely predict the viscosity/temperature relationship for a complex fluid such as a hydrocarbon base oil. However, using suitable logarithmic axes, it is possible to arrange the viscosity/temperature data, as a great majority of mineral oils lie on straight lines, simplifying the plotting and extrapolation of data.

These viscosity/temperature charts are based on the Walther equation:

$$\log_{10} \log_{10} (\nu + a) = b + c \log_{10} T$$

where  $\nu$  is kinematic viscosity,  $a$ ,  $b$  and  $c$  are constants and  $T$  is absolute temperature.

For any particular oil, knowledge of the viscosity at two selected temperatures is required for the viscosity at a third temperature to be predicted, provided extrapolation is not extended into the region of the pour point.

The VI system was devised by Ernest Woodward Dean and Garland Hale Barr Davis in 1929 and is widely used in the oil industry,

due to the convenience of the single number that expresses the viscosity/temperature relationship of an oil. Two oils were selected to express VI. One was obtained from a Pennsylvania crude oil, which was arbitrarily assigned a VI of 100, and the other was from a Gulf Coast crude oil, which was assigned a VI of 0. At the time, these oils appeared to have the absolute maximum and minimum limits of viscosity/temperature sensitivity and would, therefore, represent the end points of a 0 to 100 scale of VI.

Given measured kinematic viscosities of an oil at 40 C and 100 C, its VI can be calculated using tables published by ASTM and the Energy Institute (Institute of Petroleum, IP).

Dean and Davis anticipated that all mineral oils would fall between the limits they had proposed. Because of the introduction of solvent refining and hydroprocessing, the use of polymer additives (VI improvers) and the manufacture of synthetic oils have all produced lubricants with characteristics far outside the VI scale in both directions. The VI system (as originally devised) suffers from the following limitations:

- It is based on arbitrary standards.
- In the very high range of VIs, the scale becomes suspect since it is possible that two oils have equal viscosity at 40 C but widely different viscosities at 100 C may have the same VI.
- Anomalous VIs are obtained for very light oils having a viscosity below about 8 centistokes at 100 C.

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The only true significance of VI is that it is an indication of the rate of change of an oil's viscosity with temperature.

VI is important in machinery that must be started and operated over a wide temperature range. All other factors being equal, oils with higher VI give less viscous drag during starting and provide thicker oil films for better sealing and wear prevention. Also, oil consumption at operating temperatures is lower.

Different types of oils can have very different VIs. API Group I and II base oils have VIs in the range 95 to 105, while Group III base oils and polyalphaolefins have VIs between 125 and 140. Esters and polyalkylene glycols can have VIs up to 250. Base oils with high VIs have advantages in that less VI improver is needed to achieve a lower reduction in viscosity at higher temperatures.

VI improvers can shear in high stress applications, while base oils with higher VI have inherent shear stabilities. Lubricants made using such base oils are likely to retain their viscosities for longer periods (allowing for the effects of oxidation) and may be more suitable for extended duration oil changes.



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