Technical Bulletin

Sludge / Varnish Potential of Hydraulic Fluids

The formation of sludge and varnish from a hydraulic fluid is a problem for a hydraulic system. Sludge is formed when there is a large change in the chemical polarity as oxidation occurs. In the past, contract laboratories use oxidation and nitration (ASTM E2412-10) as an indication of sludge and varnish potential for mineral oils. Today, they perform a varnish potential analysis.

ASTM E2412 is a very important test for petroleum oils, polyol esters, and vegetable oils for determining varnish potential and suitability for continued use. This is because by-products of oxidation in these hydraulic fluids are NOT SOLUBLE in the base stock. Therefore, they precipitate from the hydraulic fluid when the temperature is decreased. However ASTM E2412 is non-predictive of varnish potential for polyalkylene glycol (PAG) hydraulic fluids (such as EcoSafe® products). EcoSafe® products do not form sludge and varnish because the high polarity of the base stock relative to the polarity of the oxidation by-products allows these materials to remain soluble in a PAG.

Let us run the numbers for model mineral oils, esters, and PAG's to understand why.

By selecting a mineral oil, vegetable oil, and EcoSafe® base stock having the same molecular weight Table 1 shows the chemical differences between the base stocks and the change that occurs with oxidation.

	Mineral Oil **hydrocarbon**	**Vegetable Oil** **ester**	**EcoSafe®** **PAG**
Number of Carbon and Oxygen per molecule in new base stock fluid	63 Carbon - 0 Oxygen	57 Carbon - 6 Oxygen	47 Carbon - 16 Oxygen
Percent Oxygen in new base stock fluid	0 %	9.5 %	25.4 %
Percent oxygen with one additional oxygen	1.5%	10.9%	26.6%
Change in oxygenation (polarity) with 1 additional oxygen	∞	15 %	4.7 %

With mineral oil, there is an infinite change in the polarity during oxidation (1.5 ÷ 0). Therefore, the oxidation by-products tend to be insoluble in the base-stock leading to sludge and varnish production.

Along with the change in polarity, the molecular weight of the decomposition by-products is important. Oxidation causes a slight increase in molecular weight of a mineral oil. Acids, esters and vegetable oil based fluids increase in molecular weight as they age. This is due to the chemical combining of the base stock through esterification.

	Mineral Oil **hydrocarbon**	**Vegetable Oil** **ester**	**EcoSafe®** **PAG**
Number of Carbon and Oxygen per molecule in new base stock fluid	63 Carbon - 0 Oxygen	57 Carbon - 6 Oxygen	47 Carbon - 16 Oxygen
Number of Carbon and Oxygen in aged fluid	63 Carbon – 1 Oxygen	114 Carbon – 12 Oxygen	46 Carbon – 17 Oxygen
Change in molecular weight with aging	1%	100 %	-1 %

To the extent that the decomposition of a mineral oil generates acid, the base stock is additionally susceptible to increase in molecular weight just like an ester base stock.

It is the carbon component of the base stock that is most susceptible to oxidation. Therefore, each base stock type can be assessed for its potential for degradation and decomposition by these two mechanisms.

	Mineral Oil **hydrocarbon**	**Vegetable Oil** **ester**	**EcoSafe®** **PAG**
Number of Carbon and Oxygen per molecule in new base stock fluid	63 Carbon - 0 Oxygen	57 Carbon - 6 Oxygen	47 Carbon - 16 Oxygen
Percent susceptible to oxidation	100%	90.5%	74.6%
Percent susceptible to esterification	0%	9.5 %	0 %

With vegetable oil based products, there is less change in the polarity with each added oxygen. However, there is a large change in the molecular weight of the oxidation by-product. This increases the potential for the polymer to form varnish as these very high molecular weight materials are traveling through the hydraulic system. A polyol ester would behave similar to a vegetable oil hydraulic fluid.

When the question is asked, "Why doesn't EcoSafe® form sludge or varnish?" you can answer.

EcoSafe® does not form sludge and varnish because the change in polarity with oxidation is low, the change in molecular weight with oxidation is low, and the amount of the material susceptible to oxidation is relatively low.

Oxidation does not significantly change the EcoSafe® hydraulic fluid. Therefore when you want to have a hydraulic fluid that has a long useful life, EcoSafe® is the way to go.