

Suggested Approach to Meeting the Oxidation Test Requirements of PC-10

**Presented at
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Background on HD Categories and Oxidation Tests



- ❖ **For many years the API C Categories did not contain a specific test to measure oil oxidation and viscosity increase**
- ❖ **API Categories CD through CF-4 relied on L-38 bearing weight loss as an indirect estimate of oxidation via bearing corrosion**
 - HD engines use oil coolers
 - Relatively low specific power output and sump temperatures
- ❖ **Increasing power output and sump temperatures drove the desire to have a diesel oxidation test**
 - No suitable diesel test could be identified

Background on HD Categories and Oxidation Tests (cont.)



- ❖ **API CG-4 adopted the Sequence IIIE light duty oxidation test as a surrogate for ensuring some level of oxidation capability**
 - No other cost effective measure of oxidation capability available
 - Test was run anyway to support BOI licensing of the S category for universal oils

- ❖ **Sequence IIIE upgraded to Sequence IIIF in API CI-4**
 - Recognized higher levels of oxidation due to EGR
 - Test options considered included John Deere 6646 and Mack T-10 IR
 - Belief at the time was that the Sequence IIIF provided a margin of safety for oxidation protection beyond the Mack T-10

API CI-4 Experience



- ❖ **Passing a Mack T-10 at the API CI-4 performance limits is more restrictive than passing the Sequence IIIF viscosity increase at the ILSAC GF-3 limit**
 - **So in effect, the Mack T-10 diesel test has been functioning as the limiting oxidation test in API CI-4**
- ❖ **ACC member companies do not support redundant tests or parameters, and in retrospect, API CI-4 should have been defined with no Sequence III requirement**
 - Moot point as IIIF was run to support API S Category licensing of universal oils
- ❖ **The Sequence IIIG is dramatically more severe than the Sequence IIIF and if included in PC-10 it may restrict base stock and additive formulation options**

Correlation Among Mack T-10 Test Parameters

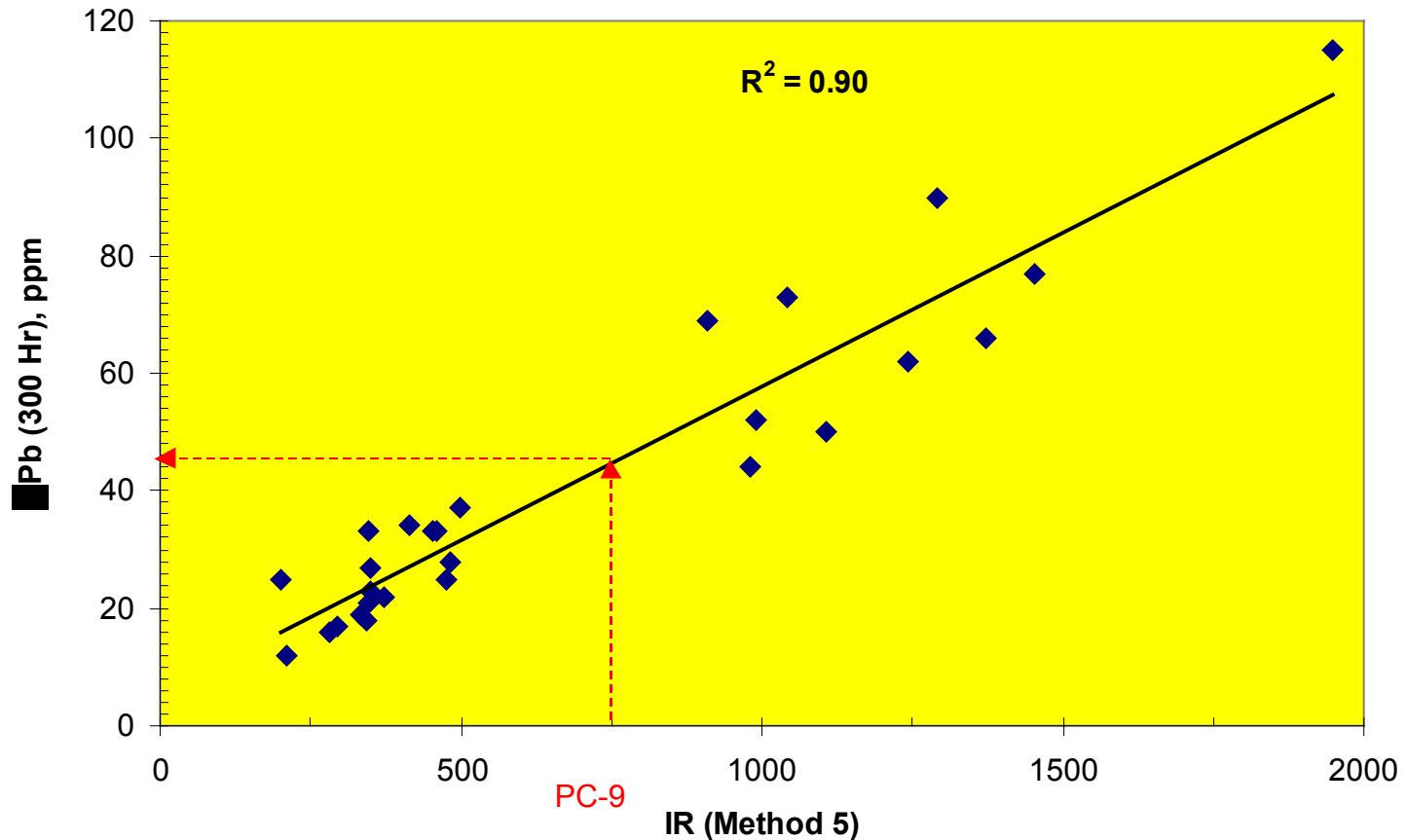


❖ PC-9 limits for the Mack T-10 test:

Average Cylinder Liner Wear	32 μ M Max
Average Top Ring Weight Loss	158 mg Max
Delta Lead at EOT (300 Hrs)	35 ppm Max
Delta Lead between 250-300 Hrs	14 ppm Max
Oil Consumption in Phase II	65 g/hr Max
Oxidation by Integrated IR	rate and report--considered 750 Absorbance Units Max

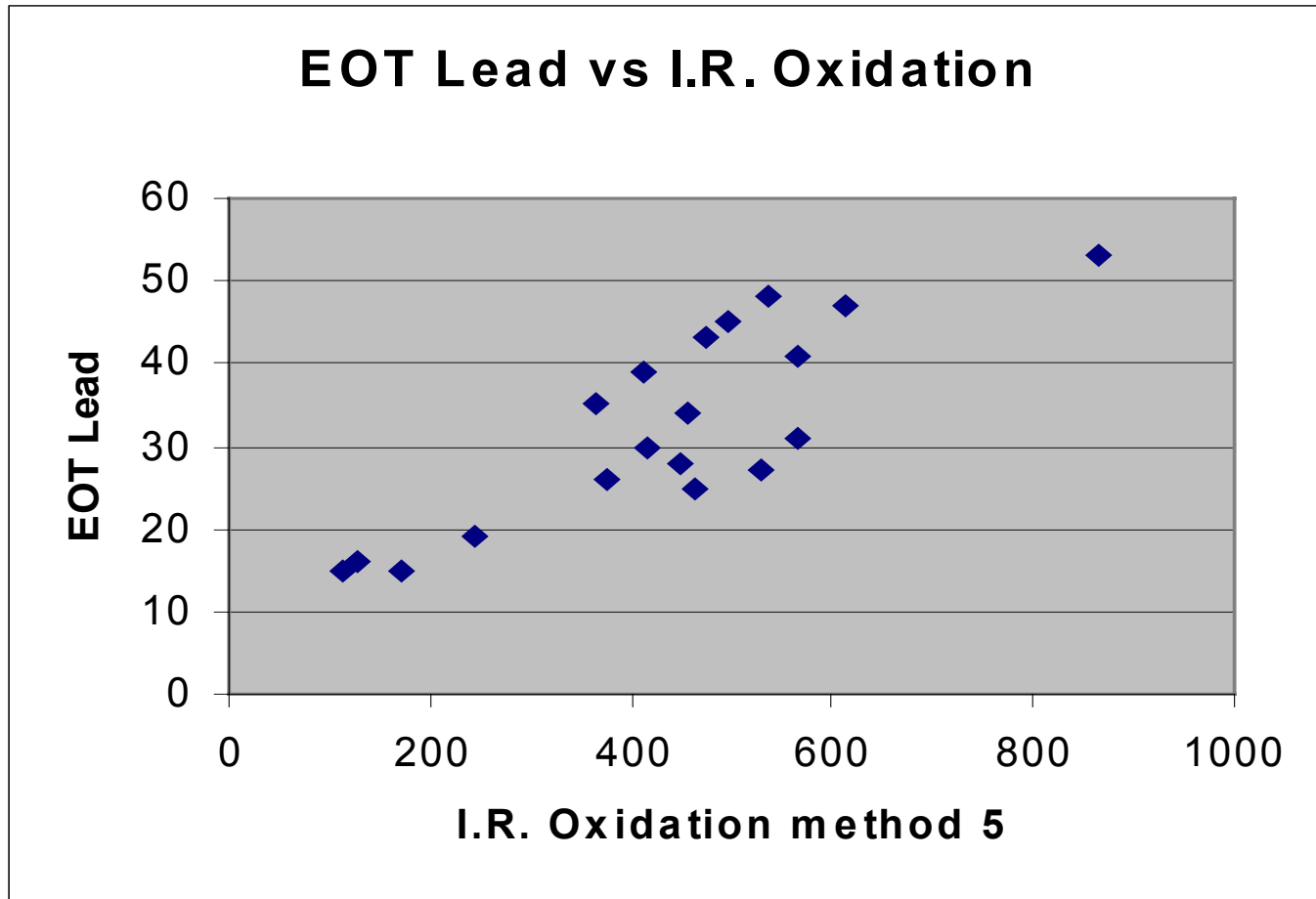
❖ Data on the following graph shows that three of these 6 parameters, *Delta Lead (300 Hrs)*, *Delta Lead (250-300 Hrs)* and *Integrated IR*, are highly correlated with $R^2 \sim 0.9$

Δ Pb (300 Hr) Strongly Correlates with IR (Matrix Data – 27 Points; One Outlier Excluded)

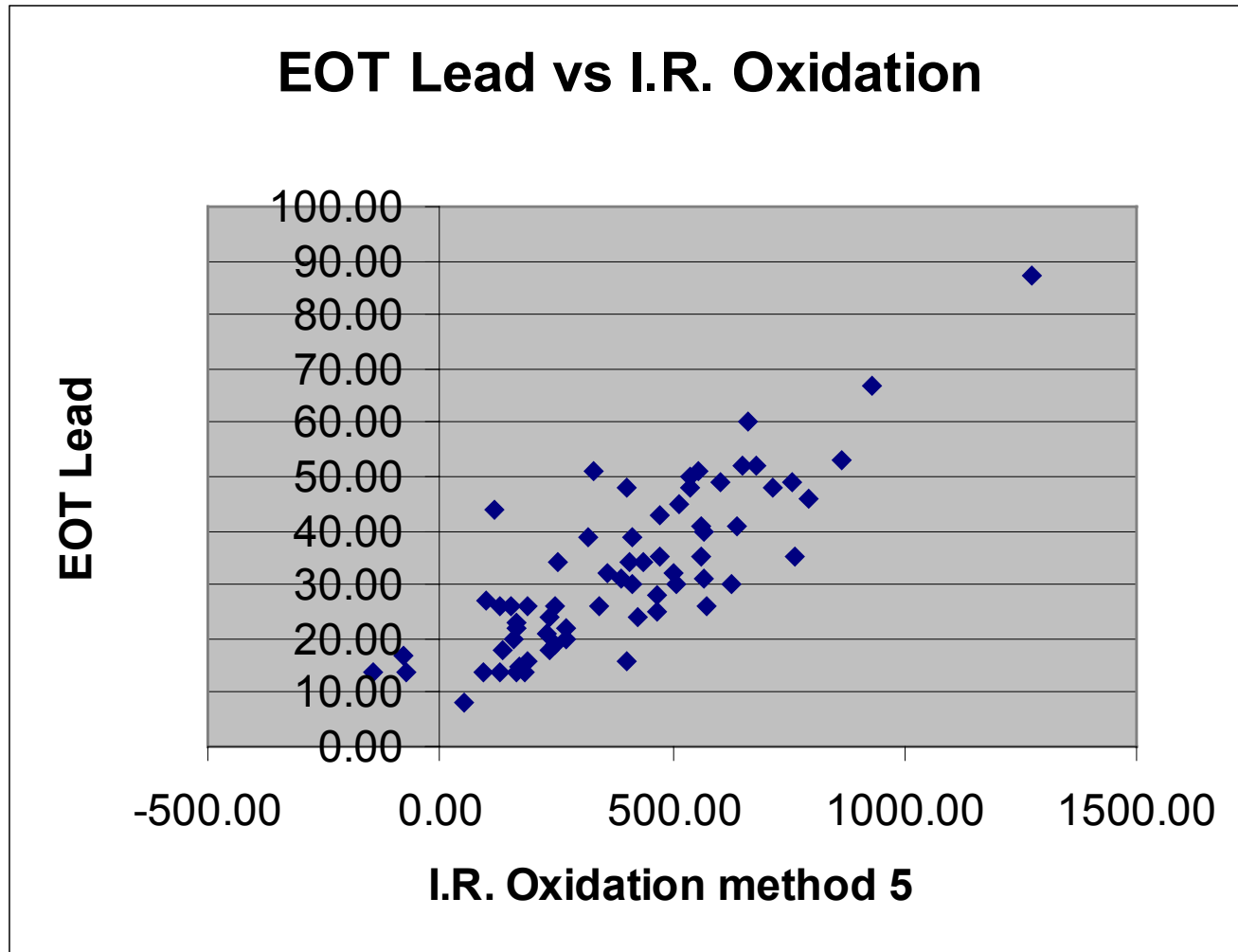


At PC-9 limit consideration, EOT Pb is limiting parameter not IR oxidation.

Infineum Data on T-10 Lead Corrosion: Delta Lead and IR Oxidation are highly correlated



Industry Data on T-10 Lead Corrosion



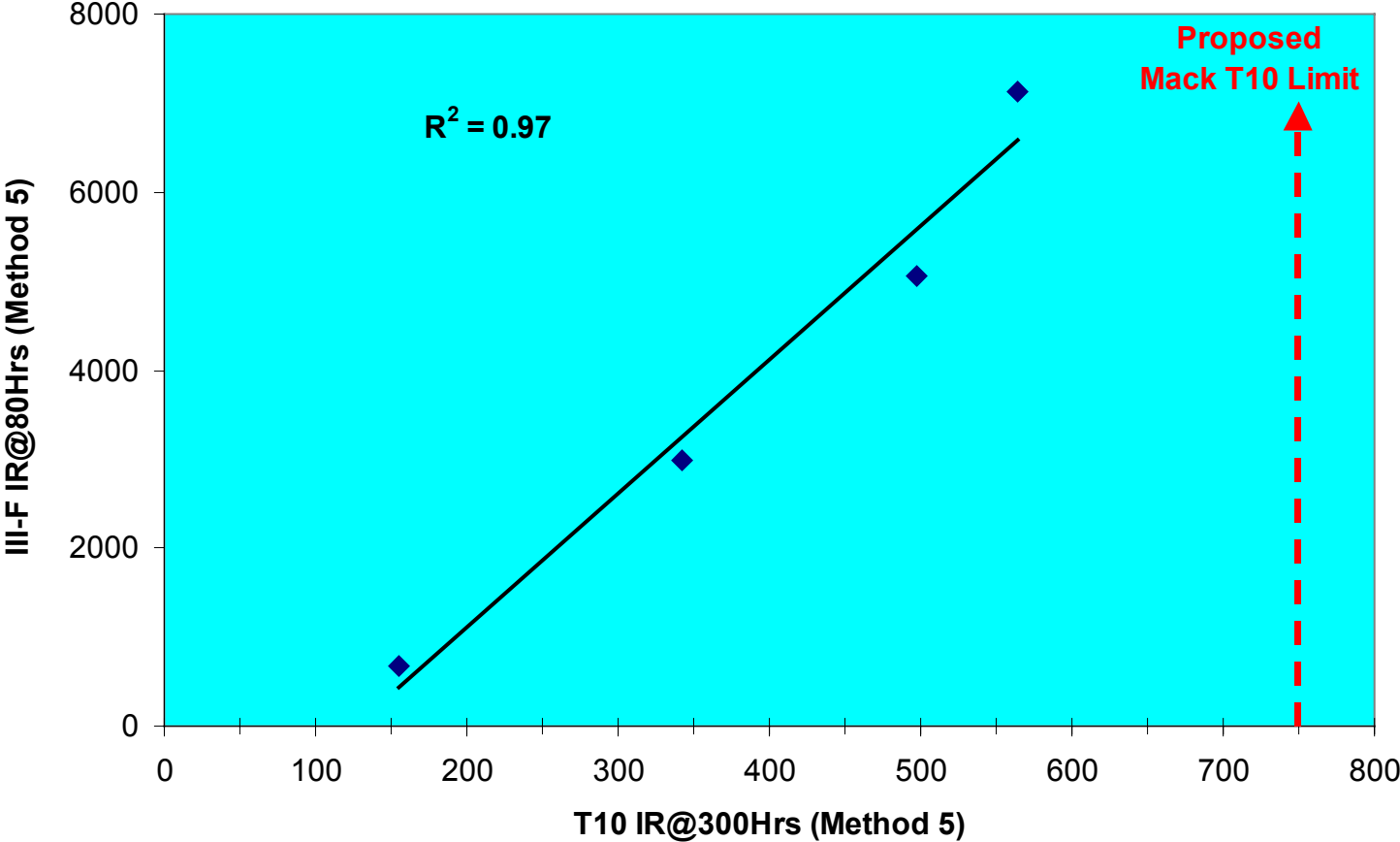
PC-9 Oils: Oxidation responses in Sequence III-F and Mack T-10 tests



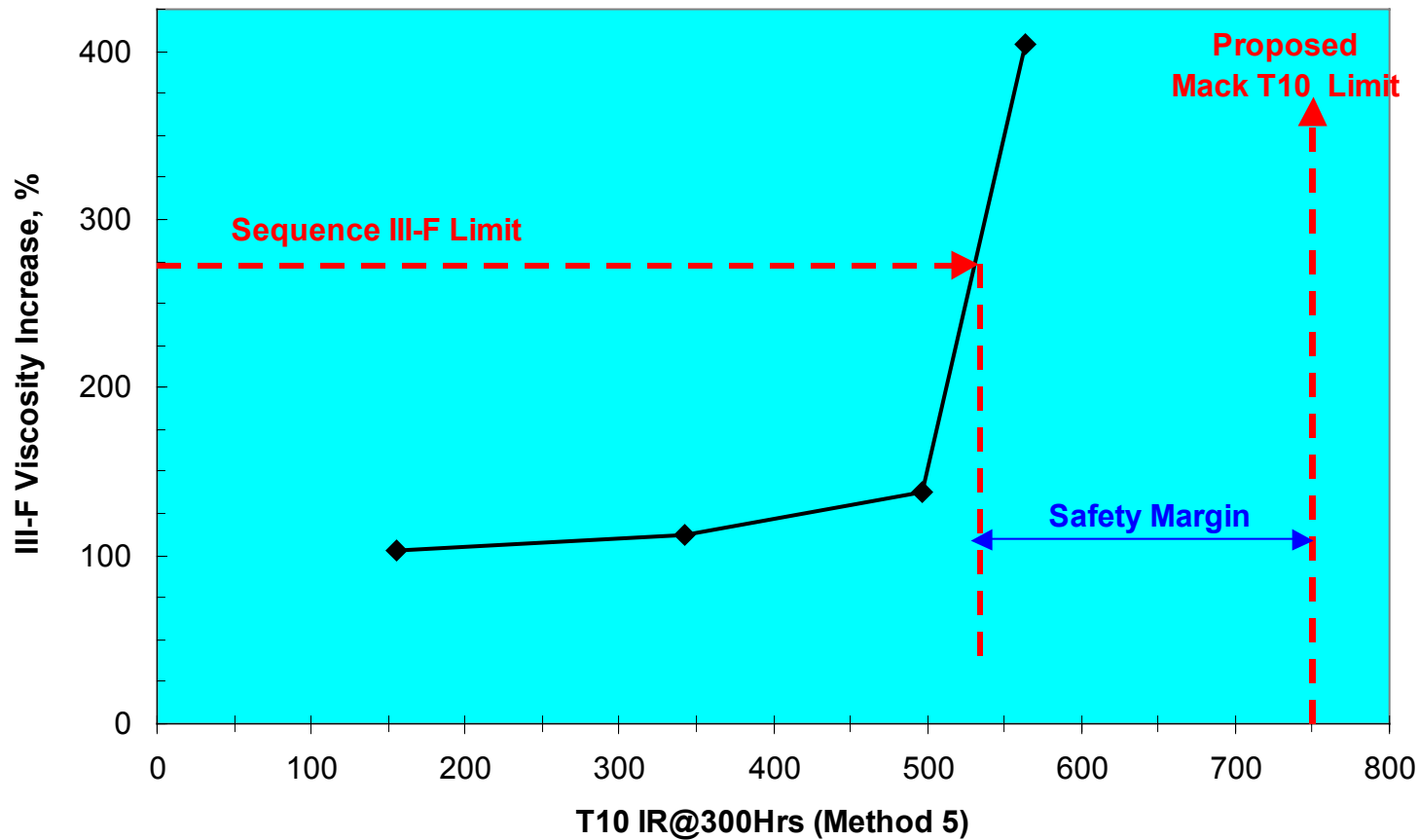
- ❖ **Infineum has found 4 oil formulations with “matched pairs” of Sequence III-F and Mack T-10 tests**
 - ie, both tests run on identical oils

- ❖ **Results from these 4 pairs clearly show that oxidation responses in the two tests are highly correlated**
 - At an I.R. oxidation limit of 750 absorbance units, the Sequence III-F is shown to be a more severe test of oxidation than the Mack T-10 test evaluated .
 - However, both T-10 EOT lead and 250-300 hr delta lead limits actually drive T-10 I.R. oxidation to a range of 400-500 absorbance units which makes the **T-10 more restrictive than a passing IIIF**
 - The I.R. oxidation limit for EO-N Premium Plus (and PP 03) is 250 absorbance units which further reduces the oil’s oxidation in the Sequence IIIF.

Seq.III-F IR shows Strong Correlation with Mack T-10 IR (Infineum PC-9 Development Data)



PC-9: T-10 IR can be used as limiting oxidation parameter



T-10 IR of 400-500 corresponding to 30 ppm Pb (p/f) is more restrictive than the current Vis Incr p/f for the IIF for CI-4

A Single Oxidation test for PC-10

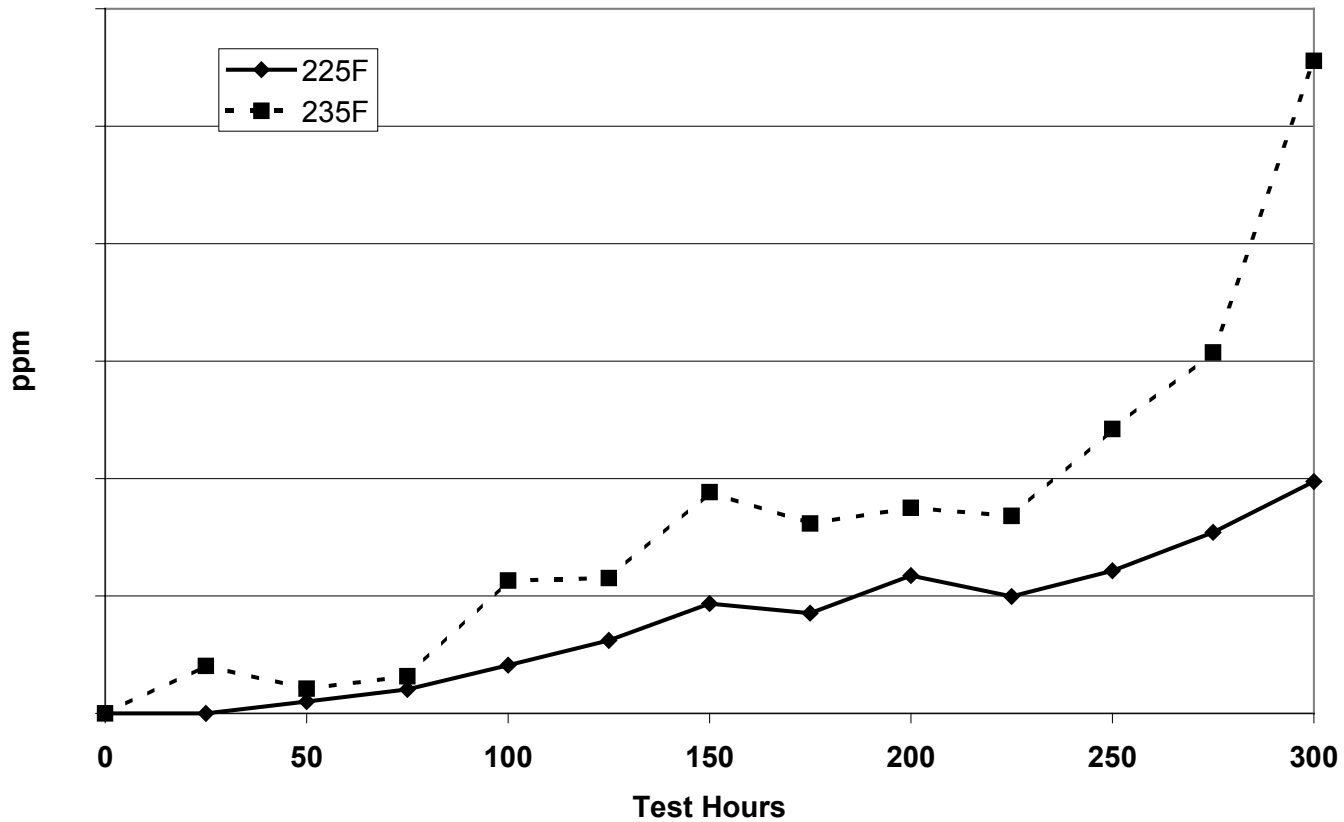


- ❖ **The Mack T-12 is still under development**
- ❖ **The sump temperature for the Mack T-12 will be 10 °F higher than the Mack T-10**
 - Should be a more severe oxidative test
- ❖ **The Mack T-12 may provide adequate oxidation protection for API PC-10**

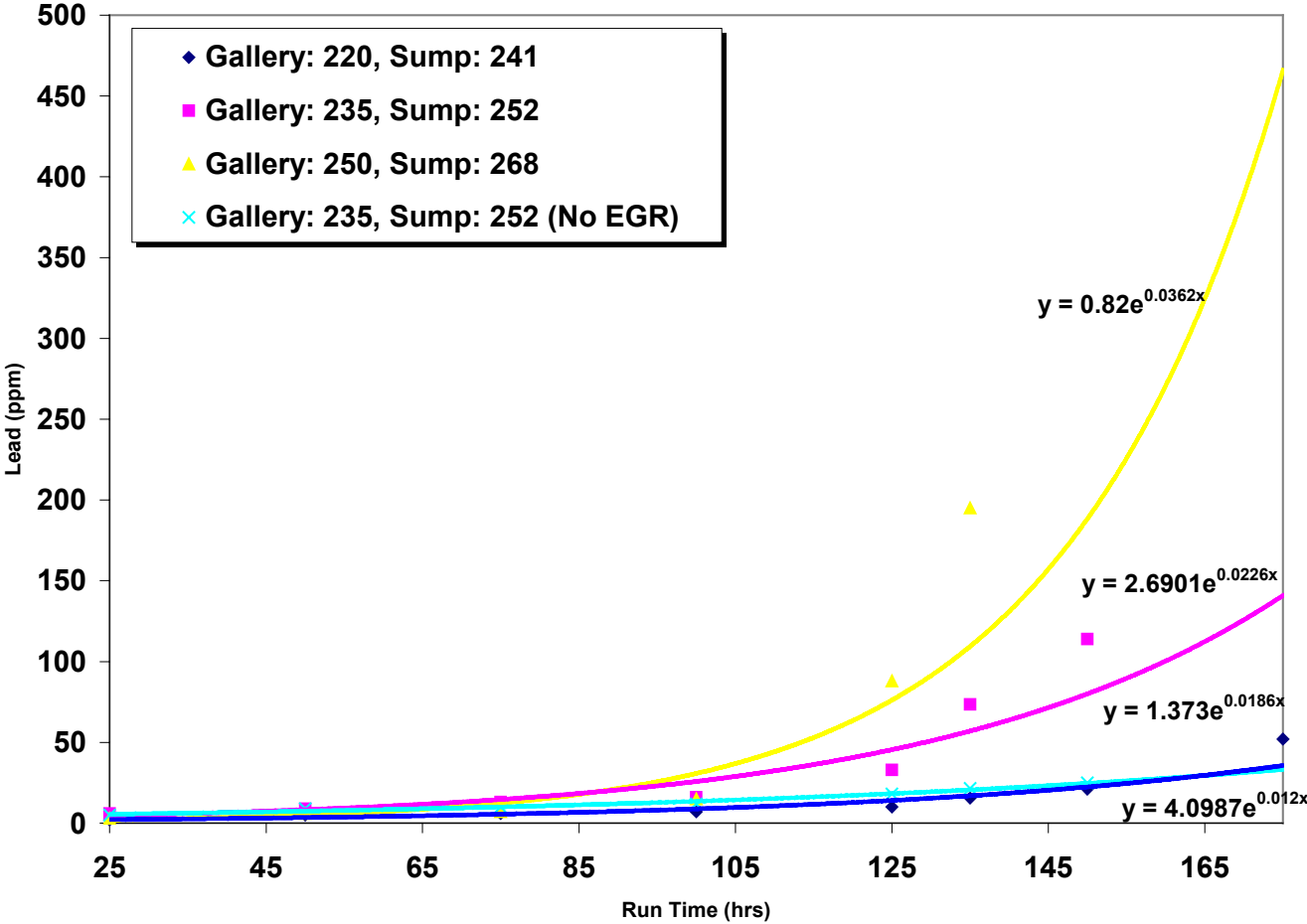
T-10: Lead (correlates to IR oxidation) Increases with Increased Temperature



Lead in Oil Corrected for Oil Consumption
T-10 (Oil 2)



Oxidation is Critical in T-10 → T-12 Sump = 260



Summary



- ❖ **Past uses of the Sequence III in API C Categories were necessary as better tests did not exist**
 - Sequence III provided the desired level of protection against oxidation and viscosity increase
- ❖ **Experience has shown the Mack T-10 defines the oxidation benchmark for API CI-4**
 - Making the Sequence IIIF redundant
- ❖ **The Mack T-12 is still under development and is likely to be more severe than the T-10**
 - sump temperature increases 10 deg F from T-10 which implies roughly a 40% increase in oxidation rate and even greater lead severity
 - New bearings may change lead versus oxidation response

Recommendations



- ❖ **Do not make any decision regarding a Sequence III test for PC-10 until the Mack T-12 is more fully developed and its antioxidant severity is understood**
- ❖ **Assess if the Sequence III is a redundant test for PC-10: If the Mack T-12 is at least as severe as the T-10, use it as the oxidation test for PC-10 and do not include any Sequence III test**
- ❖ **Allow oil marketers to decide whether to license universal oils as API SL or SM**
 - Either a Sequence IIIF or a IIIG will still be run to support S category BOI claims
 - Avoiding API SM reduces the potential for misapplication where ILSAC GF-4 oils are required