Phosphorus Retention and the Sequence IIIG

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Report to ESCIT

March 20, 2007

Outline

- Afton Preference for Catalyst Protection
- Issues with Sequence IIIG
  - Laboratory variability on ICP
  - Severity shift on phos retention
  - Need for regular data collection by TMC
  - Need for monitoring and severity adjustment system

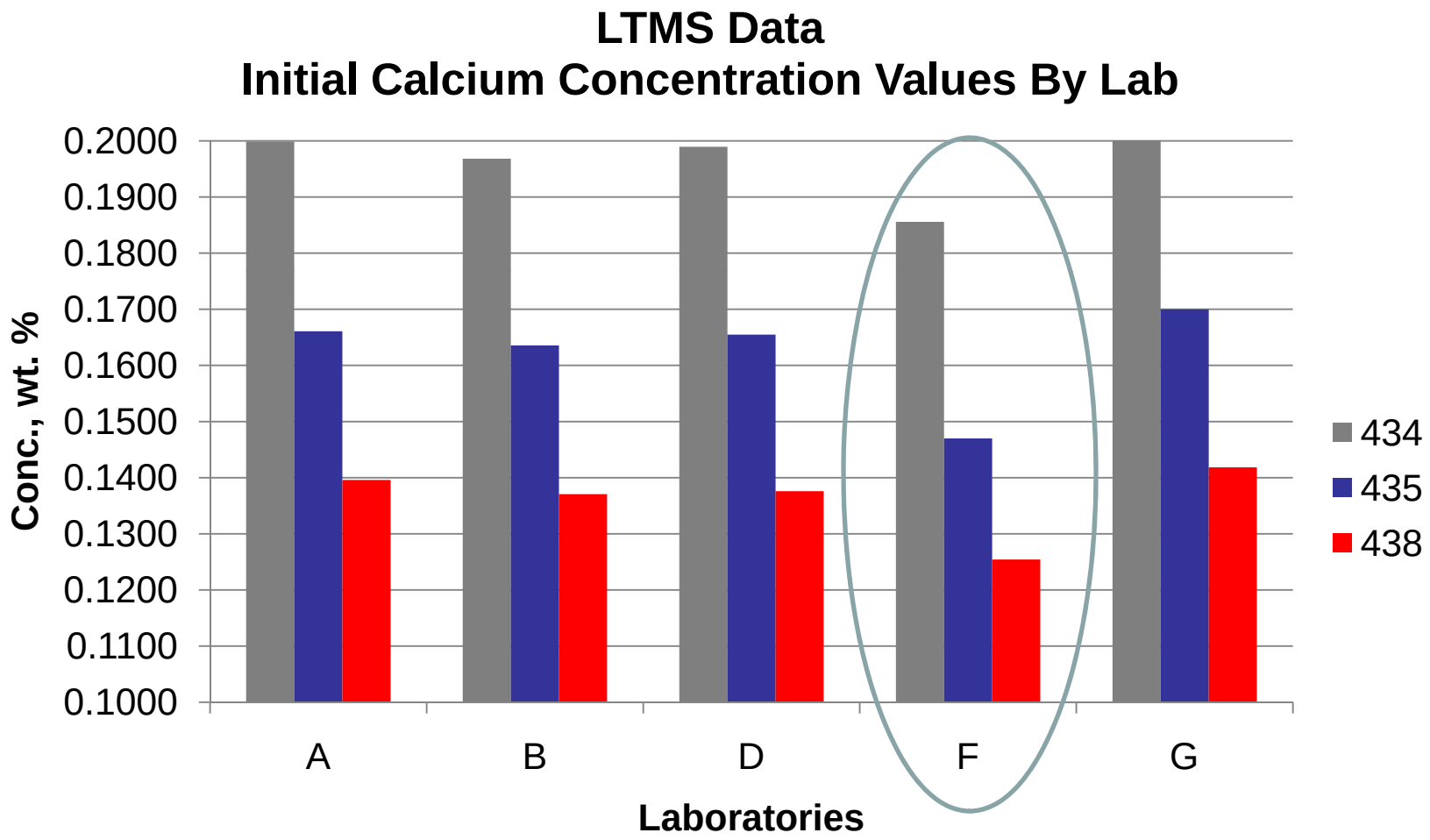
Afton Preference

- Keep it simple: Use phosphorus retention
- Phos Retention yields the required information and correlates with catalyst poisoning.
- It is acceptable for the narrow phosphorus range in which we're operating.
- It is not dependent on intermediate measurements which tend to compound errors as in the "Long Form"

Current Issues With the IIIG Test

- Testing labs display large differences in ICP measurements of initial oil sample
  - Differences too large to be related to fuel dilution
- The Sequence IIIG has experienced a large shift in Phosphorus Retention performance since about July, 2007
  - Reference oil data not updated since November, 2006
- Recommend that the TMC collect ICP data from all references and begin tracking, with the objective of developing a severity correction before GF-5

Laboratory ICP Measurements Vary Greatly



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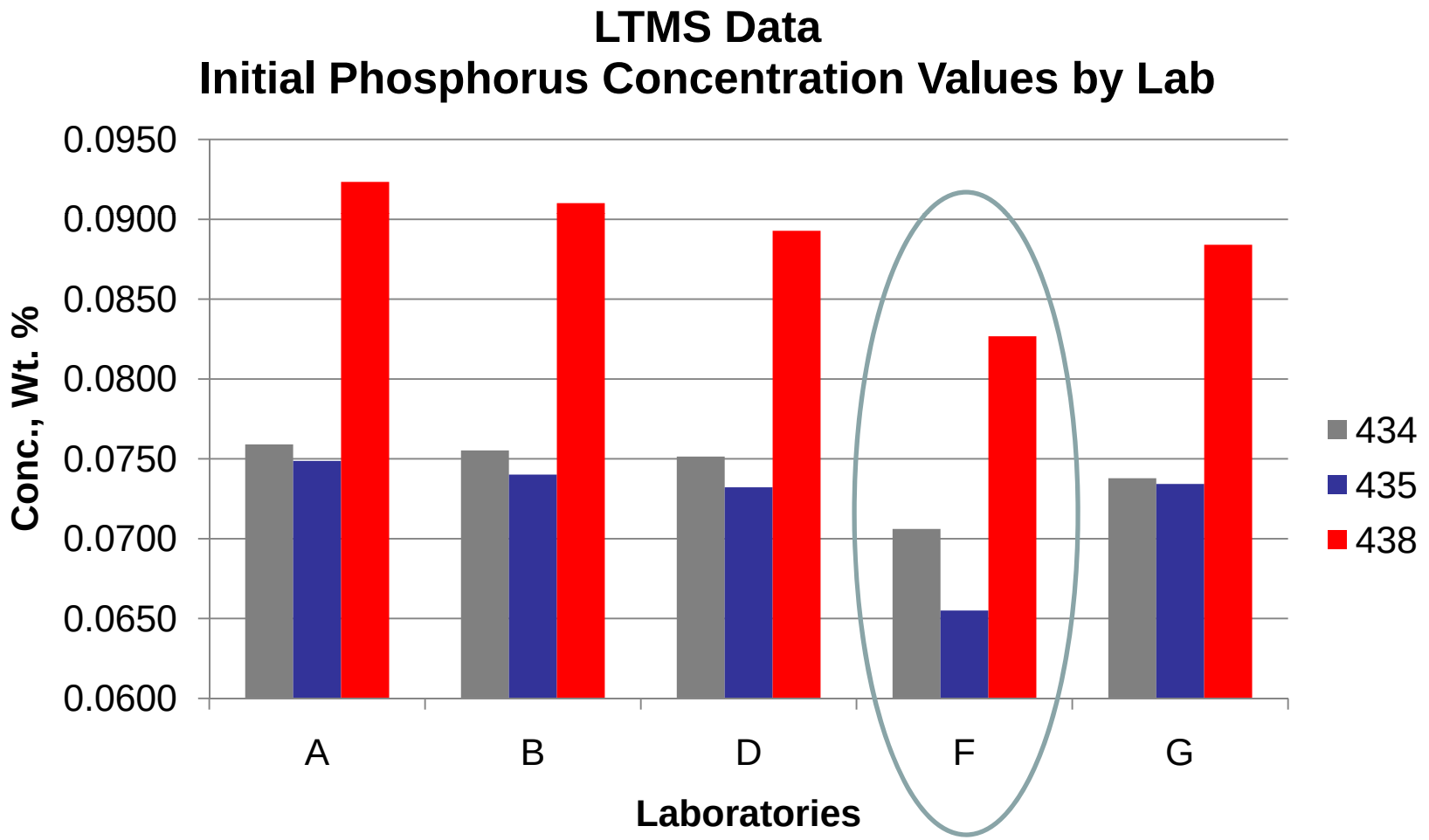
Laboratory ICP Measurements Vary Greatly



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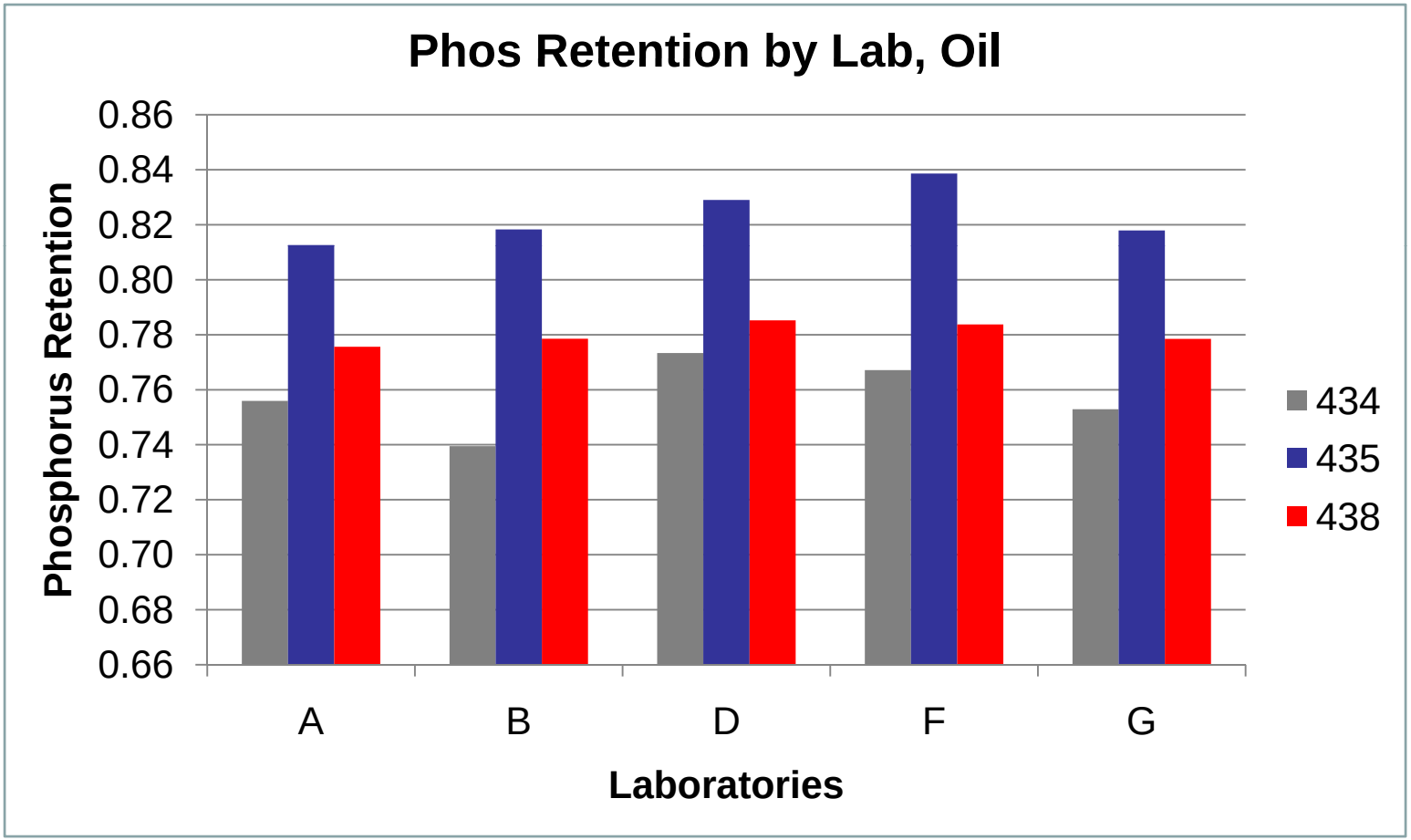
Phos Retention Varies by Laboratory



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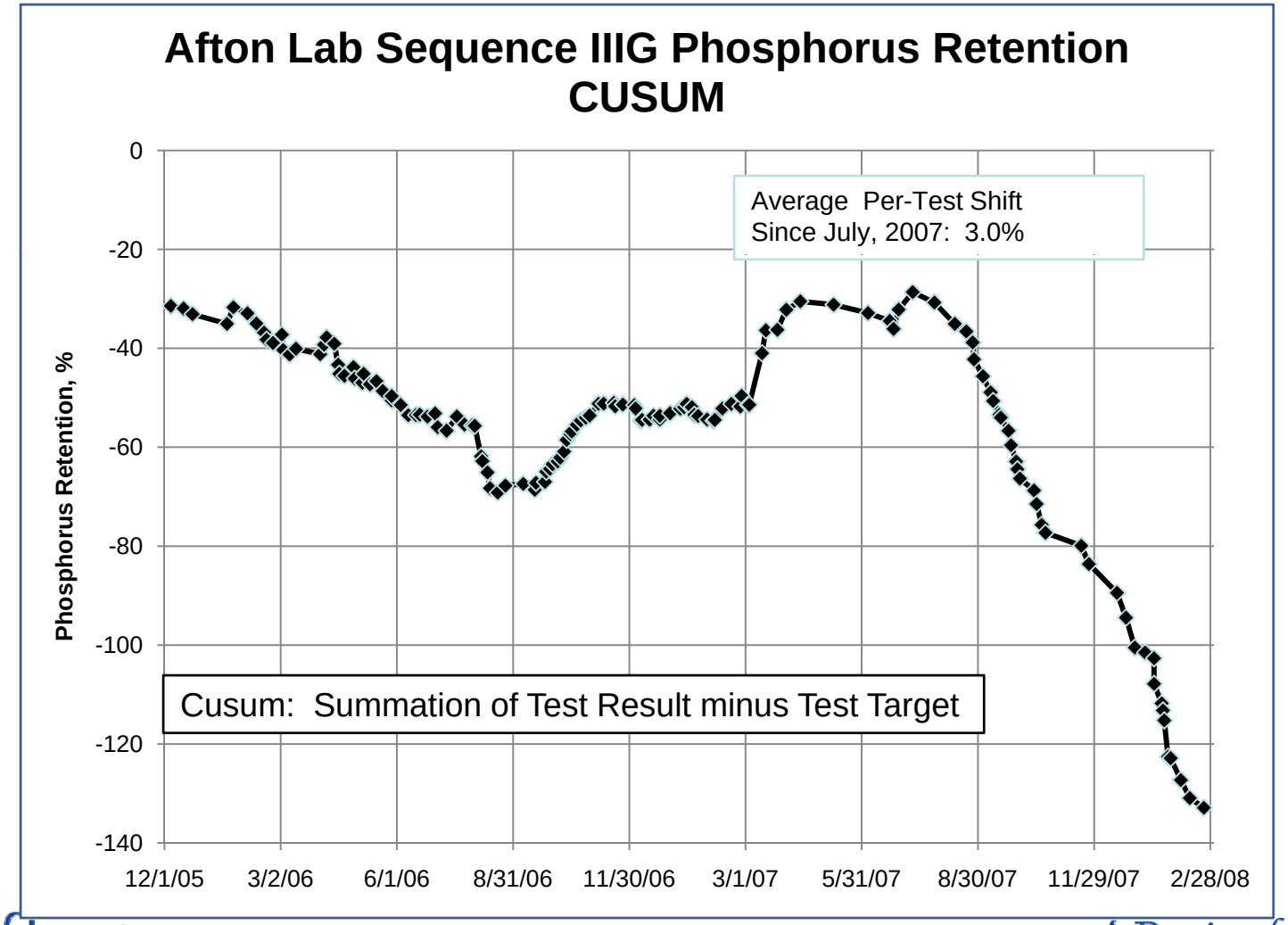
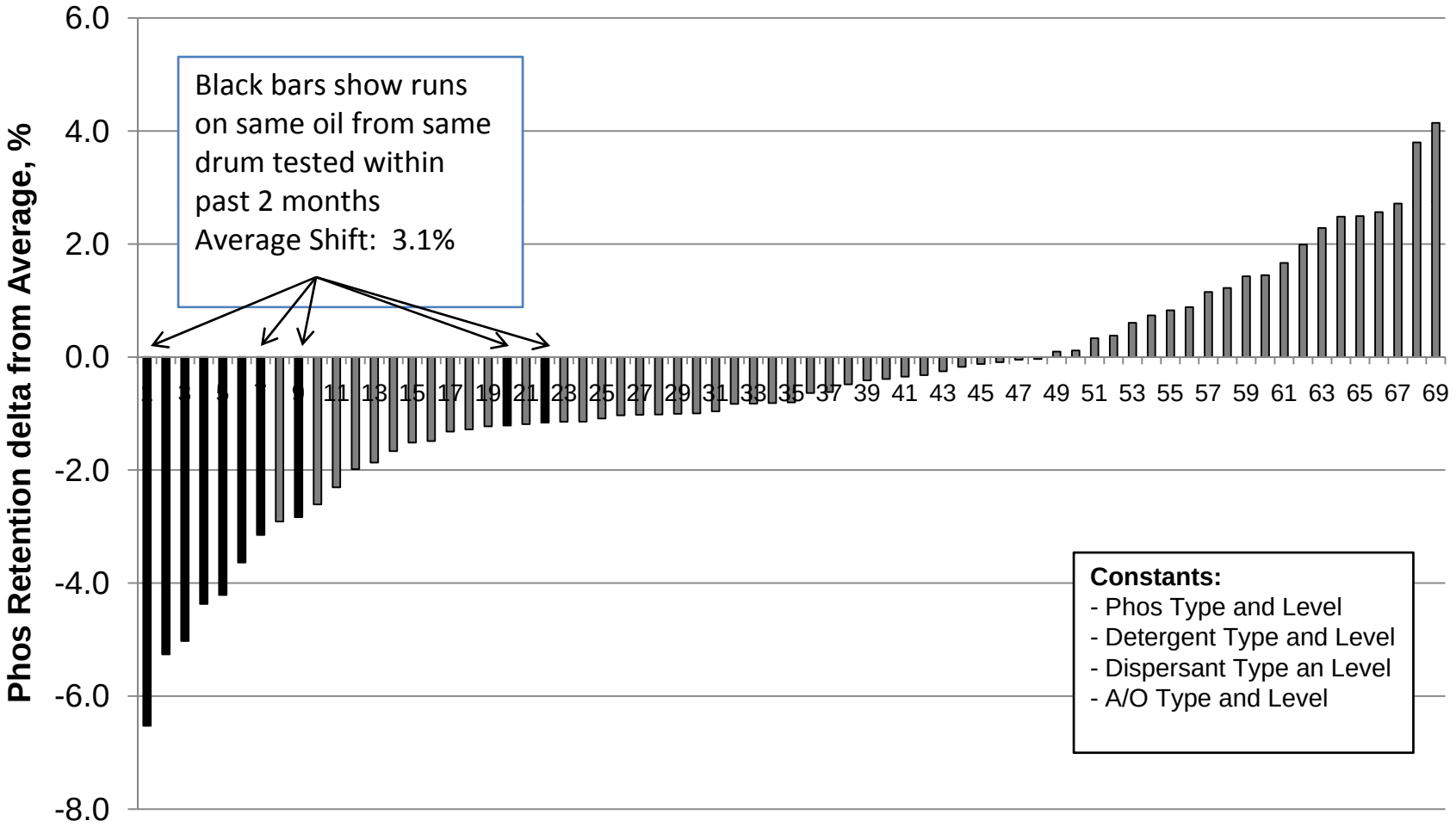
Phosphorus Retention Has Shifted Severe Since July, 2007



Phos Retention Shift on Oils with Same Technology



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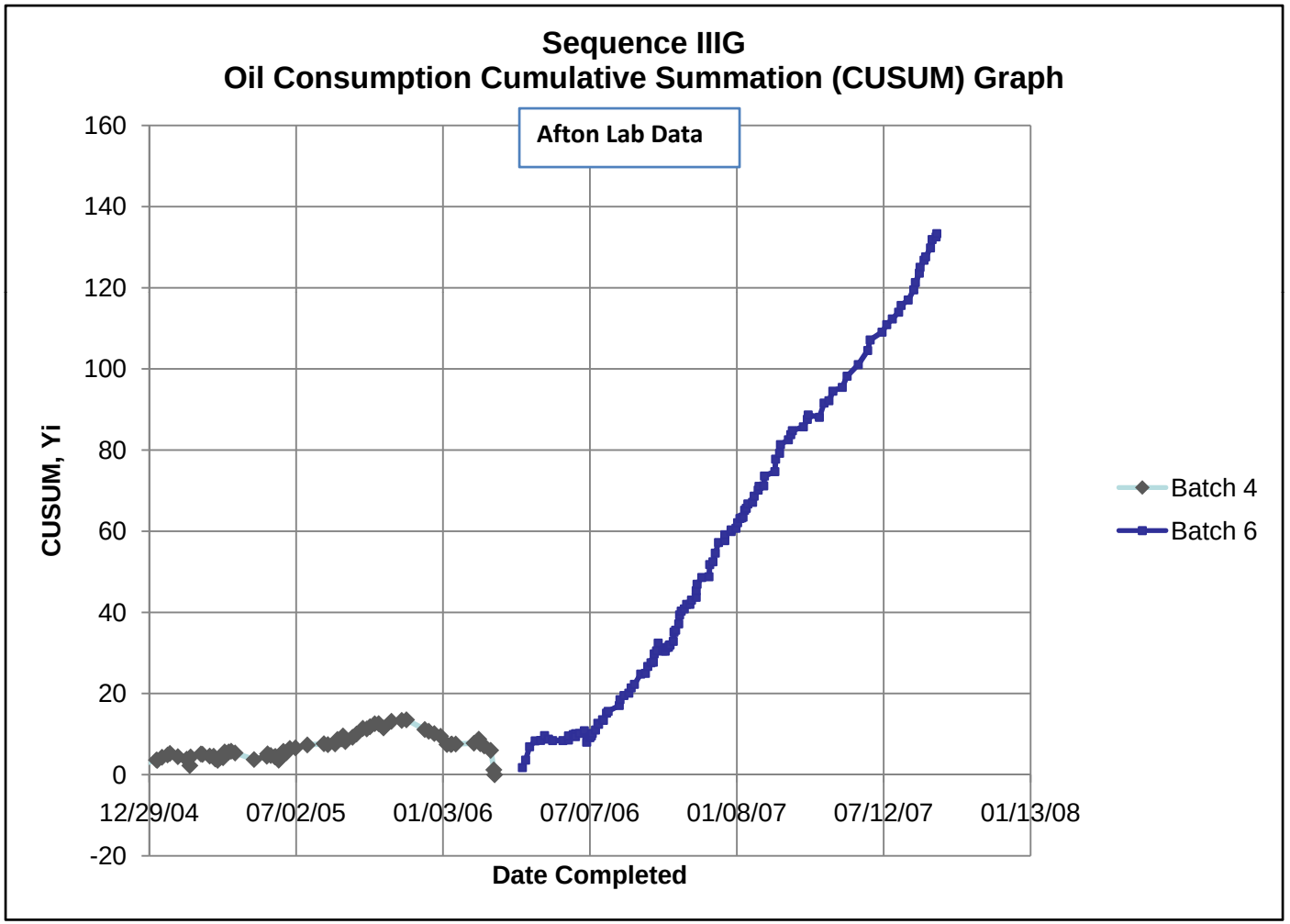
Shift in Phos Retention Correlates with Shift in Oil Consumption



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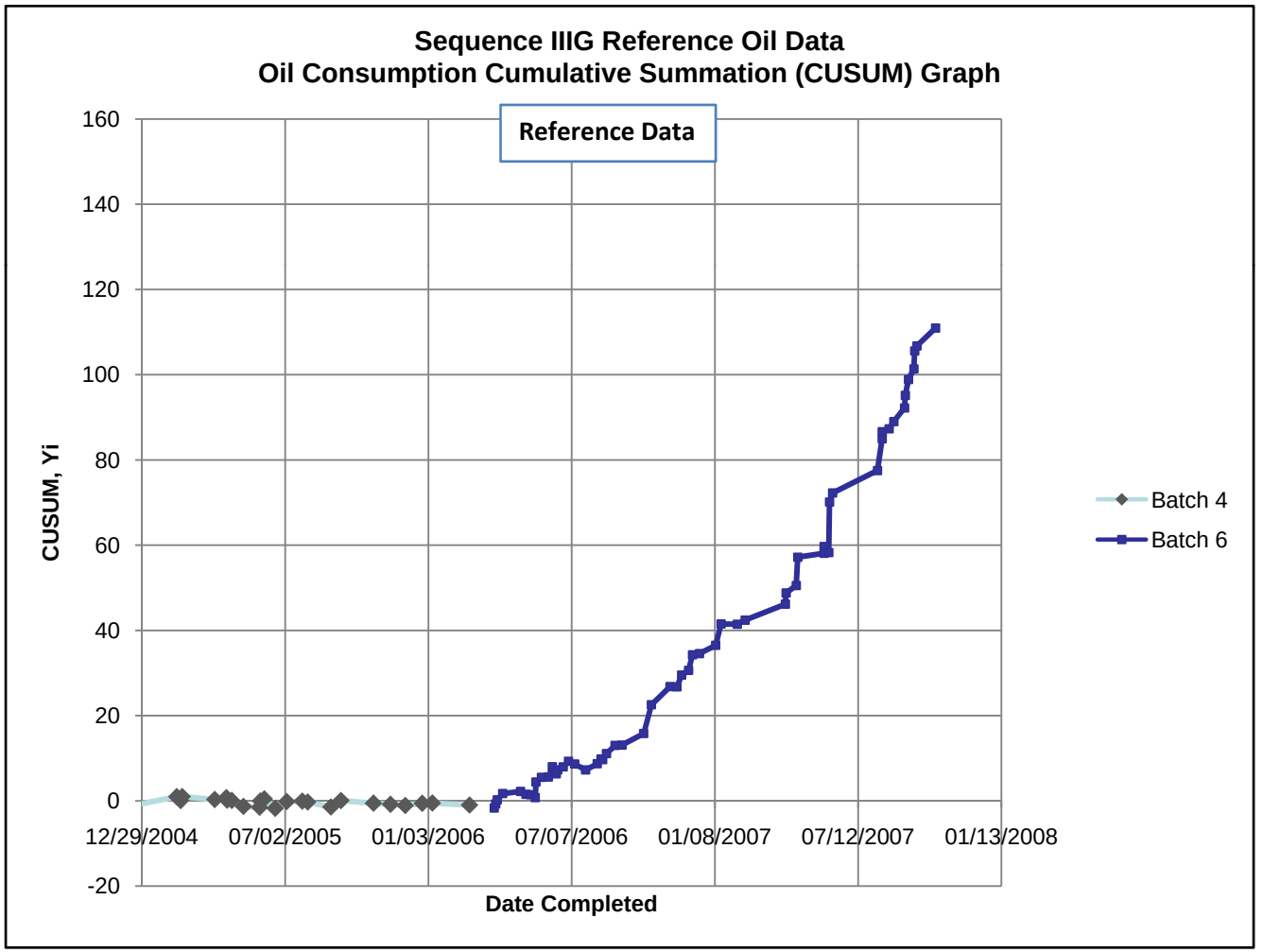
Reference Data Shows Same Shift in Oil Consumption



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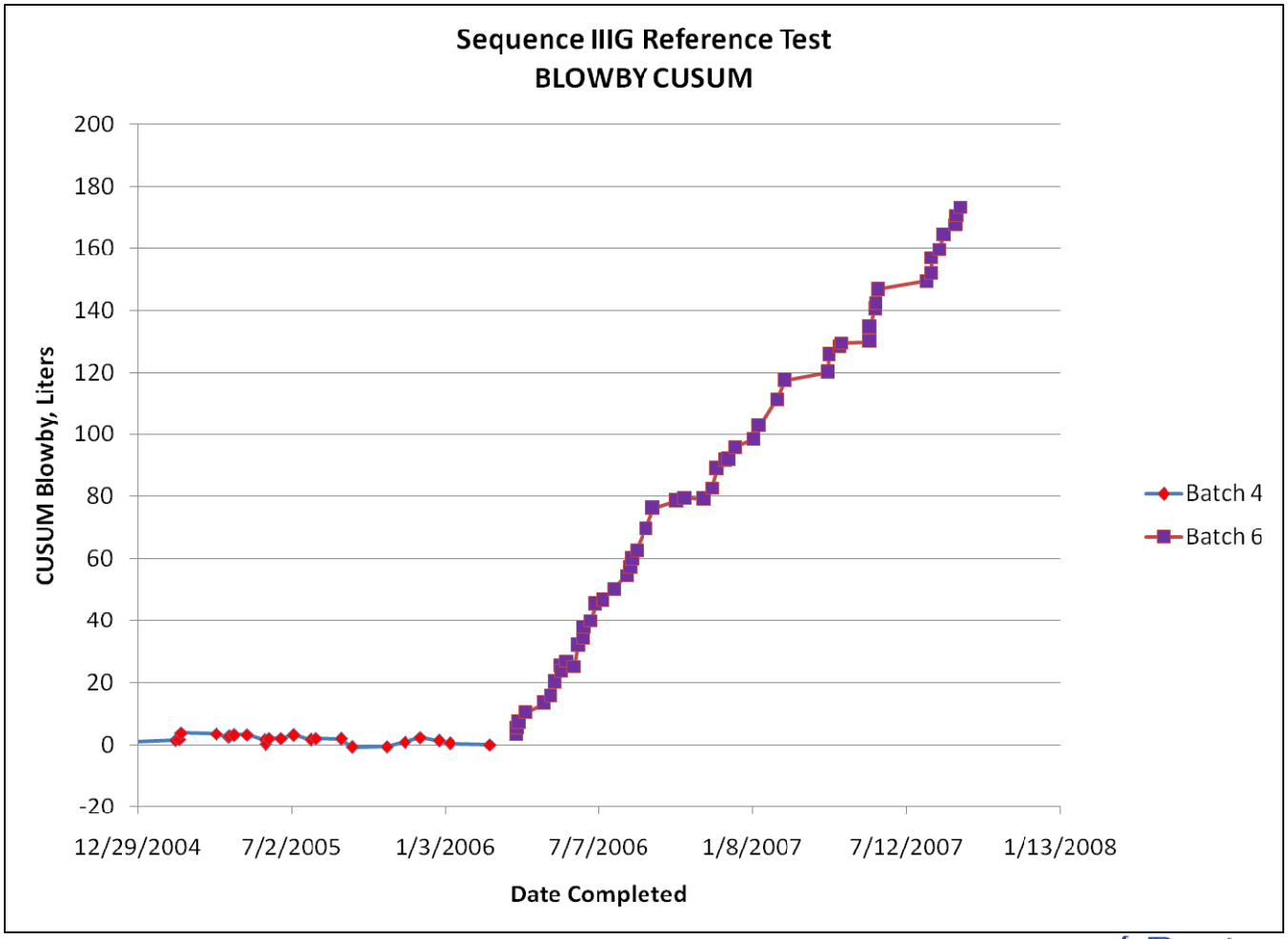
Blowby: Another indication the IIIG has shifted



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Calculation of Volatility Losses by Calcium Ratio

- **Given: Calcium concentrates in used oil proportional to the loss of base stock via distillation.**
- **Calculation accomplished by the following equation:**

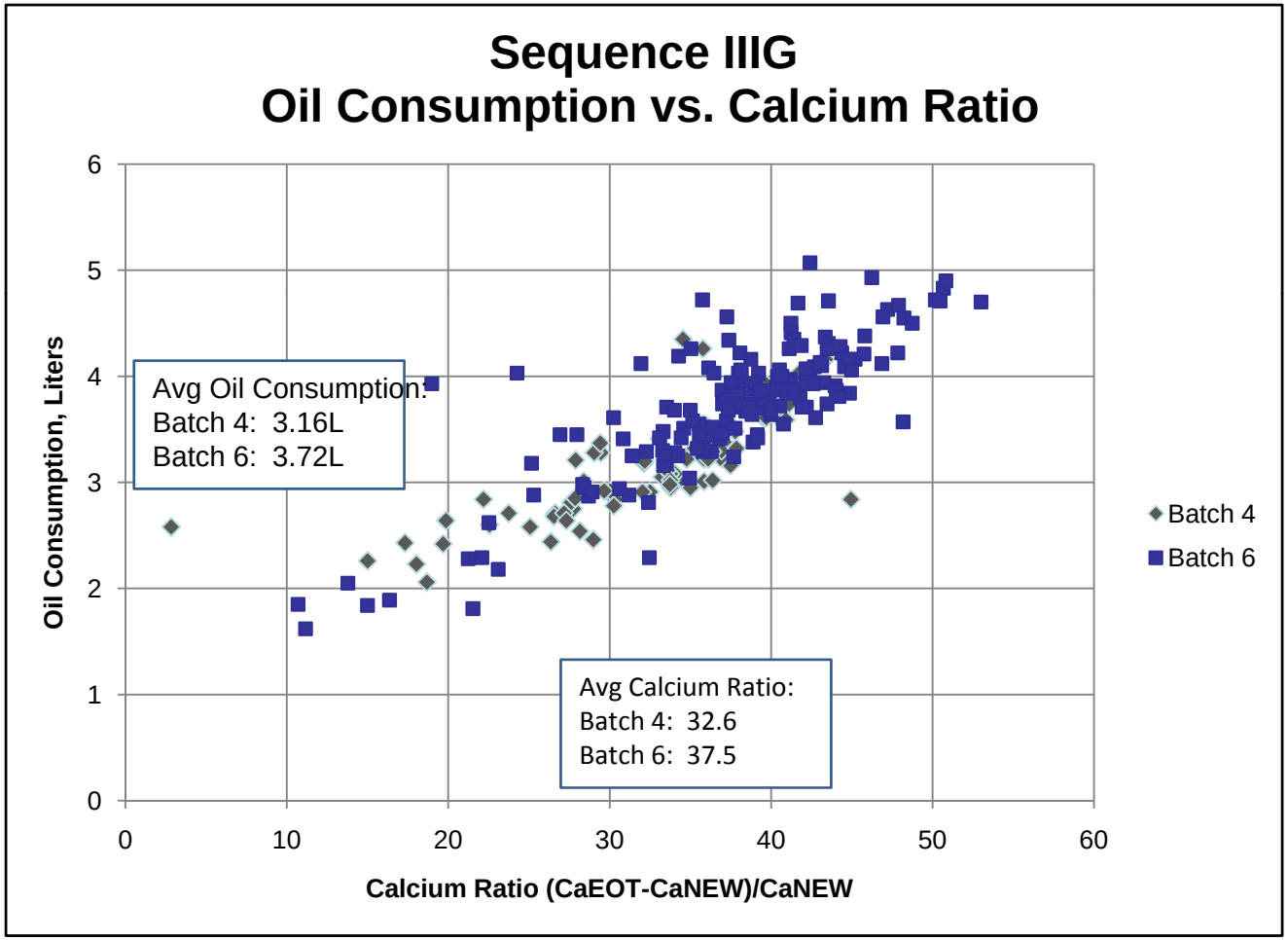
  (Used Oil Ca Value – Initial Oil Ca Value) / Used Oil Ca Value * 100

  Examples:

2000 ppm | 4000 ppm — **(4000 – 2000) / 4000 * 100 = 50% base stock loss**

2000 ppm | 3000 ppm — **(3000 – 2000) / 3000 * 100 = 33% base stock loss**

The Shift in Oil Consumption is Related to Volatility Losses



Group III Reference Oil does not show shift.

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Conclusions and Recommendations

- Understanding the present severity of the Sequence IIIG is crucial to the establishment of a catalyst-protection limit for GF-5
- The TMC needs to update their ICP database from the current cut-off of November, 2006
- The TMC and Surveillance Panel need to develop monitoring and severity correction methods

IIIG Reference Oil Phosphorus and Calcium Mass Analysis

January 31, 2008

Reference Oil Analysis Using “Long Form”

- **148 tests with ICP information at all test intervals**
- **Calcium and Phosphorus mass calculated for each 20-hour interval of IIIG test**
- **Table below shows the percent of all tests where results show an *INCREASE* in Ca or P mass, by 20-hour segment. This is an increase in mass over the previous period – an impossibility!**

Percent of Tests Showing Mass Increase

	20-Hours	40-Hours	60-Hours	80-Hours	100-Hours
Ca	38.4%	5.3%	7.3%	9.3%	6.0%
P	1.3%	3.3%	4.0%	6.0%	4.6%

Why is this important?

- **The majority of phosphorus lost in a IIIG occurs in the first 20-hours**
  - **We cannot tolerate error in this measurement**

- **"Liquid" phosphorus mass lost is calculated from liquid oil lost, which is calculated from Ca concentration and oil level. When Ca mass increases, liquid phosphorus mass lost is *less than* zero. Ca mass increases 38% of the time at 20-hours.**

- **"Volatile" phosphorus lost is calculated using "Liquid" phosphorus lost and total phosphorus lost**

- **Therefore, all of calculated phosphorus lost ends up in the "Volatile" value due to Ca and oil level error. In fact, calculated "Volatile" phosphorus lost will be GREATER than the actual total phosphorus lost from the oil.**

Impact of 20-hour Phosphorus value on total

- **The 20-hour phosphorus mass calculation has a large impact on the total calculated phosphorus throughput.**

Table1 below shows total grams of P consumed during a 100-hour IIIG test when the 20-hour value is either < 0, or >/= 0

Table 2 below shows the calculated Phosphorus Retention values for the same 100-hour IIIG tests

Table 1 – Grams P

	20H < 0	20H >/= 0
TMC	Total P	Total P
Oil 434	1.68	1.92
Oil 435	1.30	1.60
Oil 438	1.86	2.08

Table 2 – Phos Retention

	20H < 0	20H >/= 0
TMC	Total P	Total P
Oil 434	75	76
Oil 435	82	82
Oil 438	78	78

Conclusions

- **The phosphorus mass calculation is complicated by engine oil level measurements and sometimes produces increases in calcium mass at 20-hours (38% of all tests). This causes negative liquid-phase phosphorus mass values.**

- **Phosphorus retention is not affected by this error in measurement.**

- **Note: The phosphorus retention ratio at 20-hours always produces viable results (retention values less than 100%)**