What's So Special about Specialty Lubricants?

Modern, automated equipment can place heavy demands on conventional lubricants. A vast array of specialty formulations has been developed to provide reliable operation and minimize downtime.

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Longer lubrication intervals and minimum spillage are becoming important concerns to ensure the reliable operation of automated equipment. To meet this need, manufacturers of modern lubricating and process oils have developed products that operate over wider temperature ranges and in harsh environments. The key design criteria are:

- Film strength: Will the lubricant separate the running surfaces?
- Oxidation/thermal breakdown: Will it deteriorate between −100 to 600°F?
- Evaporation/creep: Will it vaporize or run off during use?
- Compatibility: Will it attack, dissolve, or swell adjoining plastics or elastomers?

Specialty lubricants are usually classified according to end use. However, a study of the various applications indicates that one or more of the following conditions or operating requirements is present:

- High temperature
- High speed
- High vacuum
- Oxidizing environment
- Corrosion
- Heavy load

High temperature

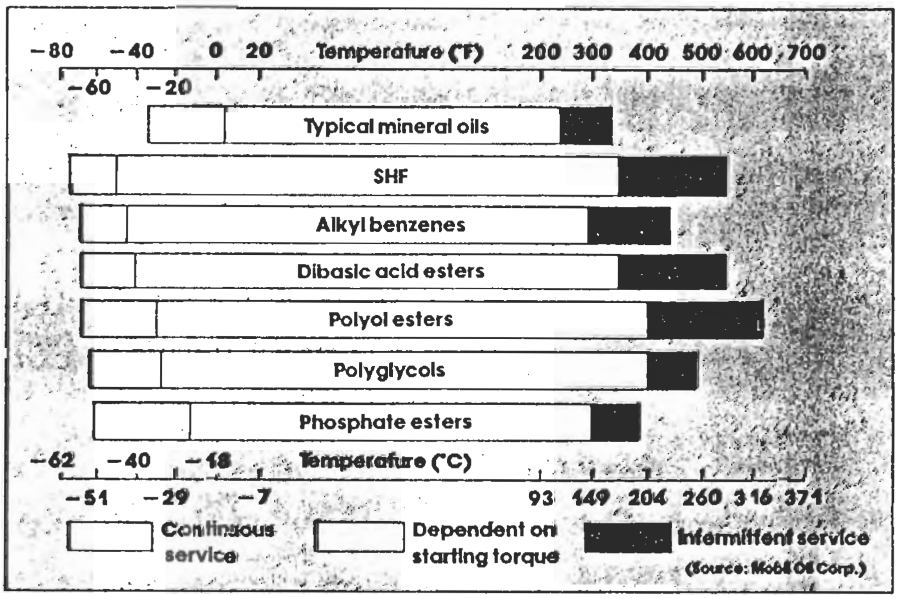
Lubricants are susceptible to failure at high temperature, especially in thin films and at long term exposure. Most lubricants can operate at elevated temperatures for limited periods provided the ratio of volume to surface area is high. But oxidation, the primary form of lubricant degradation at high temperatures, eventually occurs even under these conditions.

Oxidation is a two-step molecular process. Primary oxidation products include alcohols and ketones. Next, secondary reaction products are formed which precede sludge formation. Once the primary oxidation products are formed at high temperatures, oxidation may proceed at normal operating temperatures.

Recent research in boundary lubrication substantiates the primary role of high temperature in lubricant degradation. Increasing temperature rather than increasing shear load has been found to induce most lubricant failure.

Typically, specialty synthetic fluids are required for temperatures over 400°F. Formulations include, phenyl silicones (0 to 450°F), polyphenyl ether (40 to 550°F), and fluorinated ether (−10 to 550°F). Over 550°F, resin bonded solid-film lubricants generally replace oils and greases.

Graphite and molybdenum disulfide are the most widely used solid lubricants. Molybdenum disulfide loses its lubrication ability in wet environments but is superior in vacuum environments. Graphite, on the other hand, needs a liquid vapor film to operate as a lubricant and fails in vacuum conditions.



Graph compares temperature limits of hydrocarbon synthetics and mineral oils. Often temperature extremes limit the choice of lubricant that can be used.

The long and short of synthetic lubricant properties

Synthetic	Advantages vs. Mineral Oil	Limiting Properties
SHF	High temperature stability Long life Low temperature fluidity High viscosity index Improved wear protection Low volatility, oil economy Compatibility with mineral oils and paints No wax	Solvency/detergency* Seal compatibility*
Organic Esters	High temperature stability Long life Low temperature fluidity Solvency/detergency	Seal compatibility* Mineral oil compatibility* Antirust* Antiwear and extreme pressure* Hydrolytic stability Paint compatibility
Phosphate Esters	Fire resistant Lubricating ability	Seal compatibility Low viscosity Index Paint compatibility Metal corrosion* Hydrolytic stability
Polyglycols	Water versatility High viscosity index Low temperature fluidity Antirust No wax	Mineral oil compatibility Paint compatibility Oxidation stability*

*Limiting properties of synthetic base fluids which can be overcome by formulation chemistry.
Source: Mobil Oil Corp.

In certain applications, polyalkylene glycol and polybutenes are used as carriers for solid lubricants because these lubricants cannot be applied in their pure form of powder or flakes. The carriers provide easy application and low price. Also, they leave no residue after degradation, leaving a viable solid lubricant film in place. A drawback to solid lubricants in high temperature applications is that they do not provide cooling and have limited wear resistance.

High speed

High rotational speeds are most often encountered with precision bearings. In this application, grease lubricants are the usual choice because of design simplicity and ease of maintenance. In fact, stiffer, channeling type greases are used to minimize heat generation due to churning. In addition, the stiffer greases counteract the inherent centrifugal and gravitational forces within the bearing assembly that tend to dislodge the lubricant from the intended surfaces.

High temperatures normally dictate the use of synthetic lubricants. While petroleum-based greases have a so-called speed factor (bearing bore in mm × rpm) of 600,000 their high temperature limit is only from 200 to 250°F. Synthetic grease formulations and their speed factors and temperature ranges are:

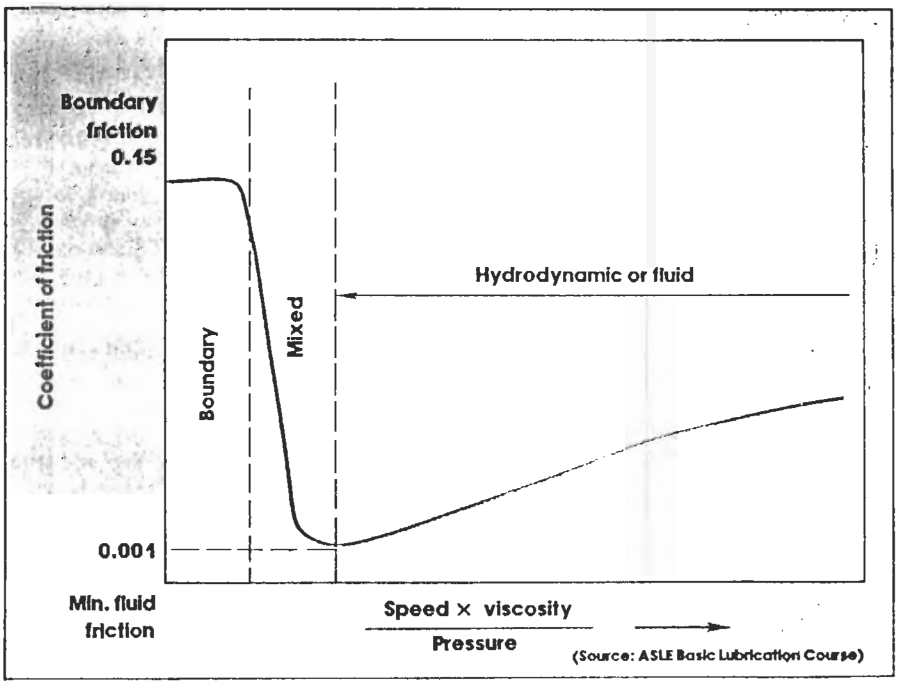
- Ester — 400,000, −100 to 300°F.
- Silicone — 200,000, −100 to 400°F.
- Synthetic hydrocarbons — 400,000, −75 to 300°F.
- Polyethers — 500,000, −50 to 350°F.
- Fluoroether — 400,000, −40 to 550°F.

Another increasingly important factor for precision bearings is the elimination of contaminants in the lubricating medium. This is because even a 100μ-in. hard particle can damage a small, precision bearing. End users require that no particle larger than 35μ-in. can be present. Consequently, ultrafiltration of precision ball bearing grease is being recommended by specialty lubricant suppliers. Thus far, only a heavy loaded polytetrafluoroethylene polymer gelled grease was found to be unfilterable.

High vacuum

Conventional hydrocarbon liquid lubricants generally evaporate from lubricated surfaces quite quickly in vacuum environment. The speed of evaporation depends upon the temperature and the molecular weight of the hydrocarbon. As a result, solid lubricants usually are preferred for vacuum conditions. The traditional vacuum lubricant is molybdenum disulfide in a bonded coating. MoS_2, which deteriorates in high humidity, actually improves its lubricity in vacuum environments. Diselenides are even better due to lower outgassing properties. One manufacturer quotes a temperature range of −325 to 450°F for molybdenum disulfide dry film lubricant.

The addition of graphite extends the temperature range to 842°F. However, graphite should not be used alone in a vacuum. Graphite depends on condensable vapors to provide a lubricant film; thus, it exhibits poor lubrication properties in a vacuum.



A combination of lubrication regimes often requires the use of specialty lubricants. For example, a start/stop application involves the boundary lubrication regime, plus the hydrodynamic or fluid regime.

ever, the high temperature limitation of such oils is still only 250°F.

Among synthetics, expensive fluorinated ethers, fluorosilicones and polyphenyl ethers have superior oxidation resistance. Silicate esters also have a wide temperature range; however, they breakdown slowly in high humidity. Silicones, also have a wide temperature range, but they are notoriously unreceptive to most additives, including antioxidants.

Shielded polysilicates are better lubricants than silicones and readily accept additives. They operate from −100 to 300°F and have the required oxidation stability. For temperatures to 500°F, polyphenyl ether grease would be required if dry lubrication could not be used. To provide an economic advantage for synthetics over dry lubricants, current research is concentrating on developing more effective antioxidants.

As with other lubrication problems, oxidation resistance normally means may occur during initial use or the break-in period. This phenomenon is caused by uncontrollable misalignment, clearances, surface finish, and thermal expansion.

Additives in mineral oil-based lubricants can increase wear resistance during this break-in period. The most widely used additive is molybdenum disulfide. Unlike antioxidants which are sometimes limited to a 1% concentration, molybdenum disulfide can be used at concentrations of 2 to 3% in oils, 5 to 10% in greases, and as high as 60% in a paste form.

Other antiwear additives used in mineral oils are fatty oils, polar organic compounds, and phosphate esters. Often, sulfurized extreme pressure additives are also used to prevent wear because high loads often breakdown the oil films that separate the metal surfaces. The additives react with the metal surface to form a supplementary lubricating film preventing the adhesive form of wear.

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Synthetic lubricants often provide increased wear protection over mineral oils due to better viscosity-temperature properties. However, even synthetics use antiwear agents. For example, synthetic hydrocarbon-based bearing oils in stop-start conditions need antiwear agents to protect the boundary lubricated surfaces. Also esters require the addition of tricresyl phosphate to improve their wear resistance. Because greases and oils thin with increasing temperature and are squeezed from their lubricating surfaces with increasing load, bonded solid-film lubricants provide superior wear protection.