Technical Topic

Elevated copper in used oil analysis

Basics of oil analysis

Routine oil analysis on critical equipment tests for common metals such as Iron, Copper, Lead, Potassium, Silicon, etc. Metals may be a wear metal, a contaminant, or an oil additive. Some metals are normal, while others can be signaling a component problem, contamination problem, or oil problem.

Generally, metals are the most telling when they are correlated with another metal or test result. For example, when copper trends with lead or tin, it may be signaling Babbitt wear. While copper trending with water or coolant additives might signal a cooler leak.

Copper is one of the most reactive metals in oil systems. It is commonly a "false alert" related to high copper that has no real impact to the equipment or can resolve itself on its own. While all alerts should be investigated, a copper alert may not require corrective action after the root cause has been correctly identified.

Where can copper come from?

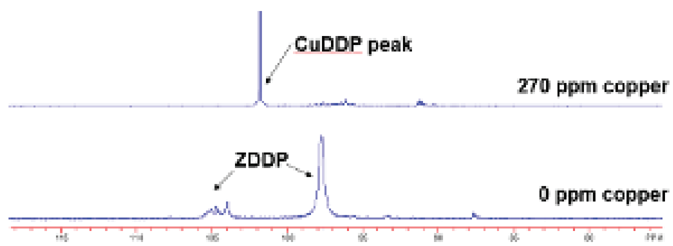
Copper is a metal regularly used in componentry of modern equipment, not as an additive in lubricating oils. Generally, elevated copper in oil analysis is internally generated (except in some rare cases of external pastes or copper manufacturing).

Wear: Copper is the main component in alloys such as brass and bronze, and it is used in layers in applications like babbitted bearings. Copper can also be used in its raw form (not alloyed) in system oil coolers. To be considered wear, the metal would be removed abrasively and is left in the oil in the form of debris, shavings, etc.

Corrosion (minor or major): Corrosion occurs as electrons transfer and allow the material to change molecularly. This occurs with water, oxygen, acids, but the same type of reaction can happen between dissimilar metals transferring electrons.

Raw copper is reactive and is more stable in its ionic form. This means that raw copper will readily oxidize or react with other chemistries to lower its energy. This reaction can be prevented with coatings, but is a natural phenomenon, especially sped up in the presence of water and heat. It will result in copper salts (ions) dissolved in the oil. These salts/ions are completely dissolved. They are not abrasive and cannot be filtered out with particulate filters. They simply stay in the oil to be drained out or may eventually react with something else to settle out. This occurs in any oil including base oil without any additives.

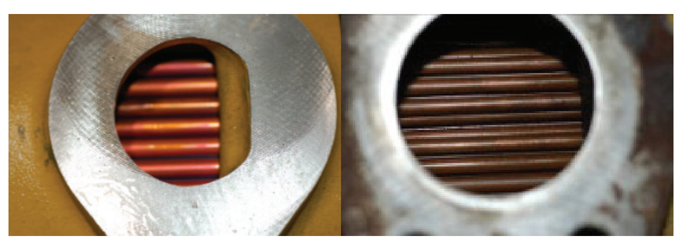
Ion Exchange with Additives: In addition to copper corrosion some oil additives are surface active and can exchange with copper. A raw/basic copper cooler in the presence of ZDDP (Zinc Di-alkyl Dithio Phosphate) oil additive can exchange copper ions and exchange zinc onto the cooler. This exchange can result in a form of CuDDP that can in some cases be observed in the used oil by NMR (Nuclear Magnetic Resonance Spectroscopy) shown below:



This is only one example of observed copper exchange. There are many other reactive additives that could undergo a similar exchange. Additionally, dissolved copper may stay in solution without any measured exchange.

Does copper hurt the oil?

While this process may sound complex, the result is typically harmless and is only observed in oil analysis or inspection of copper coolers. Below is an example of the same type of filter. The one on the left is new, while the used one on the right has undergone normal copper passivation (ion exchange). The copper tubes appear tarnished, but after the initial passivation, the process achieves equilibrium and stops.



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The remaining copper in the oil will also stop increasing. It will stay in suspension or settle out with time/reaction. The oil analysis reports may alert, but the copper levels will reduce over time with oil changes or settling.

The passivated or tarnished copper is now less reactive and less likely to work as a catalyst going forward. The dissolved copper in the oil does not have significant impact to oil health as it is now in a lower energy state and not readily reactive.

Copper levels may spike again if new copper is added to the system (new cooler) or if a different oil with different additive chemistry is introduced. Cleaning may occur and a new equilibrium may be found.

Why do some used oils show more copper than others when tested?

ExxonMobil has observed that some oil formulations show more dissolved copper than others. For the oil analysis to measure copper, the copper must be dissolved from a copper source AND the copper must stay suspended in the oil. While surface active chemistries can promote the ion exchange, dispersant technologies (cleaners) may hold the copper in solution better. The cleaning technologies can even clean up old, settled copper in dirty systems.

If you are observing elevated levels of copper, consider their root cause.

1. Raw copper is exposed due to system design.
2. The oil has surface active chemistry needed in other areas of the machine to help with wear protection, rust prevention, cleaning, etc.
3. The oil cleaning and suspending the copper rather than allowing it to settle out in other areas.

There is not a right or wrong version of the three ingredients above. It will depend on how the system is built and what the oil is designed to do in other areas of the machine.

When should I take action?

ExxonMobil recommends operating within OEM guidelines and limits. In some cases, a user may choose to safely operate outside of OEM suggested limits if the reasoning is understood and does not impact equipment or oil health. If the form of copper is unknown (i.e., possible wear), testing should be completed to understand the risks.

Filtration, microscopic analysis, visual inspection, machine sensors, and operating parameters are all potential ways to discern the form of copper present in the oil.

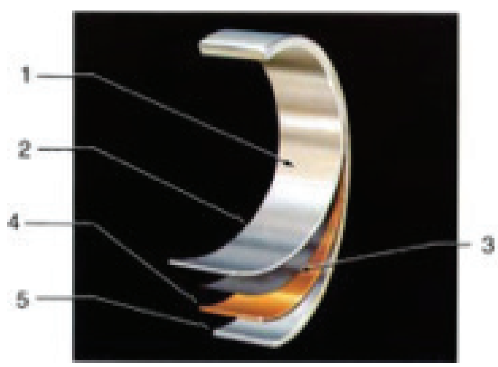
While OEM limits for copper vary (ranging from 20ppm to 200ppm), higher levels of dissolved copper have been regularly observed without impact to equipment health. A more significant measure is an abrupt change in the copper trend. Step changes should be correlated with known events and used as a tool to determine the root cause.

Dissolved copper may be left safely in the oil until it is slowly diluted or drained out. Copper wear or particulate should be actively removed (filtered or drained) to prevent further damage from three-body abrasive wear. The source or copper particulate should be identified and addressed.

How to correlate "bad" copper with other test results to take action on equipment.

There are many types of "bad" copper. For this discussion we will assume any copper that is not lightly dissolved from exposed copper is "bad." Below are several example scenarios to consider:

- **Bearings** — perhaps the most critical copper component in systems is bearing metals. Babbitted bearings are layered. The outermost layer is typically lead (Pb) and/or tin (Sn). To confirm copper is coming from babbitt bearings, the oil analysis must also show tin/lead first or at the same time. If the analysis shows only copper without tin or lead, this cannot be a result of bearing wear as it must wear through the outer surface first.



1. Flashing — Tin, protects bearing while in storage
2. Overlay — Lead and tin, provides embeddability, conformability, and protection against marginal lubrication
3. Barrier — Nickel, prevents tin migration from the tin-lead overlay
4. Lining — Copper, provides maximum fatigue strength
5. Backing — Steel, provides support for the bearing lining

- **Other brass wearable components** — (bushings, swash plates, valve plates, piston shoes, wrist pins, thrust washers, gears, cages, wear plates, etc.) — All of these components should be considered when copper is observed. Wear particles may show up in oil filters or "sparkly oil." The root cause for this may or may not be oil related. Just as any component may wear, correct selection of lubricant viscosity, type, additives, and OEM requirements are all a factor to determine the right oil is being used. Additionally, other factors may be at play: overloading, misalignment, abrasive particulate, etc.

- **Copper leaching or chemical attack due to abnormal oil acidity** — Elevated acidity of the oil due to combustion byproducts, contamination, hydrolysis, process gasses, etc. may chemically attack copper resulting in more severe corrosion or deterioration. This is observed based on the oil's acidity or contamination status (gas) and the copper becomes a result or lagging indicator. The oil may need to be changed and the source of contamination should be addressed. In the event of a process that cannot be changed, a reevaluation on the metallurgy in use may be recommended.

  Conversely, normal/reasonable oil oxidation does not correlate with copper leaching. The "weak acids" created due to oxidation are not strong enough to attack copper in any significant way. An internal study conducted across nearly 10,000 data points found no correlation between elevated copper levels and increased oxidation for a premium hydraulic oil evaluated.

- **Water and/or salts trending with copper** — when copper oil coolers fail (crack or hole), they expose new raw copper. A user may find a system with a steady copper history begins to spike up for no known reason. If water contamination is also observed, the copper may be from a failing cooler. If the coolant is simple cooling water, low levels of other minerals may also be present (Na, K, Ca). The user may test the water to compare it with cooling water to confirm a leak. In closed cooling systems using glycol-based coolants, sodium (Na) and/or potassium (K) will be present in the oil analysis. The amount of Na and K might vary depending on the glycol manufacturing process so it is not feasible to try to match these levels with coolants to find a culprit. Other coolant additives may also be present (molybdenum, boron, etc.)

Conclusion

Metals alerting in oil analysis should be evaluated case by case. Copper is one of the more common alerts observed which may not require the user to take corrective action. Copper passivation is expected and may be more or less common based on equipment components and oil chemistry. This type of copper cannot usually be filtered out nor does it have significant impact on oil life or equipment life. Conversely, copper wear debris should be addressed, removed from the system, and evaluated to correct the source.