Viscosity Classifications

The first and most important task of lubricating oil is to keep moving metal parts separated from each other, thus avoiding metal-to-metal contact, which leads to destructive wear. Even finely machined metal surfaces have a certain roughness.

Contact of these minute metal projections should be minimized; however, some contact always occurs and results in normal wear of the metal surfaces. If contact is not minimized, heat is generated when the metal parts touch. The heat causes local welding and transfer of metal, which creates scuffing or seizing of the equipment. These actions are called adhesive wear. The oil property that governs the thickness of the separating oil film is the viscosity.

Viscosity

The commonly used kinematic viscosity is defined as a measure of the restrictive flow of a fluid under gravitational force. The "cgs" unit of kinematic viscosity (one centimeter squared per second), is called one stoke (St). The SI unit for kinematic viscosity is one meter squared per second and is equivalent to 10,000 St. Usually, centistokes (cSt) is used (1 cSt = 0.01 St = 1 mm^2/s).

The absolute or dynamic viscosity is equal to the kinematic viscosity, multiplied by the density of the fluid. It is usually expressed in centipoise (cP) (1 cP = 0.001 Pa.s).

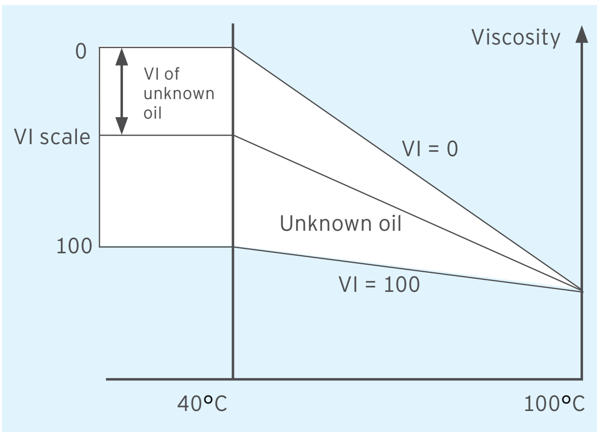
Viscosity index (VI)

The viscosity of lubricating oil changes with temperature and the rate of change depends on the composition of the oil. Naphthenic base oils change more than paraffinic base oils. Certain synthetic lubricants change much less than paraffinic oils.

To assess this lubricating oil property, the American Society for Testing and Materials (ASTM) created a method to provide a number called the Viscosity Index (VI). The VI correlates the amount of viscosity change for a given oil, compared to two reference oils having the highest and lowest viscosity indices at the time the VI scale was first introduced (1929). A standard paraffinic oil was given a VI of 100 and a standard naphthenic oil a VI of 0.

Figure 1 shows the relationship between viscosities at 40°C and 100°C. The method has been updated and revised several times to include VI values higher than 100.

Figure 1: Schematic Representation of Viscosity Index



A low VI means a relatively large viscosity change with temperature and a high VI denotes a smaller change of viscosity with temperature. Hence, the VI of an oil is important in applications where an appreciable change in temperature of the lubricating oil could affect the startup or operating characteristics of the equipment. Deck machinery and emergency equipment are examples of typical applications onboard ships.

Viscosity classification

As the selection of the proper viscosity grade is extremely important, various viscosity classification systems have been developed over the years. The viscosity classification for engine oils was developed by the Society for Automotive Engineers (SAE) in 1911. After many revisions and updates, this classification system is still in place.

The current SAE J300 Viscosity Classification is shown on the next page in Table 1. SAE grades 0W through 25W, where W stands for winter, have a maximum viscosity specified at low temperatures (−5°C through −35°C), to ensure easy starting under low temperature conditions, and a minimum viscosity requirement at 100°C to ensure satisfactory lubrication at the final operating temperature. Only SAE grades 20W through 60W have limits set at 100°C, because these grades are not intended to be used in low temperature conditions.

For marine applications, monograde oils (i.e., oils without the addition of VI improvers of SAE 30 or SAE 40) are used because of the steady operating conditions in a ship's engine room.

Conversely, automotive oils are normally formulated by adding VI improvers to provide multigrade performance and thus deliver excellent temperature/viscosity relations. VI improvers are very large molecules, which are chemically made by linking together smaller molecules into so-called polymers. The use of these special polymers makes it possible to meet the low temperature viscosity requirements of the W grades, as well as the high temperature requirements of the non-W grades. In a 15W-40 multigrade engine oil, the typical viscosities are:

Viscosity at −15°C, cP	3,000
Viscosity at 40°C, mm^2/s (cSt)	105
Viscosity at 100°C, mm^2/s (cSt)	14
Viscosity Index	135

This example shows that the high VI offers a relatively small change in viscosity with temperature, and, as a result of the high VI, the multigrade oil meets the 15W grade low temperature viscosity requirements, as well as the 40 grade high temperature viscosity requirements.

Viscosity classification: industrial oils

Many different viscosity classification systems have been used in the past in different parts of the world. It has been difficult to reach agreement on the number of different grades to be included, the viscosity limits for these grades, and the temperature at which the viscosity should be specified. It is only since 1972 that a worldwide viscosity classification system for industrial lubricants came into place.

The current ISO 3448 viscosity classification system, which is also adopted by the ASTM, is shown on the next page in Table 2. The classification is based on a series of viscosity grades, each being approximately 50% more viscous than its preceding grade, while the viscosity deviation within a grade is plus or minus 10% of the nominal viscosity of that grade.

Used oil viscosities

The viscosity is determined on every oil sample tested in Chevron's FAST™ used oil analysis service. Used lubricating oils may show an increase of the viscosity because of oxidation/nitration or contamination such as the soot loading of a diesel engine oil. Dilution with high viscosity heavy fuel oil or the use of a higher viscosity grade lubricant are other possible causes.

A viscosity decrease of a used lubricating oil may be related to the use of a lower viscosity grade lubricant or dilution with low viscosity fuel oil. Viscosity results of used lubricating oil samples are compared to the original equipment manufacturer's (OEM's) requirements whenever possible. If this is not feasible, the generally accepted limit for viscosity change is ±15% of the fresh oil value at 40°C. For large diesel engines, an increase of the engine oil's kinematic viscosity at 40°C up to 45% is still accepted. ■

Table 1: Engine oil viscosity classification – SAE J300 revised May 2004

SAE viscosity grade	Low-temperature (°C) cranking viscosity[2], mPa.s max.	Low-temperature (°C) pumping viscosity[3] mPa.s max. with no yield stress	Low-shear-rate kinematic viscosity[4] (mm^2/s) at 100°C min.	Low-shear-rate kinematic viscosity[5] (mm^2/s) at 100°C max.	High-shear-rate viscosity (mPa.s) at 150°C and $10^6 s^{-1}$ min.
0 W	6,200 at −35	60,000 at −40	3.8	–	–
5 W	6,600 at −30	60,000 at −35	3.8	–	–
10 W	7,000 at −25	60,000 at −30	4.1	–	–
15 W	7,000 at −20	60,000 at −25	5.6	–	–
20 W	9,500 at −15	60,000 at −20	5.6	–	–
25 W	13,000 at −10	60,000 at −15	9.3	–	–
20	–	–	5.6	< 9.3	2.6
30	–	–	9.3	< 12.5	2.9
40	–	–	12.5	< 16.3	2.9 (0W-40, 5W-50, and 10W-40 grades)
40	–	–	12.5	< 16.3	3.7 (15W-40, 20W-40, 25W-40, 40 grades)
50	–	–	16.3	< 21.9	3.7
60	–	–	21.9	< 26.1	3.7

1. mPa.s = 1cP; 1 mm^2/s = 1 cSt. All values are critical specifications as defined by ASTM D 3244.
2. ASTM D 5293
3. ASTM D 4684 Note: The presence of any yield stress detectable by this method constitutes a failure regardless of viscosity.
4. ASTM D 445
5. ASTM D 4683, CEC L-36-A-90 (ASTM D 4741)

Table 2: Industrial lubricant viscosity classification

Viscosity system grade ISO standard 3448 ASTM D 2422	Mid-point viscosity, mm^2/s (cSt), at 40°C	Kinematic viscosity limits, mm^2/s (cSt), at 40°C	
		Min	Max
ISO VG 2	2.2	1.98	2.42
ISO VG 3	3.2	2.88	3.52
ISO VG 5	4.6	4.14	5.06
ISO VG 7	6.8	6.12	7.48
ISO VG 10	10	9.00	11.0
ISO VG 15	15	13.5	16.5
ISO VG 22	22	19.8	24.2
ISO VG 32	32	28.8	35.2
ISO VG 46	46	41.4	50.6
ISO VG 68	68	61.2	74.8
ISO VG 100	100	90.0	110
ISO VG 150	150	135	165
ISO VG 220	220	198	242
ISO VG 320	320	288	352
ISO VG 460	460	414	506
ISO VG 680	680	612	748
ISO VG 1000	1,000	900	1,100
ISO VG 1500	1,500	1,300	1,650