Field Correlation with Bench Test Studies of Engine Oil Phosphorus Volatility

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Bench and Field Comparison of Engine Oil Phosphorus Emission

Background

Phosphorus emissions from the ZDDP in engine oil have produced a proverbial 'stone and a hard place' since it is necessary to

1. **protect the engine from wear and its oil from premature oxidation (at which ZDDP is excellent) but also**
2. **assure that the exhaust catalyst system will meet government standards regarding pollution control (which is adversely affected by volatile phosphorus).**

Relief for this situation was offered when relatively recent bench volatility studies showed large differences in engine oils on the basis of their comparative phosphorus emissions as affected by the nature and interaction of ZDDPs and other additives.

Determination of the phosphorus volatility of oils thus showed a potential benefit of careful formulary choice of ZDDPs and additives.

This was particularly interesting if informed choice of 1) ZDDP and 2) formulation would simultaneously reduce adverse catalyst effects and retain ZDDP in the engine oil where it could fulfill its purpose.

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Background (cont.)

An early and necessary question about how well results from this bench test correlated with field engines seemed answered – on a limited basis – with three samples from a cooperative taxi fleet study conducted by Ford Motor, Afton Chemical, and Delphi.

However, it was later shown that these three ZDDP-containing fleet test oils varied only in the presence or absence of other additives (including the ZDDP) and, thus, the correlation, while significant, was primarily affected by these additive benefits.

Question has also been raised more recently about the effect of the high test temperature of 250°C of the bench test not reflecting the bulk temperature of the circulating engine oil and thus making the test too harsh.

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Background (cont.)

Considering the need for more information, techniques were found to run the special Noack bench test under other time and temperature protocols.

NMR studies of the paths of decomposition or degree of stability of ZDDP in these PEI investigations have been very informative.

Interestingly, special Noack data gathered at 165°C over a 16-hour exposure period demonstrated considerably higher levels of phosphorus emission. Other PEI tests have also been conducted at 140° and 120°C over varying lengths of time.

A new taxi-fleet test study of phosphorus volatility was reported at the last ESCIT meeting by Lubrizol and Ford and has provided reference oils for testing the comparative correlation of bench tests.

Moreover, Afton Chemical has reported on interesting work with their special dynamometer test called the Afton Catalyst Test (ACT) and cooperative efforts are underway comparing these engine oil test results with PEI protocols.

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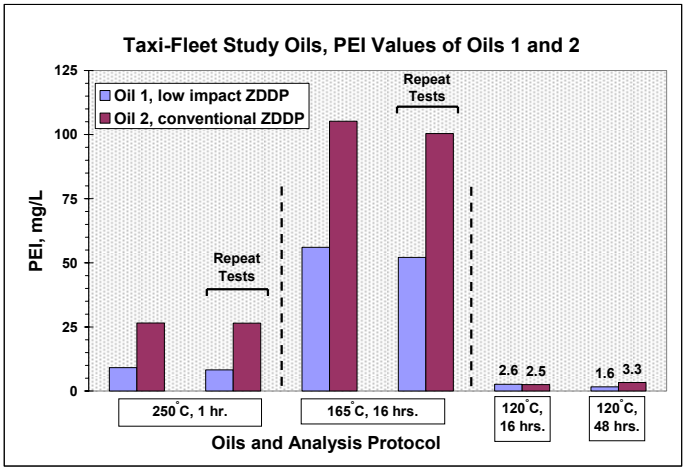
Recent Studies – Taxi-Fleet Oils

Two oils from the Lubrizol and Ford taxi-fleet study, one with conventional ZDDP and one formulated with low impact ZDDP, were sent to Savant Labs and studies begun in early September. Results of these first studies are shown below:



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Recent Studies – Taxi-Fleet Oils

Observations

The repeatability of PEI is reasonable at both 250°C and 165°C for both the conventional ZDDP oil and the low impact ZDDP oil.

However, $PEI_{165\text{-}16}$ results are not only more definitive than for $PEI_{250\text{-}1}$ but, for some types of ZDDPs, believed to be more relevant.

It is evident that the low impact ZDDP oil is superior in having ~52% less phosphorus volatiles than the conventional ZDDP oil. Essentially, this suggests that catalyst life of a vehicle should be extended considerably using oils having low phosphorus volatility.

PEI results at 120°C are interesting. At 16 hours $PEI_{120\text{-}16}$ shows essentially no difference between the oils. However, extending the exposure time to 48 hours gave about the same ratio, ~50%, as was shown at the higher temperatures.

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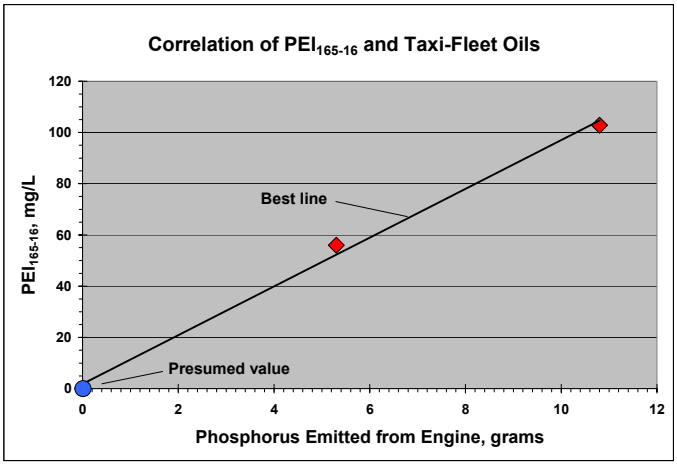
Recent Studies – Taxi-Fleet Oils and PEI Correlation

Correlation of the $PEI_{165\text{-}16}$ with the taxi-fleet results shown at the last ESCIT meeting was generated by averaging the data in the Lubrizol-Ford Slide 8 showing measured phosphorus emission from the engines in grams versus the averaged $PEI_{165\text{-}16}$ values just shown.



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Conclusions from Present Studies

The $PEI_{165\text{-}16}$ correlates well with the latest Lubrizol-Ford taxi fleet data – even to the extent that the percent decrease in phosphorus volatility was essentially the same (52% decrease reported for the taxi fleet study and an average of ~52% for the $PEI_{165\text{-}16}$ study).

Observations

A. It is apparent from the PEI and the present and earlier fleet studies that phosphorus volatility is not only a function of the ZDDP but also the other additives present. This is why previously presented data collected from the IOM database showed a wide range of phosphorus volatility response in oils.

B. Considerable time, effort, and cost will be needed to establish an engine test giving sufficient repeatability and reproducibility 1) to provide a specification as well as 2) to correlate with field phosphorus emissions.

C. The PEI test is simple and repeatable. It has been shown to correlate well with the field and provides a direct, acceptably precise, measure of engine oil phosphorus volatility.

Actions and Recommendations

1. A test method is being written for the PEI protocol.

2. Consideration be given to forming a task force under ESCIT and/or within the ASTM D02 to evaluate precision and formalize a PEI test method.

Ongoing Studies

Work is continuing in the study of NMR data of oils and conditions generated in past studies and in the joint study with Afton. These will be reported at ESCIT meetings and in future technical papers.

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Thanks for listening

Now: Question Time