

Copper and Your Diesel Engine Oils

[Jim Fitch](#), Noria Corporation

I recently analyzed a database of more than 30,000 oil analysis reports from diesel engine samples (Class 8, long-haul trucks). With so much information at my fingertips, I was like a kid in a candy store. Today's database software products empower users with versatile analytical tools that can rapidly search, sort, graph and statistically analyze data. With the right queries, one can turn huge amounts of raw oil analysis data into new interpretation guidelines, fault trees and rule sets for the oil analyst.

Naturally, after a couple of hours of slicing and dicing this rich database, I discovered many interesting facts. One such fact relates to copper. In diesels, copper is second only to iron as the most abundant wear metal. I've always known copper was important, but I never put it on the same scale as iron. Take a look at the numbers below for the 30,000-plus oil samples:

	Average	Highest Reading	Standard Deviation (SD)
Iron	52 ppm	1549 ppm	42 ppm
Lead	9 ppm	412 ppm	9 ppm
Copper	33 ppm	999 ppm	67 ppm

These statistics obviously show that copper readings fluctuate much more than iron readings. For instance, 95 percent of the data for iron was below 136 ppm (average plus 2 SDs). However for copper, the average was lower but the data had much greater variability; that is, 95 percent of the data was below 167 ppm. This is due to the fact that, unlike iron, there are sources that can release copper into the oil at rates faster than that produced by classical wear modes.

Cooler Core Leaching

As distinguished from mechanical wear, cooler core leaching is a chemical process. Although well documented in the literature, it has been only recently that the factors leading to the phenomenon have been understood. It seems to boil down to three things: zinc dialkyl dithiophosphate (ZDDP), heat and new engines. The principle elemental component of ZDDP is sulfur. For new engines with less than 1,500 hours of service life, the cooler core becomes an active reaction site for the ZDDP, resulting in copper sulfides forming on the copper cooler tubes. These sulfides later slough off into the oil, contributing to a rising copper concentration that can reach well over 300 ppm. As alarming as this sounds, it has been reported that copper sulfide, even in these high concentrations, is generally benign and as such may not be associated with (cause or effect) cooler failure, accelerated wear or lubricant oxidation. While I personally have not seen the data that support these claims, I also have no basis to refute them.

Interestingly, the reaction starts at oil temperatures around 220°F (104°C) and is magnified (worsens) at higher oil temperatures at an exponential rate. The good news is that over time the cooler core copper

surfaces will begin to pacify as a clear varnish-like coating forms over the copper sulfide. The release of copper sulfides into the oil will then begin to slow considerably or stop altogether. It can take several oil changes for this to occur. Until then, copper levels from 100 ppm to more than 300 ppm might be expected. Even after the varnish coating forms, a change in oil chemistry can lead to its sudden removal and a return to high copper readings. For instance, a change to a different brand of motor oil or the addition of an additive supplement can potentially result in depacification.

Copper Source	Unique Potential Companion Elements	Reliability Risk	Detectability		
			Filtergram Microscopy	ICP/RDE Spectroscopy	XRF/SEM-EDX Spectroscopy
Cooler Core Leaching	None	Minimal	Poor	Good	Marginal
Coolant Leak	Sodium, Silicon, Potassium, Boron and Molybdenum	High, from Glycol	Poor	Good	Marginal
Wear Metal	Zinc, Tin, Iron	Depends on Severity	Good	Marginal	Good
Antiseize Compounds	Aluminum, Nickel	Minimal	Marginal	Good to Marginal	Marginal
Antiwear Additive	Phosphorous	None	None	Good	Poor

Coolant Leak

In most cases, a coolant leak into the crankcase oil will bring a detectable and often sizeable concentration of copper. Companion elements typically also appear from additives that are formulated with the glycol or introduced as a supplement into the coolant. These additive elements could be various combinations of sodium, silicon, potassium, molybdenum and boron, among others. It is always good to baseline the antifreeze to determine the normal family of elements found in its formulation. When the same relative concentrations of elements, along with copper, are found in the used engine oil, one should rightfully suspect a coolant leak.

Copper as a Wear Metal

Copper is the principle metallurgical component of brass and bronze. Such metals are commonly found in bushings used in rocker arms, wrist pins and the turbo bearings, for instance. Many crankshaft and camshaft bearings may have a layer of bronze residing just below a lead/tin bearing overlay. There are still other sources of copper in a diesel engine, including the governor, the oil pump and the service meter drive gear. Companion alloying elements such as zinc and tin may help reveal the source, as well as metals generated from mating surfaces (typically iron). Expect alloying elements to be low in concentration compared to copper.

Copper from wear debris will rarely produce concentrations greater than 50 ppm, in fact, 10 ppm to 20 ppm would be more typical. As such, higher concentrations of copper from cooler core leaching and coolant leaks may mask more serious sources of copper associated with wear.

If copper associated with wear is suspected, perhaps it is best to prepare a filtergram and perform a microscopic analysis of the particles. Because copper suspensions from cooler core leaching and coolant leaks are soluble or the associated copper particulates are smaller than 1 micron, they likely won't appear

on the membrane for microscopic analysis. Only the copper from wear will be visible, which is helpful in distinguishing the source.

It is also worth noting that elemental spectrometers are limited by particle size. Bronze and brass particles generated from active wear zones may not be fully revealed by conventional spectrometry in their true concentrations due to this limitation. As particle sizes exceed 5 microns, they become sharply less quantifiable by emission spectrometers. According to a study by Northeastern University, only 7 percent of copper particles ranging in size from 1 micron to 11 microns are measured with elemental spectrometers (RDE or ICP). This emphasizes the need for microscopic analysis or perhaps XRF/SEM-EDX spectrometry, neither of which are affected by particle size limitations.

There are many other origins of copper that must be considered. These include environmental sources (dust from a copper mine for instance), antiseize compounds, gaskets, paint and certain antiwear additives. A close inspection of the work environment and the elemental constituents of materials that are handled and processed by diesel-powered machinery is a wise beginning.

In sum, copper found in diesel engine oils can come from wide-ranging sources and can exist in the oil in varying states. From the oil analyst's perspective, determining the source, nature and state of copper is essential to correctly interpreting the alarm in terms of engine reliability and the appropriate response. Although very valuable, elemental analysis has only limited capability and, in fact, may produce false alarms or mask real alarms unless other tests are performed concurrently or on an exception basis. A properly designed oil analysis program that mitigates these risks is the best game plan.

Practicing Oil Analysis (9/2004)

About the Author



Jim Fitch

Jim Fitch, a founder and CEO of Noria Corporation, has a wealth of experience in lubrication, oil analysis, and machinery failure investigations. He has advised hundreds of companies on developing ... [Read More](#)