Discussion of
Mack T-10
Oxidation-Related Test Parameters

Presented to:

Heavy Duty Engine Oil Classification Panel

Chicago, IL

September 12, 2001

Introduction

- This presentation is intended to show that three of the six proposed specification parameters in the Mack T-10 test are highly correlated

- We are concerned that, given the high random variability of these parameters relative to their respective proposed limits, over-specification of these parameters will result in unnecessary repeat testing, even for otherwise excellent additive technologies

- Data is provided to show that Sequence III-F test offers a higher level of oxidation protection that the Mack T-10 IR without additional engine test burden for the additive industry

Correlation Among Mack T-10 Test Parameters

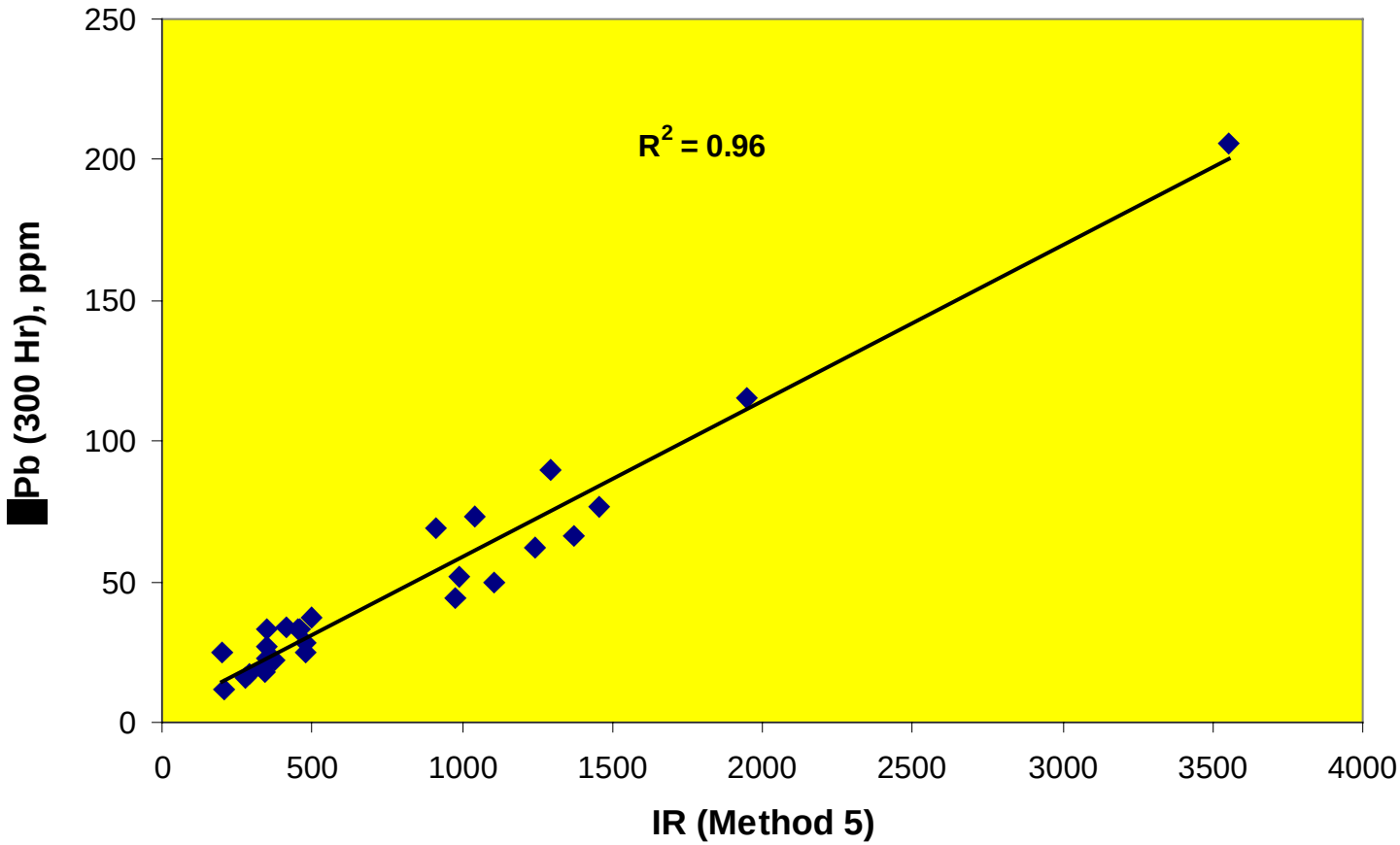
- **Following PC-9 limits have been proposed for the Mack T-10 test:**

Average Cylinder Liner Wear	30 μM Max
Average Top Ring Weight Loss	140 mg Max
Delta Lead at EOT (300 Hrs)	30 ppm Max
Delta Lead between 250-300 Hrs	10 ppm Max
Oil Consumption in Phase II	60 g/hr Max
Oxidation by Integrated IR	750 Absorbance Units Max

- **Data on the following pages 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 ~0.9**

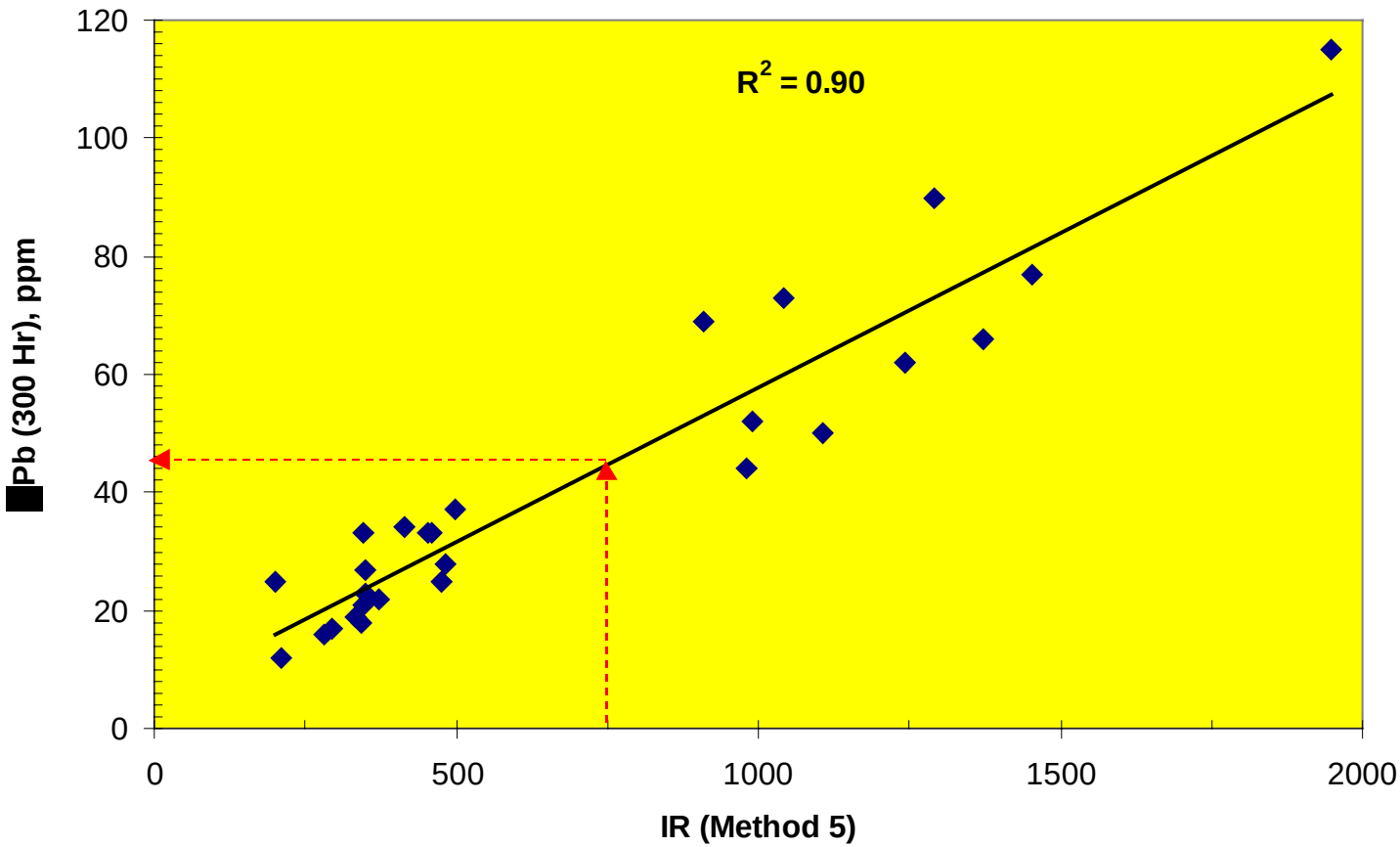
ΔPb (300 Hr) Strongly Correlates with IR

(*Matrix Data – All 28 Points)*



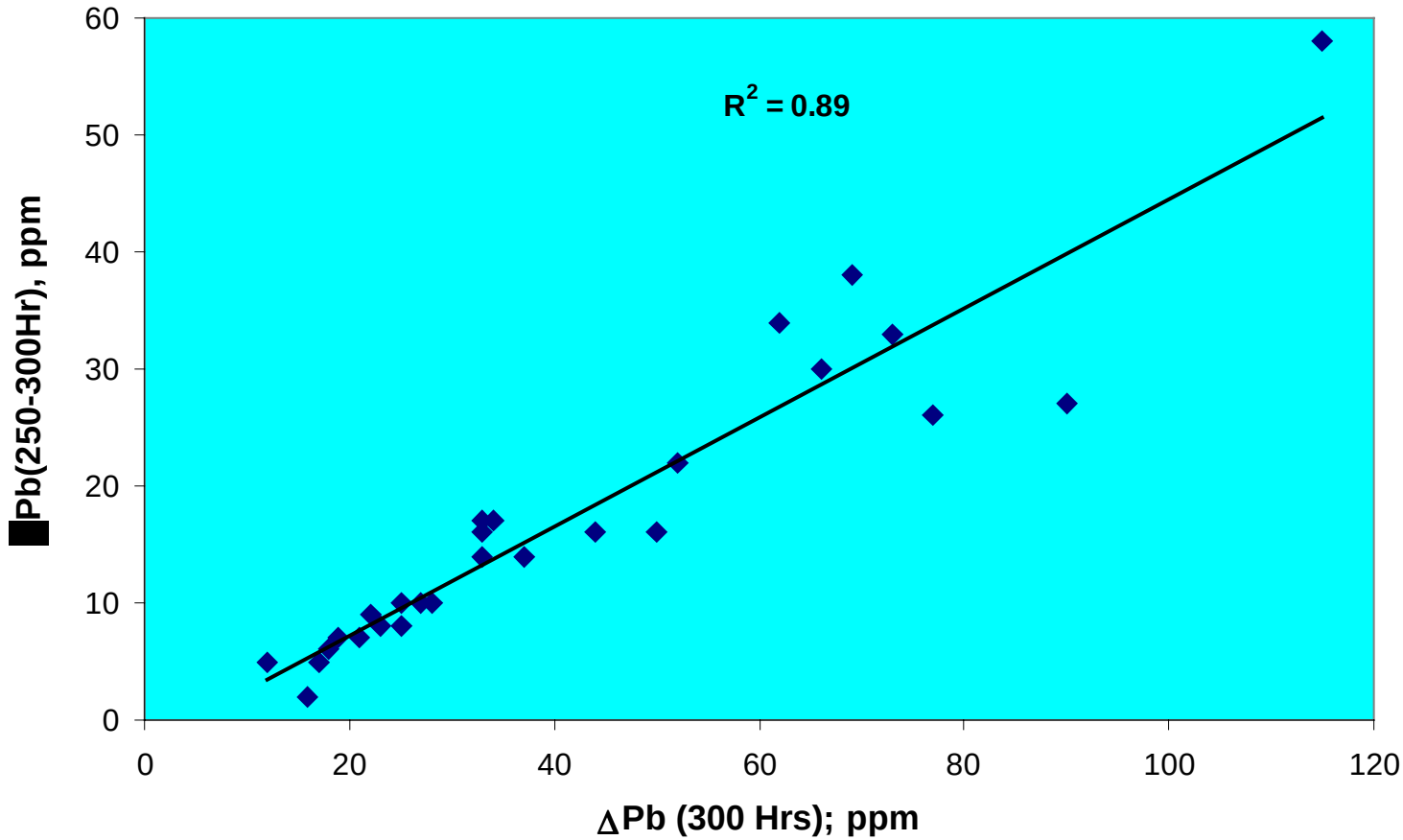
ΔPb (300 Hr) Strongly Correlates with IR

(*Matrix Data – 27 Points; One Outlier Excluded)*

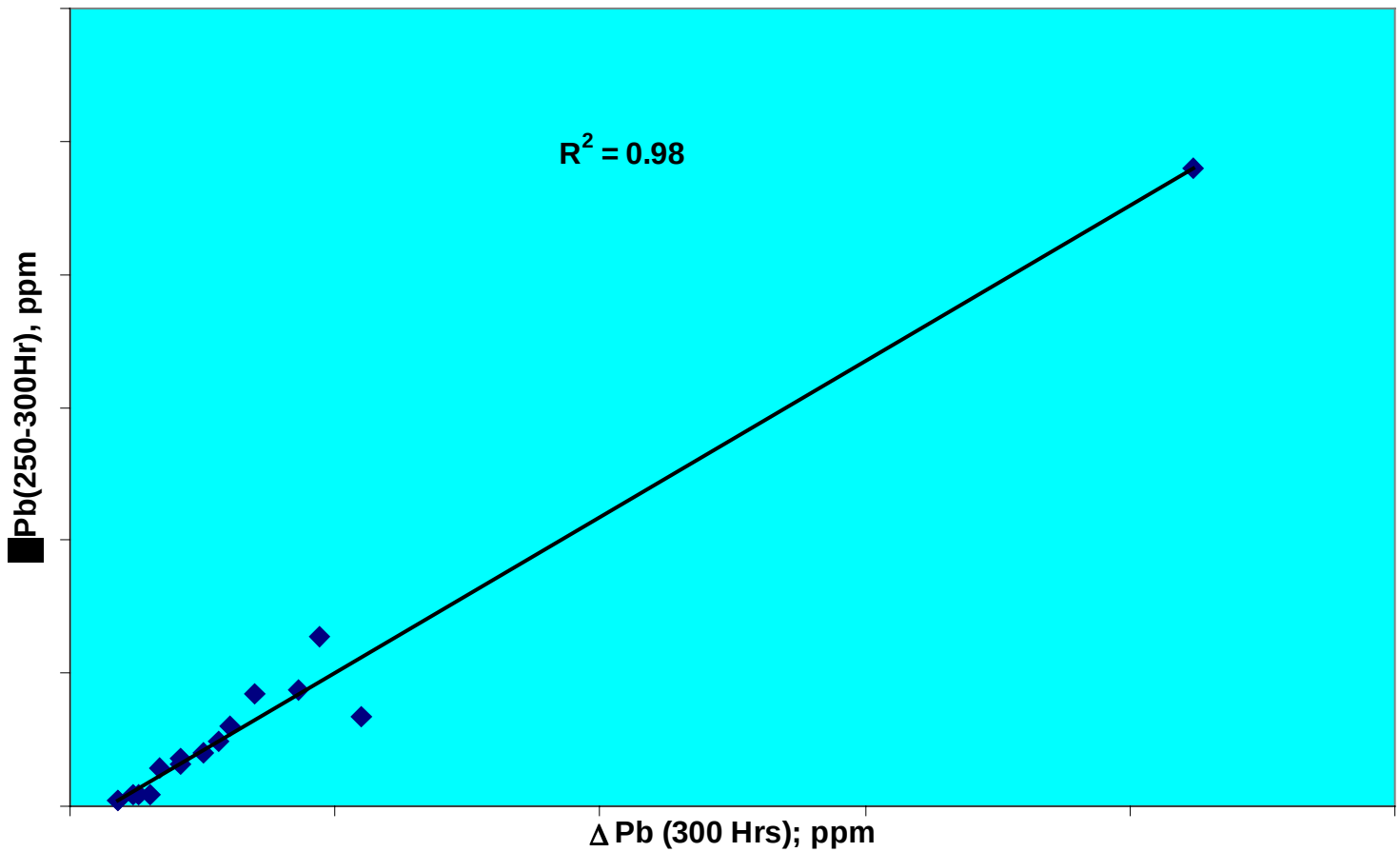


ΔPb (250-300Hr) Strongly Correlates with ΔPb (300Hr)

(*Matrix Data – 27 Points)*



Infineum PC-9 Development Data Exhibit Same Parametric Correlations as Matrix Data



…So what's the problem?

Correlated test parameters exhibit high random variability

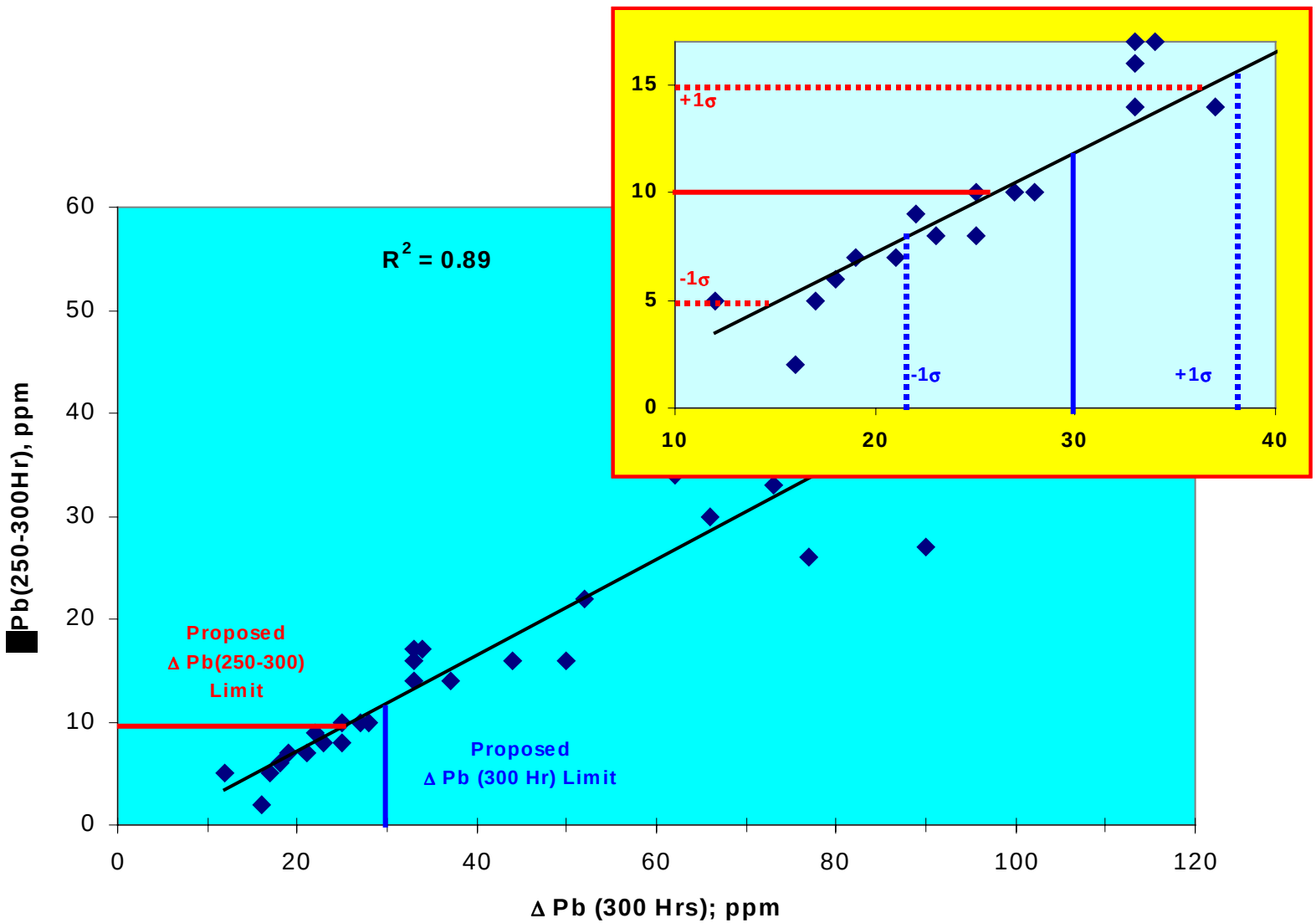
Infineum

Precision Data on Featured Oil (Oil A)

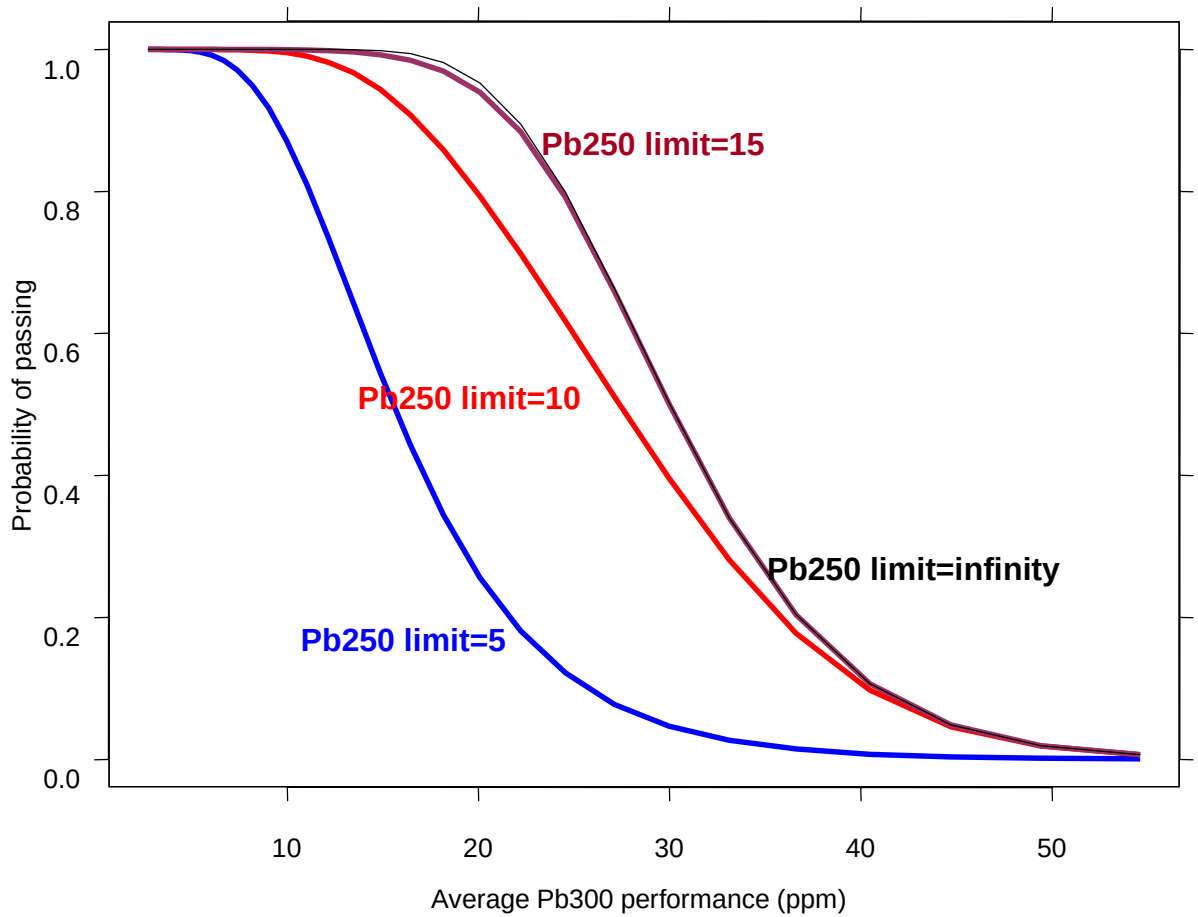
CMIR	IR (Method 5)	ΔPb (300)	ΔPb (250-300)	
38809	348	23	8	
38810	334	19	7	
38811	210	12	5	
38814	452	33	16	
38942	280	16	2	
38951	497	37	14	
40230	200	25	8	
41135	482	28	10	
41410	347	33	17	
41412	1372	66	30	*Outlier?*
Mean (10 pts)	**452.2**	**29.2**	**11.7**	
StDev (10 pts)	**339.4**	**15.2**	**8.0**	
Mean (9 pts)	**350.0**	**25.1**	**9.7**	
StDev (9 pts)	**109.9**	**8.4**	**5.1**	
Proposed Test Limits	**750.0**	**30.0**	**10.0**	

For each test parameter, the random variability is quite large in relation to the proposed limit

Overlapping Specifications Could Drastically Affect Pass Rate Due to Random Variations



Probability of Passing is Drastically Affected by Overlapping Limits



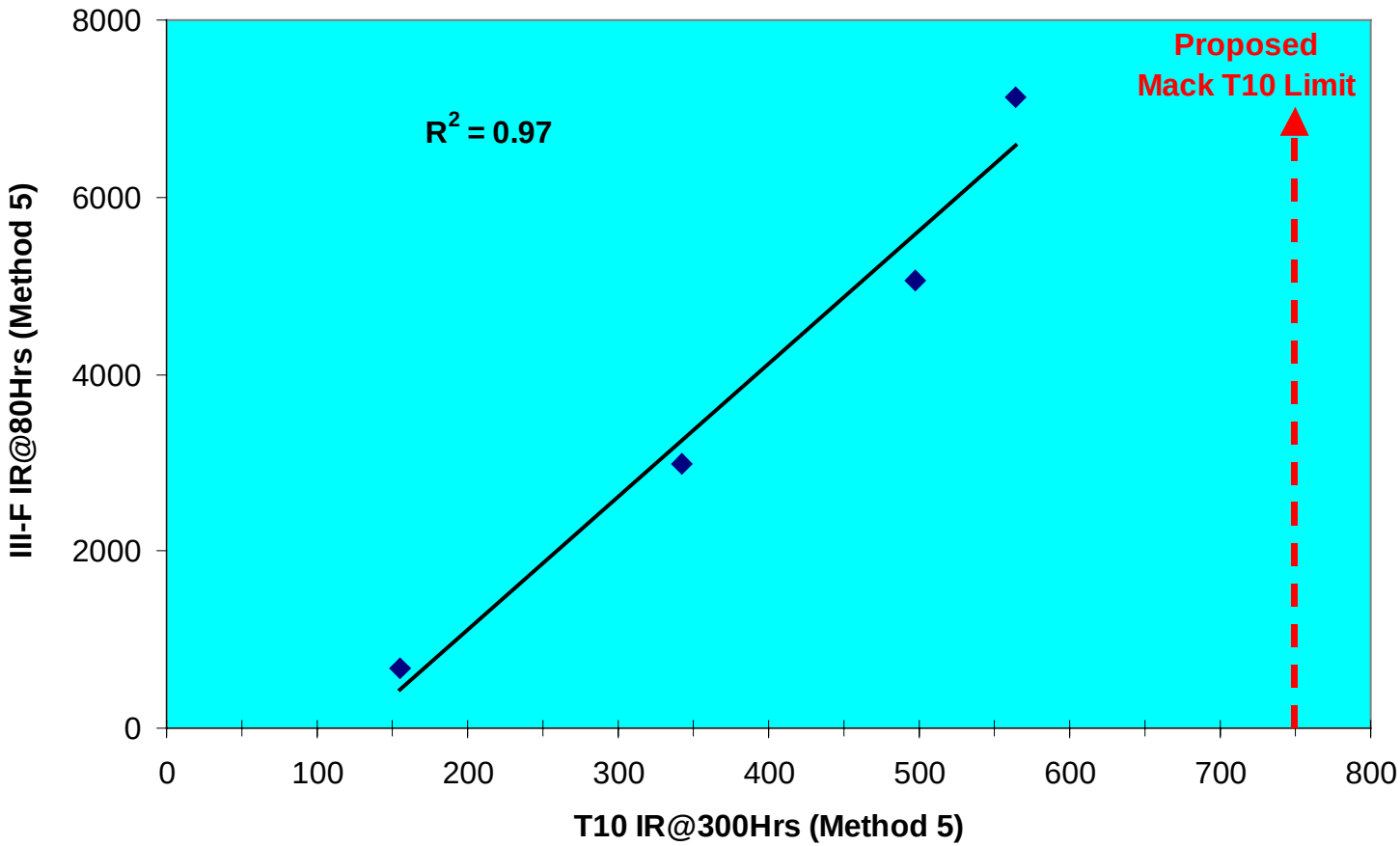
Oxidation responses in Sequence III-F and Mack T-10 tests

- **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

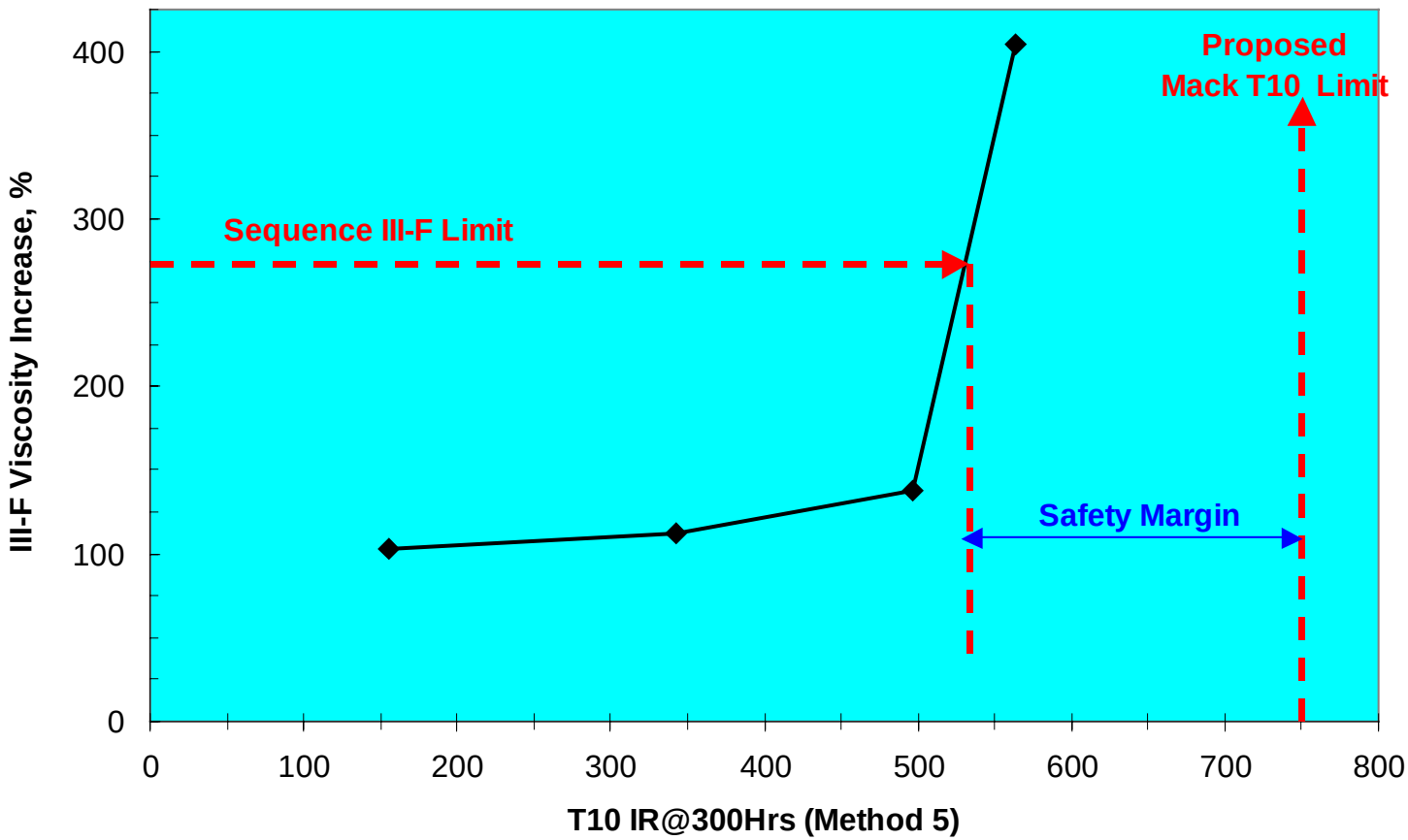
- **Results from these 4 pairs clearly show that oxidation responses in the two tests are highly correlated**
  - Indeed, Sequence III-F is shown to be far more severe test of oxidation than the Mack T-10 test

Seq.III-F IR shows Strong Correlation with Mack T-10 IR

(Infineum PC-9 Development Data)



Sequence III-F Offers Significantly Higher Protection Against Oxidation Than Mack T-10 IR



Summary

- **Three of the proposed spec parameters in Mack T-10 test, ΔLead(300 Hrs), ΔLead(250-300 Hrs) and IR (Method 5), are highly correlated**
  - Typical R2 ~0.9
- **Over-specification of correlated parameters can drastically reduce affect pass rate for Mack T-10 test**
  - Random variability of any of the three correlated parameters could cause a passing oil to fail
  - At $100K per test, this could result in very costly repeat testing without offering any additional hardware protection
- **Sequence III-F offers much better protection against lube oxidation than Mack T-10**

Recommendations

- **Elimintate T-10 IR and ΔLead (250-300 Hrs) paramters from PC-9 pass/fail limits for the Mack T-10 test**

- **Specify the Sequence III-F viscosity increase at the API SL limit as the PC-9 oxidation test**
  - Sequence III-F will be run in every basestock anyway for the API SL claim
  - Sequence III-F test will ensure that antioxidant treat rate is properly matched for all basestocks