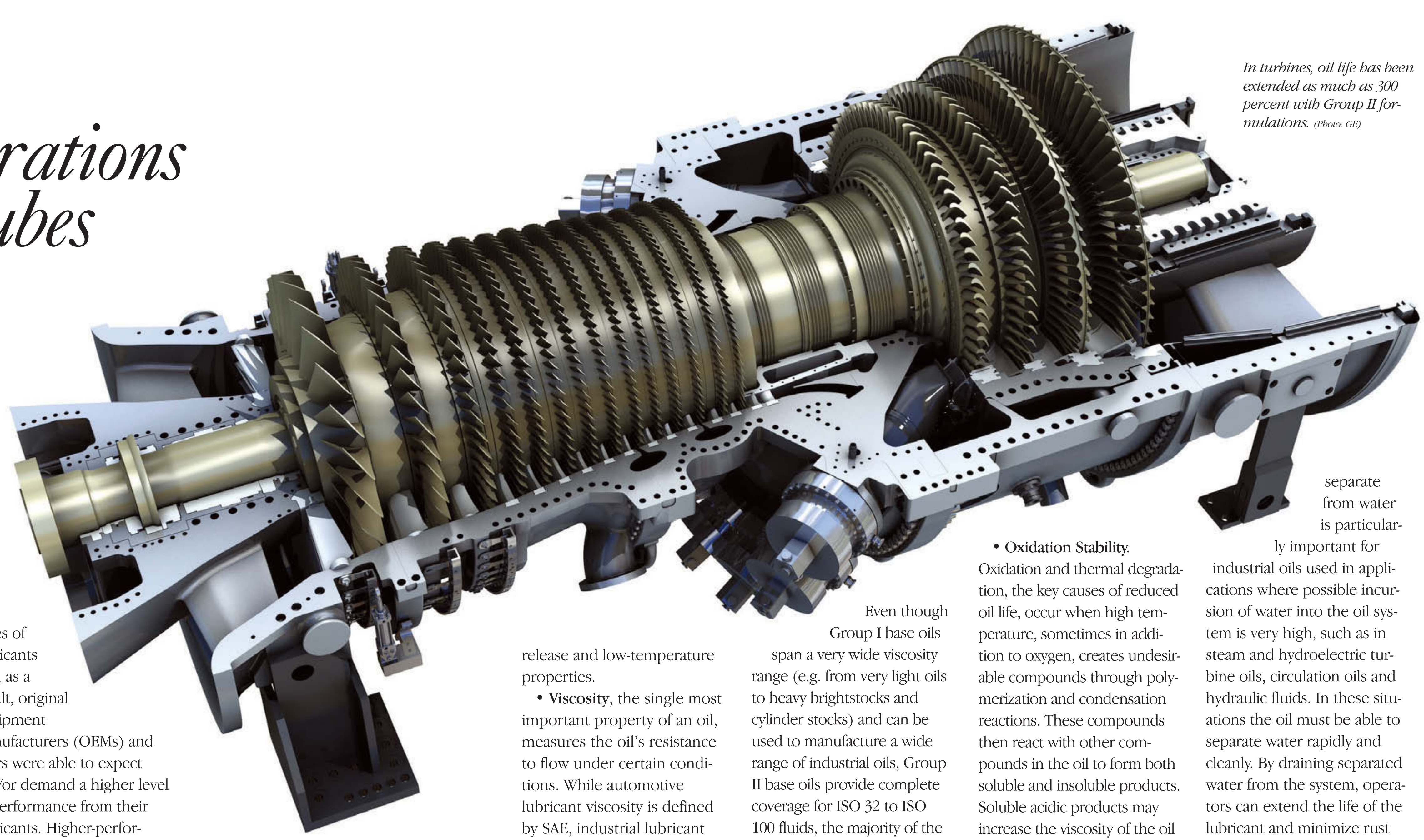
Base Oil Considerations for Industrial Lubes

By John Rosenbaum and Allan Hee



In turbines, oil life has been extended as much as 300 percent with Group II formulations. (Photo: GE)

Industrial lubricants encompass a wide range of applications, without an industry-wide definition of what the category includes. Even if we focus on oils that lubricate machines that are not mobile, this is a huge category that touches practically every person in the world, every day. It includes everything from power plants to sewing machines, in operating environments ranging from hostile to benign. While the applications for industrial lubricants run the gamut, all operators of this equipment share two goals — increasing productivity and reducing down time.

Despite the broad range of applications, industrial products (not including process oils) account for only about half the volume of automotive lubricants. Industrial lubricants are important, but because development, licensing and certification for automotive engine and gear oils are complicated and costly, the majority of lubricant R&D dollars is invested in meeting the requirements of automotive engine oils.

Many industrial oil formulations are typically 90 to 99 percent base oil (compared to 75 to 85 percent for automotive lubricants), and only 1 to 10 percent additives. Because of these low additive treat rates, the performance of many of these lubricants relies heavily on the physical and chemical properties inherent in the base oil.

A major improvement to base oil quality came in the early '90s when Chevron introduced and licensed Isodewaxing technology that enabled cost-effective production of API Group II and Group III mineral oil base stocks. Compared to solvent-processed Group I base oils, these base stocks offer excellent purity and low-temperature performance.

The widespread availability of Group II and III base stocks led to a step-change in value/performance for many types of lubricants and, as a result, original equipment manufacturers (OEMs) and users were able to expect and/or demand a higher level of performance from their lubricants. Higher-performance machinery was then developed that required lubricants to withstand tougher operations and environments (higher operating temperatures, smaller sumps, higher power densities, longer drain intervals, lighter materials, and more compact designs).

In many industrial applications, premium mineral base oils can lead to dramatic performance improvements with minimal cost increases. For example, turbine oils made with Group II base stocks can greatly extend fluid life — up to three years in some applications. This article will focus on why Group II base oils are able provide very good performance for a broad range of industrial applications.

Five Factors

Five base oil attributes are key to industrial oil performance: viscosity, oxidation stability, water separability, air release and low-temperature properties.

- **Viscosity**, the single most important property of an oil, measures the oil's resistance to flow under certain conditions. While automotive lubricant viscosity is defined by SAE, industrial lubricant viscosity is expressed by ISO value, set by the International Standards Organization. ISO value corresponds closely to the fluid's kinematic viscosity at 40 degrees C. Industrial oils are produced in a broader viscosity range than automotive lubricants (see Figure 1, page 30), and run from ISO 10 to greater than ISO 3200. However, a large majority of industrial oil demand falls in the ISO 32 to ISO 100 range.

Even though Group I base oils span a very wide viscosity range (e.g. from very light oils to heavy brightstocks and cylinder stocks) and can be used to manufacture a wide range of industrial oils, Group II base oils provide complete coverage for ISO 32 to ISO 100 fluids, the majority of the industrial oil volume (see Figure 2, page 30).

Additionally, when blended with Group I brightstock, Group II base oils can comprise a significant portion of ISO 150 and ISO 320 industrial fluids as well, improving their performance over an all-Group I formulation. Group III oils, by contrast, cover the narrowest viscosity range because the heaviest Group III stocks are only 35 to 45 centiStoke at 40 C.

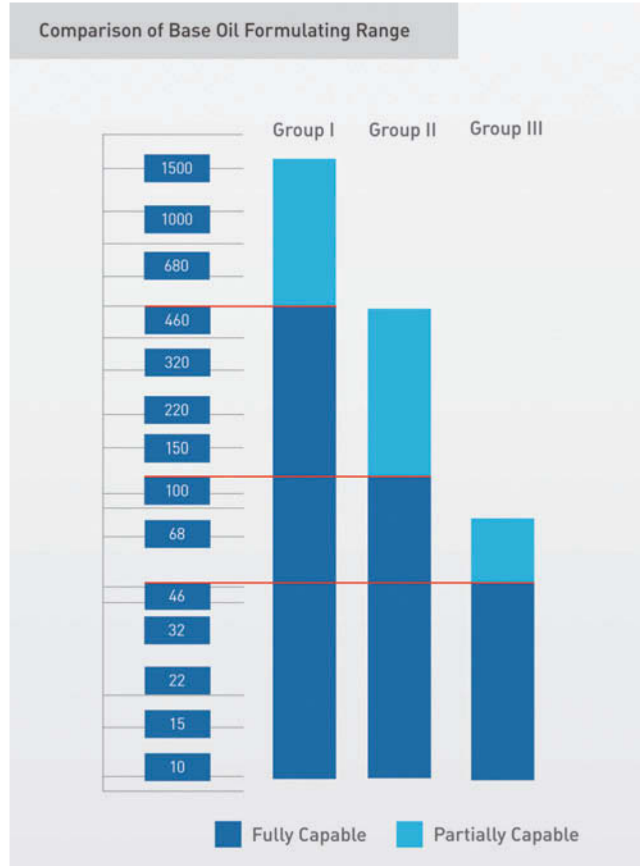
- **Oxidation Stability.** Oxidation and thermal degradation, the key causes of reduced oil life, occur when high temperature, sometimes in addition to oxygen, creates undesirable compounds through polymerization and condensation reactions. These compounds then react with other compounds in the oil to form both soluble and insoluble products. Soluble acidic products may increase the viscosity of the oil and corrode the system, while insoluble products (e.g. gum, sludge, varnish) may increase wear and will eventually plug lines and valves and reduce clearances, which could lead to system failure. Group II base oils have excellent inherent oxidation stability, although a small amount of antioxidant is frequently used in almost all lubricant applications to greatly extend oil life.

- **Water Separability.** The ability of an oil to "shed" or separate from water is particularly important for industrial oils used in applications where possible incursion of water into the oil system is very high, such as in steam and hydroelectric turbine oils, circulation oils and hydraulic fluids. In these situations the oil must be able to separate water rapidly and cleanly. By draining separated water from the system, operators can extend the life of the lubricant and minimize rust and corrosion formation. Due to their very high levels of saturated hydrocarbons and very low levels of polar compounds, Group IIs will usually separate water from oil more rapidly than Group Is.

- **Air Release.** All oils absorb air. Air entrainment is a dispersion of tiny air bubbles throughout the bulk fluid. Hydraulic systems depend on the fluid being incompressible — a property that is compromised if air

Figure 1

Figure 2



Industrial oils are produced in a broader viscosity range than automotive lubricants (left). Most of these industrial oil viscosity grades (right) can be covered using Group II base oil alone ("Fully Capable"), or by blending in an additional volume of another Group ("Partially Capable").

bubbles are present. In addition to compressibility problems, circulating excessive air can also cause pump cavitation and erratic movement of machine parts. High-purity base oils like Group IIs are less likely to stabilize microfoams, and tend to have better air-release times as measured by ASTM D3427.

• **Low-temperature Properties.** Group II base oils have excellent low-temperature properties and, because of their extremely low residual normal-paraffin content, respond readily to pour point depressants (PPD). As with Groups I and III base stocks, careful selection of the correct PPD is important in optimizing the final formulation.

Let's now look at three industrial oil segments that have benefitted from the physical and chemical properties of Group II base oil, beginning with hydraulic oils.

Hydraulic Systems

Group II base oils are a good fit for hydraulic oils, especially since most of the hydraulic oil volume falls within the ISO 32-68 range. Possible advantages of Group II based formulations over Group I formulations include higher oxidation stability, better or more rapid water separation, and lower foaming tendency.

High oxidation stability significantly extends the life of hydraulic oils. In Rotating Pressure Vessel Oxidation Tests (RPVOT, ASTM D2272), hydraulic oils formulated with Group II base stocks demonstrated significantly longer oil life than Group I formulations (see table, left).

Enhanced water separability is another factor. Any moisture that enters the hydraulic system, whether through contamination or condensation, may emulsify, promoting rust, which will increase friction and wear. Group II based formulations can minimize this. In fact, due to their excellent water separability and resistance to foaming, such formulations

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Comparing Hydraulic Oil Performance *(Same additive package and treat rate for all oils)*

Test	ISO 32 Group I	ISO 32 Group II	ISO 46 Group I	ISO 46 Group II
RPVOT (ASTM D2272), min to 25 psig drop	360	449	323	419
TOST (ASTM D943), hrs to 2 TAN	2,520	5,917	2,016	6,460
Foaming Sequences* (ASTM D892)				
Sequence I	10/0	0/0	0/0	0/0
Sequence II	30/0	0/0	30/0	0/0
Sequence III	50/0	10/0	10/0	0/0

**Each Sequence conditions the oil differently. The two numbers signify initial foaming tendency/foam stability. Zero is best.*

Source: Chevron Base Oils

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usually require no or minimal amounts of demulsifiers.

Power Generation Turbines

Turbine oil, in both gas and steam power generation systems, provides clean and cool lubrication to bearings and frequently acts as the working fluid in associated hydraulic systems. Most turbine engines require oils in the ISO 32 or 46 viscosity grades. A lower-viscosity fluid may be needed to lubricate high-speed shafts, while an ISO 68 or ISO 100 fluid may be needed for geared-turbine equipment.

It is well recognized in the industry that turbine oils formulated with Group II base oils have much longer life than those formulated with Group I. As with hydraulic oils, Group II based turbine oils will separate rapidly from water or air with no or minimal assistance from demulsifying additives or anti-foaming agents.

Turbine OEMs have stringent oxidation-related specifications for turbine oils. Two of the most common tests are the RPVOT and the Turbine Oil Stability Test (TOST). Both tests are commonly used in the industry as measures of oxidation stability and service life. When turbine oils are properly reformulated from Group I to Group II base oils, TOST values can triple.

Varnish has become an issue in some turbine oil systems, where unwanted deposits can adversely affect the operation of servo valves, bearings, filters and other components. While some have blamed varnish on the base oil used, this is usually a gross oversimplification. Varnish in turbine oils can vary from one application to the next, and the many causes are currently under investigation in several labs. Multiple root causes for varnish formation have been postulated, including microdieseling, certain additive types, electrostatic discharge and overextending oil drain intervals.

Avoiding varnish formation requires the development of a robust formulation — both in terms of additives and base oil — that properly balances the (sometimes opposing) requirements for oxidation resistance and low-varnish tendency.

Natural Gas Engines

Natural gas engines used in industrial applications operate at high loads, high temperatures and for long periods of time, while exposing the oil to severe oxidation and nitration conditions. The engines are often in remote locations and must run with minimal operator attention, so engine reliability is critical. There are no industrywide tests for evaluating natural gas engine oil performance. Instead, OEM approvals are granted only following field trials.

Here too, Group II base oils have proven to be an excellent, cost-effective fit. Most gas engines use an SAE 40 viscosity grade oil or, in some cases, an XXW-40 multigrade. As a result, the base oil blend of these lubricants can be mostly or all Group II.

Group II base oils also enable a formulator to maintain the same additive treat rate as would be used with a Group I base oil and achieve higher oxidation stability. Or, a lubricant company may choose to reduce the additive treat rate when using a Group II and offer a product with equivalent stability to a Group I formula.

Gas engine oil formulators must watch out for sulfated ash. Sulfated ash is combusted residue (ash) left when a certain quantity of oil is burned using the ASTM D874 test method. This ash is an inherent property of certain additives, some of which are necessary to protect exhaust valves in natural gas engines. Gas engine temperatures are typically high, so deposits are a common problem if ash levels are not kept low in the engine lubricant. Piston deposit control is critical to prevent ring and liner wear. If deposits accumulate in the grooves, they will push the ring against the liner and cause adhesive wear. Also, excessive buildup of deposits on the piston lands may polish and abrade the liner surface.

A key way to improve piston deposits is through a well-formulated lubricant that taps into Group II's strong oxidation and nitration control. One back-to-back field test compared two NGEOs made with Group II and Group I, running over 8,000 hours each in a natural gas pipeline operation. The Group II showed far greater oxidation stability, TBN retention and nitration control, with less than half the piston deposits. And it did so even though the Group II formulation's drain intervals were 50 percent longer.

To summarize, almost all industrial oils can benefit from the use of Group II base oil in their formulations. What is critically important is that the lubricant be formulated properly and optimized for the operating environment in which the oil will be used. Every application is different, and additive companies have many years of experience making industrial oils with a broad range of base stock types. ▮


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