Phosphorus Emission Index and Its Application to Engine Oils

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Background

ILSAC's formation of ESCIT has given opportunity to choose relatively simple and inexpensive bench measurement to reduce dependence on chemical limits in formulating desirable engine oils.

This opportunity, if successfully met, is a win-win situation for all concerned –

1. Automobile manufacturers,
2. Engine oil formulators and producers,
3. Engine oil additive manufacturers and suppliers, and, of course,
4. The automobile owner.

For a bench test to be considered acceptable, it must shown to correlate with engine results in some meaningful way.

However, before such correlation can be tested, relevant and acceptably reproducible data must be generated using chosen engines and oils.

The oils from these engine tests can then be made available to develop acceptable bench test correlation.

Background

Two methods of engine testing of engine oils are generally used and both have favorable as well as less favorable aspects.

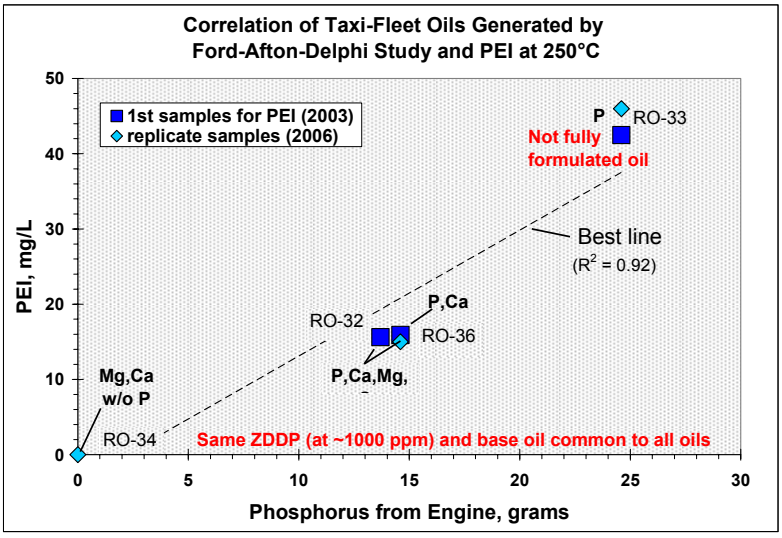
1. Extended automobile field tests with controlled driving conditions closely reflect the 'real world'. However, careful monitoring and servicing of a car fleet is required over a considerable period of time.
2. Engine dynamometer tests allow rigorous control of operating conditions and generally easier collection of relevant information. However, to reduce test time, operating conditions may be made much more severe than normally encountered in the field and this, in turn, may be a step away from the 'real world'.

Both methods have often been applied in phosphorus volatility tests and both approaches have been a source of engine oils for correlation with bench tests, one of which is the subject of this presentation.

The Phosphorus Emission Index (PEI) bench test collects all volatile material from moderate size samples of engine oils and has demonstrated the ability to be used over a broad temperature range corresponding to the relevant temperatures of automotive engines.

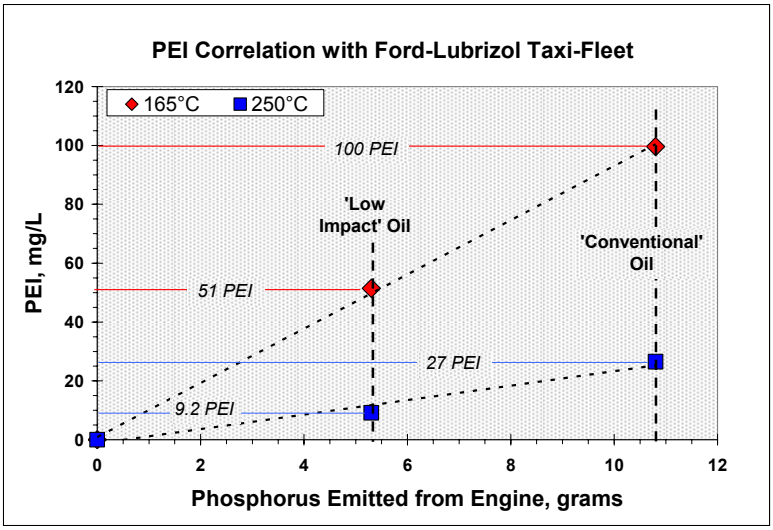
Background – Correlation with Fleet Tests

Previously reported PEI studies showed good correlation with an earlier Ford-Afton-Delphi taxi-fleet study at 250°C (~ring-belt temperatures). (It was said to be more a field test of additive effects than ZDDP chemistry.)



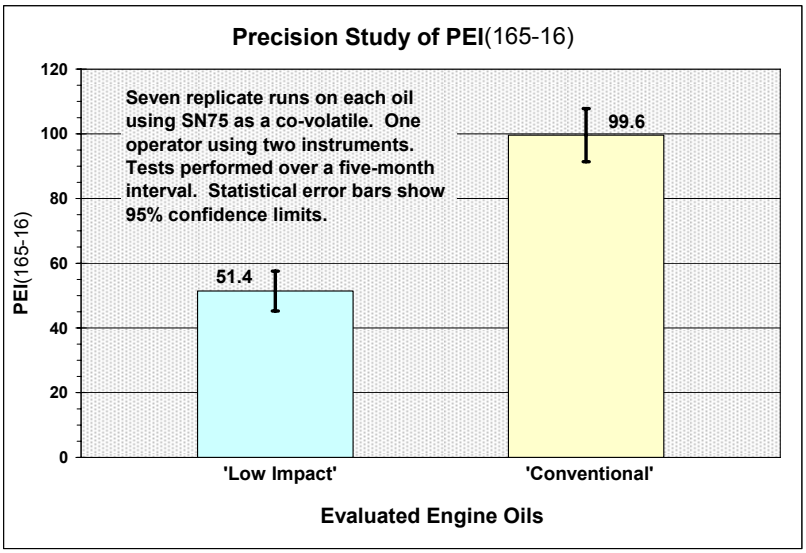
Background – Correlation with Fleet Tests

A recent Ford-Lubrizol taxi-fleet study directly tested ZDDP chemistry and provided two oils for further PEI correlation studies at both 165°C (severe engine operation) and 250°C (normal ring-belt temperatures):



Background – Correlation with Fleet Tests

A study of precision of the PEI technique at 165°C for 16 hours of exposure using a co-volatile was a combination of Reproducibility and Repeatability.



Application of PEI Values from Field Tests

Since the Ford-Lubrizol fleet studies showed effects of variation in ZDDP chemistry, the latter fleet study will be used to apply selected PEI values to the Institute of Materials (IOM) Engine Oil Database.

Phosphorus volatility and PEI values at 250°C have been reported in the IOM Engine Oil Database since the year 2000 for several hundred engine oils per year from the markets of Europe, Asia, and North America.

The PEI data at 250°C that follow are taken from the North American database and are used with the permission of the Institute of Materials.

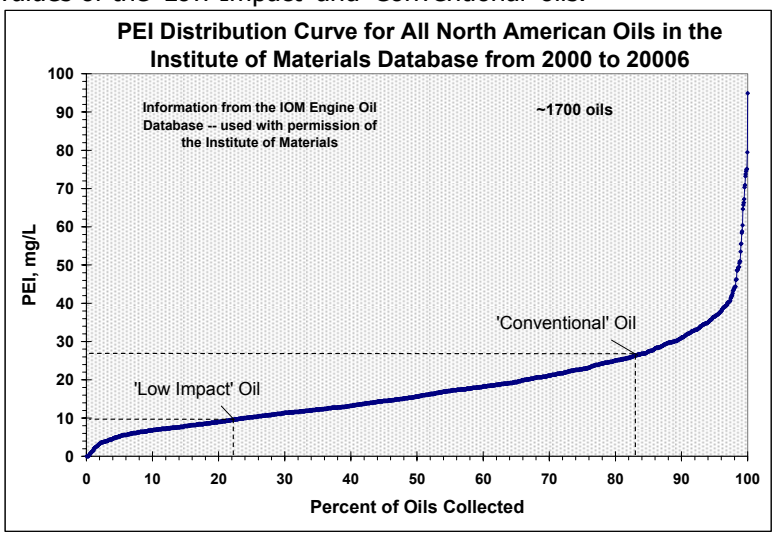
Such PEI data relate to the phosphorus produced at ring belt temperatures in the engine and, as shown, correlate with the Ford-Lubrizol fleet studies where PEI values of **9.2** and **27** mg/L respectively correspond with phosphorus emissions of so-called 'Low Impact' and 'Conventional' ZDDPs.

Similar information could also be generated at severe engine operating temperatures of 165°C with a PEI database on engine oils available at that temperature. In that case, the corresponding 'Low Impact' and 'Conventional' PEI values for 165°C are **51**±6 and **100**±8 mg/L, respectively, on the basis of a recently completed precision study.

Application of PEI Values to North American Oils

All IOM Database Oils from 2000 to 2006

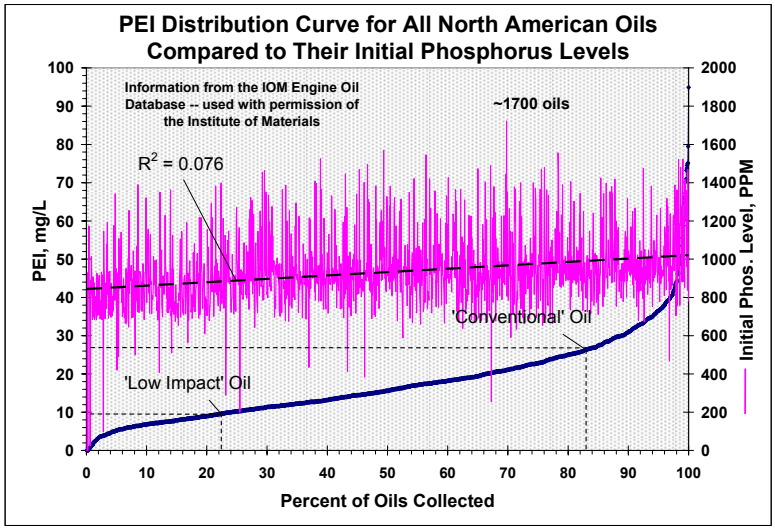
A distribution plot of all PEI values at 250°C is shown intersected by the PEI values of the 'Low Impact' and 'Conventional' oils.



Application of PEI Values to North American Oils

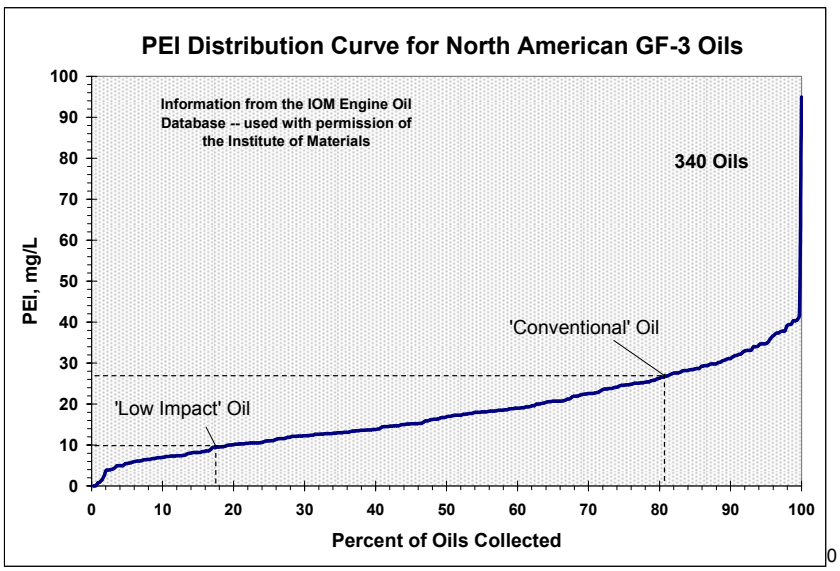
All IOM Database Oils from 2000 to 2006

A plot of the initial phosphorus concentration of each oil in the distribution curve shows little relation between initial and volatile phosphorus levels.



Application of PEI Values to North American Oils

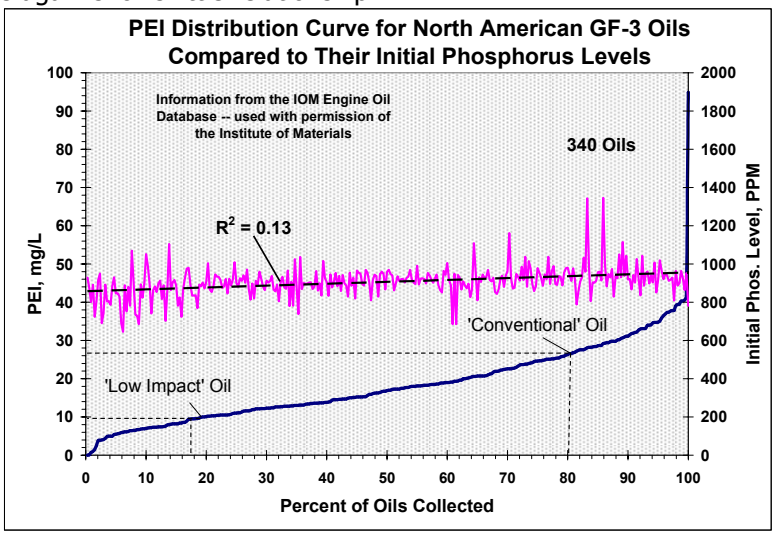
IOM Database Oils Carrying GF-3 Identification



Application of PEI Values to North American Oils

IOM Database Oils Carrying GF-3 Identification

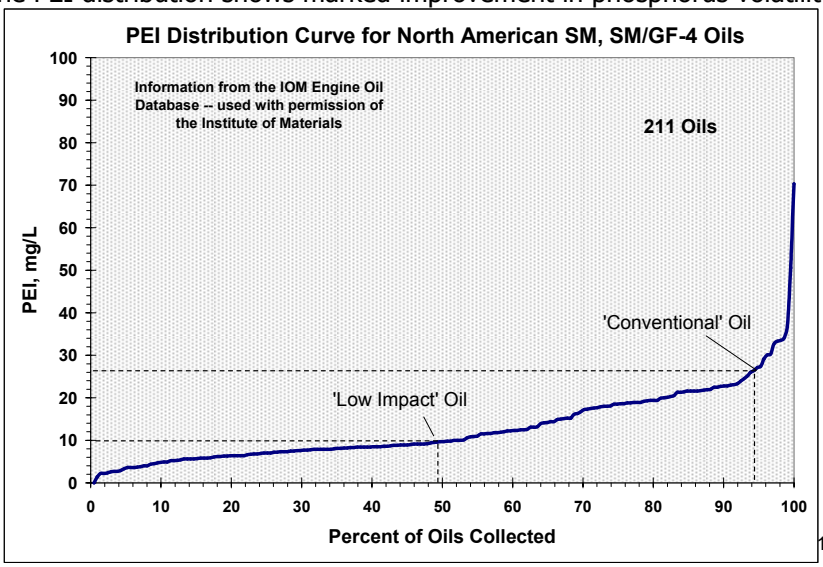
The comparison of initial phosphorus concentration of each oil to its PEI value again shows little relationship.



Application of PEI Values to North American Oils

IOM Database Oils Carrying SM or SM/GF-4 Identifications

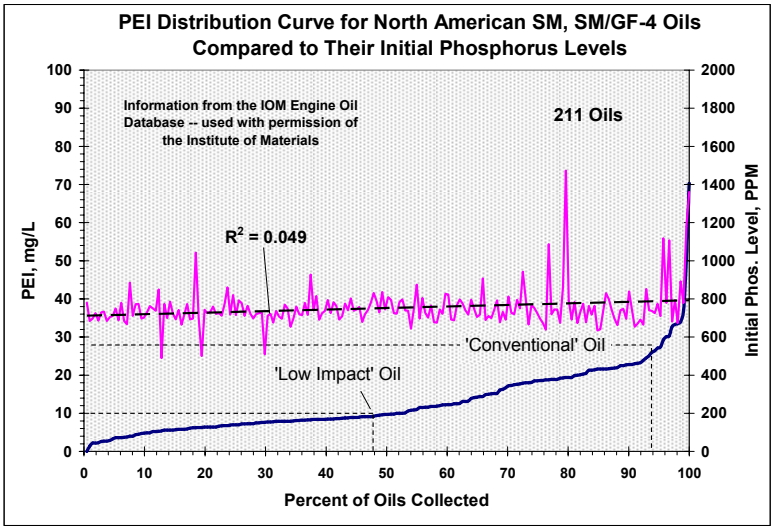
The PEI distribution shows marked improvement in phosphorus volatility.



Application of PEI Values to North American Oils

IOM Database Oils Carrying SM or SM/GF-4 Identifications

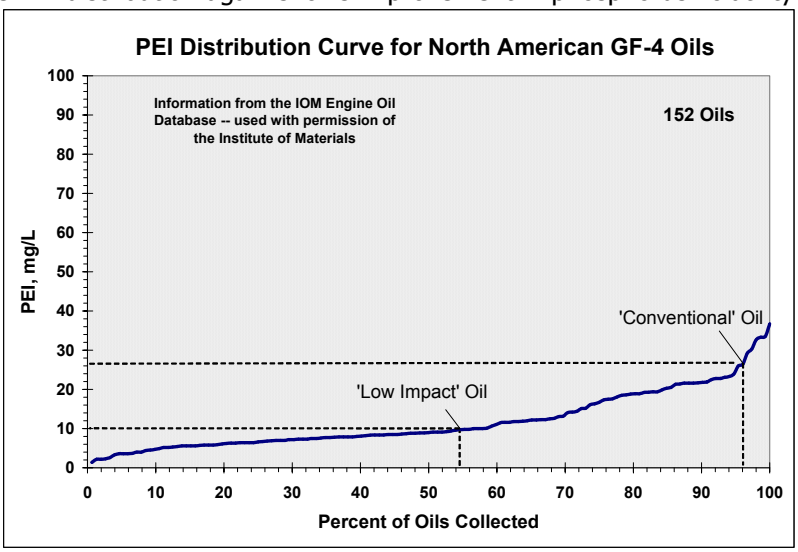
While comparison of initial phosphorus level of each oil to its PEI value shows little direct relationship, overall phosphorus volatility level is lower **...**



Application of PEI Values to North American Oils

IOM Database Oils Carrying Only GF4 Identification

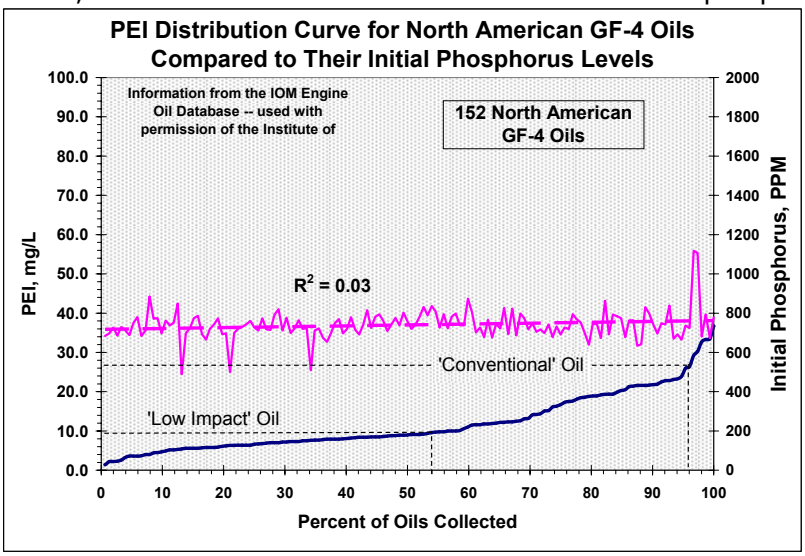
The PEI distribution again shows improvement in phosphorus volatility.



Application of PEI Values to North American Oils

IOM Database Oils Carrying Only GF4 Identification vs. Initial PPM

However, there is little correlation between initial and volatile phosphorus.



Observations

1. GF-4 oils are markedly lower in phosphorus volatility than their GF-3 counterparts.
2. Even so, PEI values of GF-4 indicate that phosphorus volatility of engine oil formulations themselves vary considerably between oils considered 'Low Impact' and 'Conventional'.
3. Initial phosphorus chemical limits are essentially unrelated to this wide variation in phosphorus volatility between 'Low Impact' and 'Conventional' oils demonstrated by the PEI.
4. Considering that PEI correlates with the Ford-Lubrizol taxi-fleet data at 165°C, it would now seem reasonable to determine the PEIs at 165°C of a reasonable number of GF-4 oils across the IOM Database and find the effect of the Low Impact oil's PEI value of ~50 mg/L.

With this bench test data in hand, sufficient information would seem to be available to form a PEI test matrix and ASTM round robin for GF-5.

Thanks for listening

Any questions?