Definition[1]

The production of synthetic lubricants starts with synthetic base stocks that are often manufactured from petroleum. The base fluids are made by chemically combining (synthesizing) low molecular weight compounds that have adequate viscosity for use as lubricants. Unlike mineral oils which are a complex mixture of naturally occurring hydrocarbons, synthetic base fluids are manmade and tailored to have a controlled molecular structure with predictable properties.

A mineral oil is a mixture of many compounds. There is no economical way to select from this mixture only those compounds with the best properties for a particular application. Thus, mineral oils have properties that are the average of the mixture, including both the most and the least suited compounds.

With synthetic base stocks, on the other hand, the process of combining individual units can be controlled so that a large portion of the finished base fluid is either one or a few compounds. The compounds can have the properties of the best compounds in a mineral base oil. They can also have such unique properties as miscibility with water or complete non-flammability that are not found in any mineral oil.

History of Synthetic Lubricants

Synthetic lubricants are not new; as a matter of fact, lubrication by synthetic lubricants goes back to antiquity when such materials as animal fats were used. Synthetic lubricants became more prominent during World War II in Europe, largely by the Germans' efforts, when the severe cold temperatures rendered war machinery inoperative with conventional petroleum lubricants; this need for synthetic lubricants was enhanced by petroleum shortages associated with that war. The jet engines used in aircraft during the Korean conflict required the stability of a synthetic lubricant. The aerospace industry then became involved in synthetic lubricant research and devised further uses for them. Finally, in the 1960s synthetic lubricants gained commercial acceptance.

Classes of Synthetic Lubricants[1]

There are many classes of synthetic lubricants, some of which are listed below:

- **Synthetic Hydrocarbons**
  - Polyalphaolefins (also called Olefin Oligomers)
  - Polybutenes
  - Alkylated Aromatics
  - Cycloaliphatics
- **Organic Esters**
  - Dibasic Acid Esters
  - Polyol Esters
  - Polyesters

Others

Phosphate Esters
Polyglycols
Silicones
Silicate Esters
Polyphenyl Esters
Halogenated Fluids

Some properties of these classes are given in Table 1.

Advantages of Synthetic Lubricants

High temperature thermal stability (in excess of 500°F operation is achievable)

Low temperature fluidity

High Viscosity Index (low change of viscosity with temperature)

High flash, fire, and autoignition temperatures (safety)

Less carbon and varnish forming tendency

Superior lubricity

High film strength

Longer service life (8,000 hours with synthetic lubricants in air compressors, for example)

Oxidative stability (does not thicken due to changes brought about by oxidation)

Synthetic Lubricant Applications[2,4]

Synthetic lubricants are being utilized in almost every industry to reduce maintenance and energy consumption. Energy and cost savings can be achieved from reduced maintenance, fuel consumption, lubricant consumption, and downtime.

Most of the initial energy conservation work was done and documented in the automotive industry, whereby reports of 3.5 to 7 percent fuel consumption savings were reported in controlled tests using synthetic lubricants against a set of standards using petroleum oils. These automotive tests led to industrial field tests in such equipment as large gas engines, gear boxes, turbines, electric motors, compressors and so forth. In each class of equipment, it has been determined that synthetic lubricants, when properly selected, can result in energy and cost savings, some examples of which follow.

A pipeline company in Texas reported a fuel savings of 3.6 percent at all load conditions on their main engines at a compressor station as a result of using a synthetic gas engine oil, SAE 40 grade. Further power improvement averaged 39.9 bhp throughout the load range of the engines and oil consumption was reduced by 50 percent. In addition to these savings, the engine operating temperatures were lowered and the internal parts of the engine were much cleaner. This oil was in service for over five years of operation.

Thousands of companies report that the use of synthetic lubricants in their air compressors has virtually eliminated downtime for compressor maintenance and has increased lubricant life by up to eight times. Oil consumption is considerably reduced and because of superior lubricity, the feed rates to compressor cylinders have been reduced by 30 to 50 percent.

Table I

Properties of Various Base Fluids

	Lubricant Class					
	Petroleum Oil	PAO	Esters	Phosphate Esters	(Polyalkylene Glycols) Polyethers	Highly Fluorinated Compounds
Lubricity	Good	Good	Excellent	Fair	Good	Good
Software Compatibility	Good	Excellent	Fair	Poor	Fair	Good
Additive Response	Good	Fair	Excellent	Good	Good	Poor
Volatility	Fair	Excellent	Excellent	Fair	Fair	Good
Oxidation Stability	Fair	Excellent	Excellent	Fair	Fair	Excellent
Compatability with Petroleum	Good	Excellent	Excellent	Good	Poor	Poor
Fluid Range	Poor	Excellent	Excellent	Fair	Good	Fair
Fire Resistance	Poor	Fair	Good	Excellent	Fair	Excellent

Excellent ● Good ◍ Fair ◌ Poor ○

(1) Strongly corrosive degradation

A refinery in Louisiana using an ISO-68 petroleum in a mist system found that after changing to an ISO-32 synthetic fluid, their electric motor bearing failure rate decreased to the point that it is almost non-existent. Because the synthetic lubricant has such superior lubricity, the viscosity could be reduced to an ISO-32 grade, reducing the power consumed by the motors as well.

In a southern textile mill, the plant engineer decided to find out whether or not power could be saved in the twisters laying tire cord on 144 bobbins. There were 75 such units, each driven by a 50 hp motor. Careful metering and correlation with variable production rates convinced him that a real power cost reduction of over $6,000 per year had been achieved by switching from mineral to synthetic lubricants. In this case, the lubricated components were spur gears, chains, bearings and cams.

A midwestern tube mill had experienced fires, gear failures, burned oil seals, and severe sludging in a number of worm gear drives to the extent of about 15 failures annually. Replacing the mineral oil with the appropriate synthetic lubricant reduced gear and bearing losses dramatically so that fewer replacement parts, less repair time, and increased production yielded a $40,000 annual savings.

One synthesized hydrocarbon-based gear oil was used continuously for one year at -40°C in variable-speed gear drive units in freeze-dried coffee production. Practically no wear had occurred on the chain and gear discs after the one year period. The previous oil had to be changed every three months because of wear debris and the chain and gear discs replaced every year.

Another example involved a worm gear that operated at 100 to 225 percent of rated load. A synthetic gear oil increased the efficiency of the unit by 10 percent over a compounded mineral oil.

The longer life expectancy of the polyalphaolefin-based gear lubricant predicted by long term laboratory oxidation tests has been substantiated in several field tests. In one test of this gear lubricant, worm gears were operated continuously 24 hours per day[1] with no deterioration after 5,000 hours. This, plus various other field tests, showed that the life of the synthetic oil was three to ten times that of mineral oils used in the respective applications.

The broad temperature range and greater oxidation stability of polyalphaolefin lubricants also are beneficial when utilized in critical circulating oil service. One such oil gave 10,000 hours of service at 121°C, compared to 1,500 hours for a compounded mineral oil. A similar oil used in stationary gas turbines extended the oil life to 8,000 hours from 800 to 1,000 hours with a mineral-based turbine oil.

Compatibility[3]

Are synthetic lubricants compatible with conventional mineral oils? Not always. Many are designed to be fully compatible with conventional oils, seals, paints, and metals commonly encountered. The manufacturer should always be consulted for assurance in this regard. The potential for benefits designed into the synthetic is compromised, of course, by the presence of whatever volume of mineral oil is admixed. In extreme cases, even small amounts of mineral oil depreciate the performance of the mixture far beyond the extent its presence would lead one to believe.

Disposal[3]

How does the use of synthetic lubricants affect disposal procedures? Depending upon the chemistry of the fluid, there could be disposal questions to be addressed to the supplier, but many are handled just as conventional lubricants would be. The advantage, of course, comes from the fact that smaller volumes are involved because of the long life characteristics. There are fewer drums to buy, inventory, and return and there is less used oil to burn or have hauled away.

Price

What about the price of synthetic lubricants? Typically, the polyalphaolefin and diesters will cost three to four times that of the best mineral oils. Some of the more exotic ones might be a hundred times more.

Overall Energy Savings

Since synthetic lubricants require more energy to manufacture than do mineral oils, questions about the overall energy balance have been raised. One detailed study[5] examined this balance by comparing a synthetic SAE 5W/20 passenger car engine oil with a conventional SAE 10W/40 oil. Assuming 6,000 mile oil drains and a four percent fuel economy advantage, it was found that for each barrel of synthetic oil used in place of a conventional oil, the net energy savings was 38 million BTU, equivalent to 6.6 barrels of crude oil.

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