Sequence IV Surveillance Panel | MINUTES

REVISION DATE: 11/26/2018 7:27:00 AM

Relevant Test:	Sequence IVB
Note Taker:	Chris Mileti
Meeting Date:	10-18-2018
Comments:	Sequence IV Surveillance Panel meeting hosted by Intertek.

1. OPENING COMMENTS:

1.1. Action Item Review (Chairman):

1.1.1. There were three action items from the Surveillance Panel meeting on 10-04-2018.

1.1.2. Action Item #1:

1.1.2.1. The Statistics Group is to proceed with their FEWMEOT analysis and LTMS development without an engine hour correction factor.

1.1.2.2. This action item is complete.

1.1.3. Action Item #2:

1.1.3.1. Chairman is to provide a Surveillance Panel response to the ACC by 10-12-2018.

1.1.3.2. This response was provided on 10-16-2018 instead of 10-12-2018.

1.1.3.3. This action item is complete.

1.1.4. Action Item #3:

1.1.4.1. The Chairman is to request a reply from the ACC by 10-18-2018.

1.1.4.2. The ACC has already replied.

1.1.4.3. This action item is complete.

1.1.5. Several motions were proposed and voted on during the last meeting.

2. STATISTICAL PRESENTATION:

2.1. Background:

2.1.1. Jo Martinez represented the Statistics Group and gave the presentation.

2.1.2. The presentation provided an update on the FEWMEOT analysis and development of the LTMS system.

2.1.3. The first (8) slides are summary slides.

2.1.4. The remaining slides have supplemental details and appendices.

2.2. Slide #3:

Executive Summary without EngHr Adjustment

Analysis Highlights:

- This analysis includes the results of 44 precision matrix and post-PM tests
- Data supports the use of Ln(FEWMEOT_Ca_Adj) transformation
  - Statistically significant oil difference: 1012 < 300
  - Marginal oil difference: 1012 < 1011
  - Marginal lab difference (F < B)
  - No statistically significant Stands within Lab differences
- Correlation between sqrt(AVLI) and Ln(FEWMEOT_Ca_Adj) is high (indicating parameter redundancy)
- Estimated within a stand test precision (r; ASTM repeatability)
  - Ln(FEWMEOT_Ca_Adj) = 0.7996
- Estimated test precision across labs and stands (R; ASTM reproducibility)
  - Ln(FEWMEOT_Ca_Adj) = 1.0081
- Oil means and standard deviations

Ref. Oil	Number of Tests	Target Mean Ln(FEWMEOT_Ca_Adj)	Target Mean FEWMEOT_Ca_Adj	Target Standard Deviation Ln(FEWMEOT_Ca_Adj)
300	12	5.3781	217	0.3921
1011	16	5.1677	176	0.3505
1012	16	4.9350	139	0.3548

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2.2.1. The dataset included (44) Precision Matrix and post Precision Matrix tests.
2.2.2. The statisticians performed the analysis with and without an engine hour correction.
2.2.3. There is a marginal difference between Lab F and Lab B.
2.2.4. There are no statistical differences between stands from a single lab.
2.2.5. The correlation between AVLI and iron is high.
  2.2.5.1. This indicates redundancy between parameters.
  2.2.5.2. Previous analysis conducted by this group showed the same redundancy.
  2.2.5.3. The statisticians are still analyzing the calcium-adjusted iron.
2.2.6. The table lists means and standard deviations.

2.3. Slide #4:

Executive Summary with EngHr Adjustment

Analysis Highlights:

- This analysis includes the results of 44 precision matrix and post-PM tests
- Data supports the use of Ln(FEWMEOT_Ca_EngHr_Adj) transformation *(with Ca and EngHr Adjustments)*
  - Statistically significant oil difference: 1012 < 300 and 1012 < 1011
  - Statistically significant lab difference (F < B)
  - Statistically significant stand within lab differences:
    - B-2 is statistically different than B-3
- Correlation between sqrt(AVLI) and Ln(FEWMEOT_Ca_EngHr_Adj) is high (indicating parameter redundancy)
- Estimated within a stand test precision (r; ASTM repeatability)
  - Ln(FEWMEOT_Ca_Adj) = 0.6349
- Estimated test precision across labs and stands (R; ASTM reproducibility)
  - Ln(FEWMEOT_Ca_Adj) = 0.9052
- Oil means and standard deviations

Ref. Oil	Number of Tests	Target Mean Ln(FEWMEOT_Ca_EngHr_Adj)	Target Mean FEWMEOT_Ca_EngHr_Adj	Target Standard Deviation Ln(FEWMEOT_Ca_EngHr_Adj)
300	12	5.3062	202	0.3031
1011	16	5.1328	169	0.3226
1012	16	4.9072	135	0.3466

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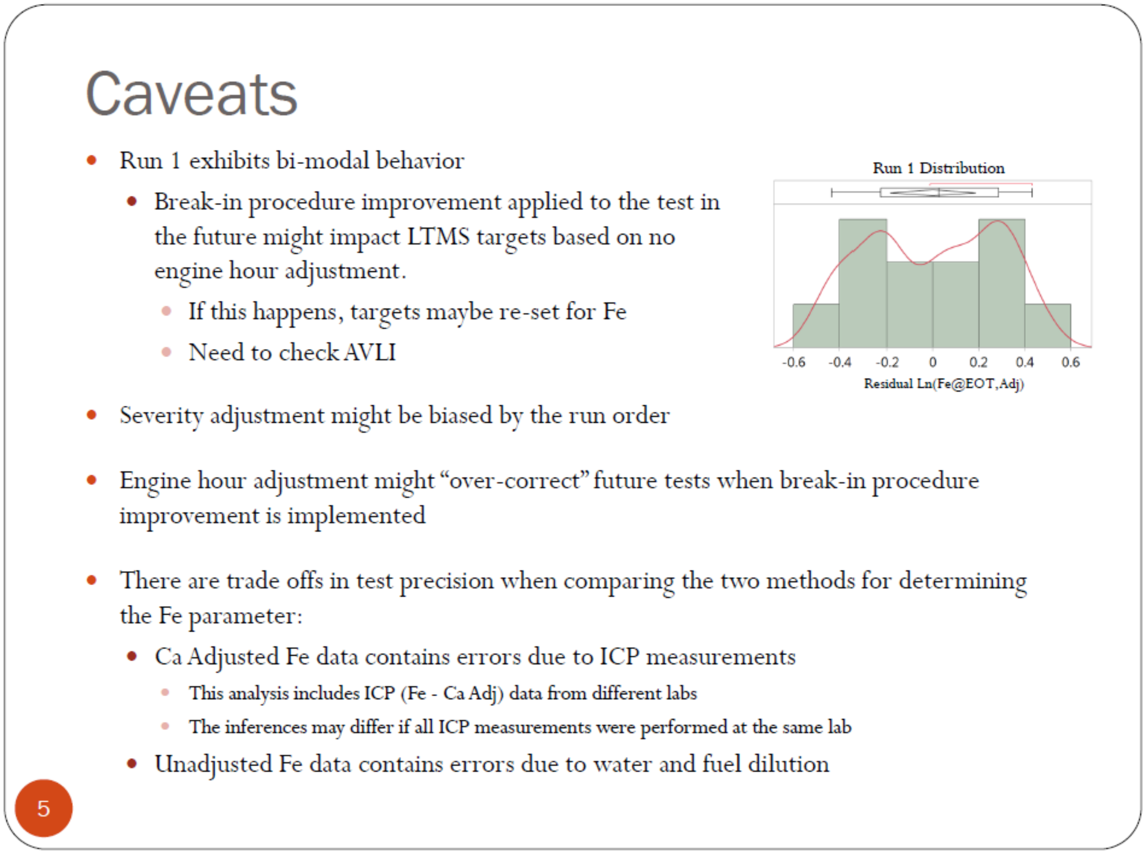
2.3.1. The difference between oils is more significant with this analysis.
2.3.2. There is a significant difference between Lab F and Lab B.
2.3.3. There is a significant difference between Stand B2 and Stand B3.
2.3.4. The means for the oil targets are lower when an engine hour adjustment is used.
2.3.5. Applying an engine hour adjustment resulted in a standard deviation for REO300 that is lower than the standard deviation for the other two oils.

2.4. Slide #5:



2.4.1. This slide lists the caveats from each of the two analysis options (with and without an engine hour correction).

2.4.2. Chart:

2.4.2.1. The chart in the upper right-hand corner shows the residuals for Run #1.

2.4.2.2. The data clearly displays bimodal behavior.

2.4.2.3. Does this bimodal behavior mean that something is being missed in the analysis?

2.4.3. The engine hour correction attempts to "bring down" the iron for Run #1 and "bring up" the iron for Run #2.

2.4.4. Any new break-in procedure may impact the LTMS targets that were developed without an engine hour adjustment.

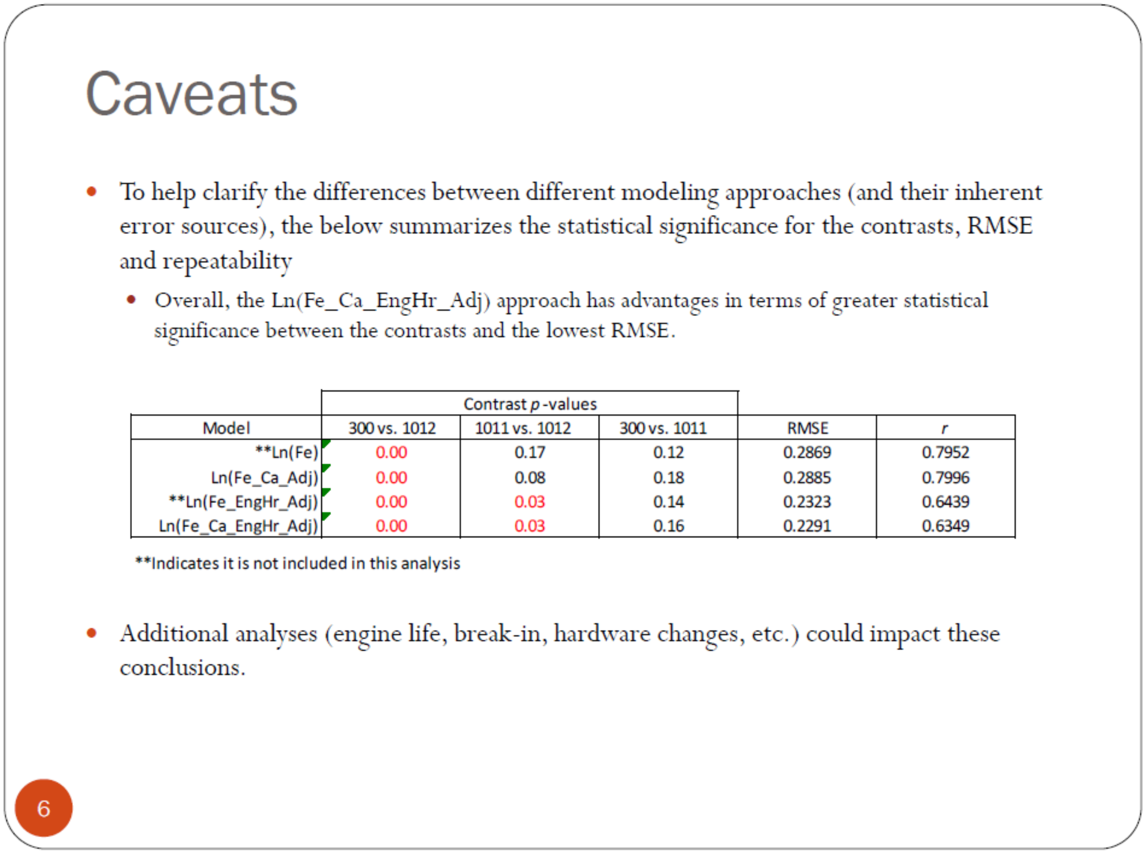
2.4.5. An engine hour adjustment may over-correct future tests that utilize the new break-in procedure.

2.4.6. There are trade-offs with test precision for the two methods being proposed to determine the iron parameter.

2.4.6.1. Bias in the ICP measurements (used to calculate the calcium adjustment) contribute to error.

2.4.6.2. Oil consumption, water content and fuel dilution in the sump contribute to error if no calcium adjustment is used.

2.5. Slide #6:



2.5.1. This slide lists additional caveats.

2.5.2. Items in the table that have a double asterisk (**) are not included in the analysis.

2.5.2.1. The "**" items are shown in the chart for comparison purposes only.

2.5.3. The significance of the difference between REO1011 and REO1012 increases when the engine hour adjustment is applied.

2.5.3.1. The standard deviation goes down when the engine hour adjustment is added.

2.5.4. Additional analysis of the database could impact the conclusions of this presentation.

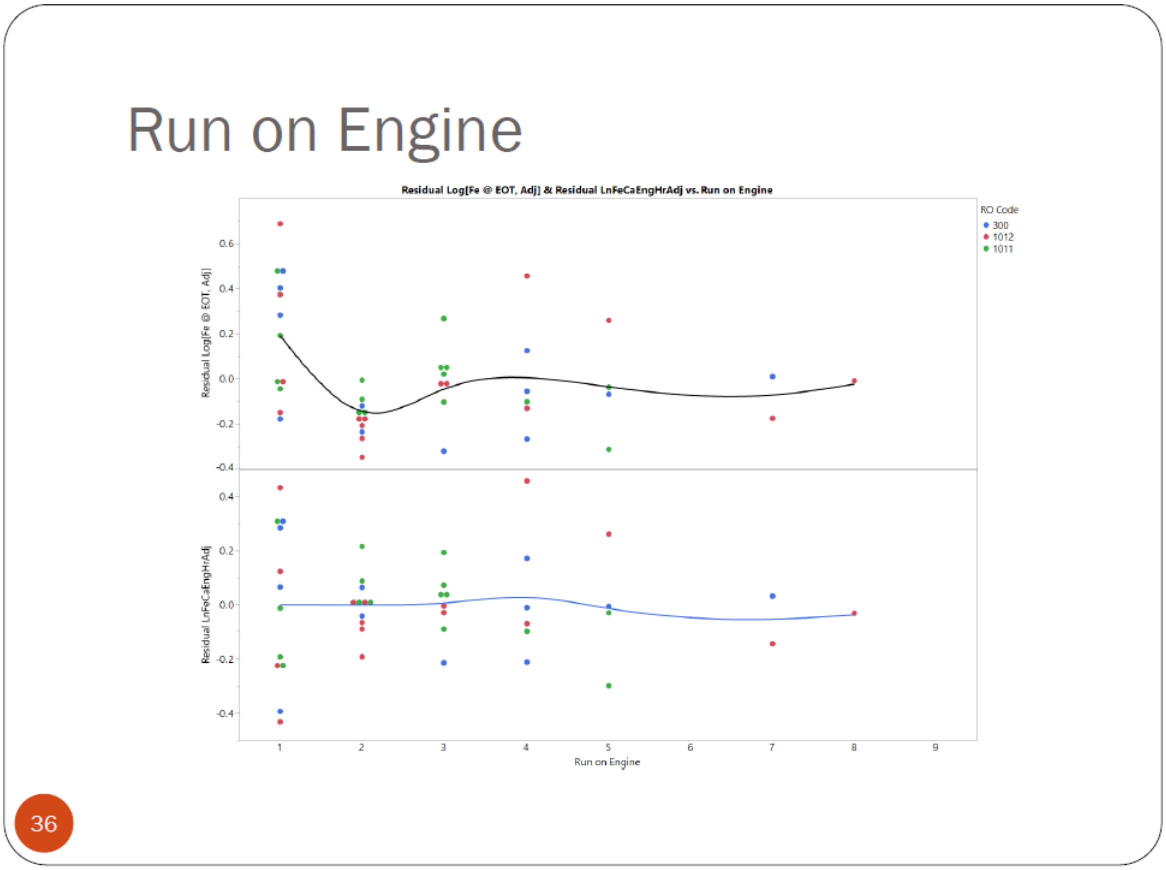
2.5.5. Comments from Infineum:

2.5.5.1. There is a statistically significant effect with the engine hour adjustment.

2.5.5.2. It is probably a better test with the engine hour adjustment in place.

2.5.5.3. The first test is unfavorable, and the second test is favorable [in terms of iron] if the engine hour adjustment is not used.

2.6. Slide #36:



2.6.1. Comments from Afton:

2.6.1.1. The top chart does not have an engine hour adjustment while the bottom chart does.

2.6.1.2. The engine hour adjustment clearly reduces variability.

2.6.1.3. Toyota and Intertek agree with Afton's comments, although Toyota noted that the amount of data is limited.

2.6.2. The TMC is concerned that there is no data available for a 6th run engine.

2.6.3. Comments from M. Chadwick:

2.6.3.1. There are targets for uncorrected iron.

2.6.3.2. Uncorrected iron targets are like the iron targets established during an earlier statistical analysis when AVLI was initially implemented.

2.6.3.3. A calcium correction ranks oils in the same way.

2.6.3.4. REO300 has the largest standard deviation when uncorrected iron is used.

2.6.3.5. REO300 has the largest standard deviation with a calcium correction.

2.6.3.6. The standard deviation for REO300 decreases dramatically with an engine hour adjustment.

2.6.3.6.1. Is the engine hour adjustment more of a byproduct of the dataset and not an accurate indication of how the test works?

2.6.3.7. <u>D5185 Test Method:</u>

2.6.3.7.1. Repeatability within a lab is 84ppm when the calcium level is 2000ppm.

2.6.3.7.2. This is the kind of variance that needs to be overcome when applying a calcium correction to iron.

2.6.3.8. <u>Review of LTMS Charts with New Data:</u>

2.6.3.8.1. Two tests are not chartable.

2.6.3.8.2. Test Stand A2 is milder.

2.6.3.8.3. Test Stand B2 is more severe.

2.6.3.8.4. The remaining stands are close to the target.

2.6.3.8.5. A calcium adjustment does not change how the stands are ranked in terms of severity.
2.6.3.8.6. For all practical purposes, severity adjustments do not have a major impact on the LTMS model.
2.6.3.8.7. Adding an engine hour adjustment and calcium correction just add complexity.
2.6.3.8.8. The yellow bars in LTMS get smaller with an engine hour adjustment and calcium correction, but the range of data gets smaller as well.
2.6.3.8.9. Additional data (N=28 → N=44) does slightly improve discrimination between oils.
2.6.3.8.10. He recommends using standard iron as the pass/fail parameter and reporting calcium-corrected iron.
2.6.3.8.11. A calcium-correction generally makes iron more severe.
2.6.3.8.12. There is no good reason in the data to implement a calcium adjustment.

2.6.4. Comments from Exxon:

2.6.4.1. The entire dataset uses a calcium adjustment for iron.
2.6.4.2. What happens when a high magnesium formulation is tested?
2.6.4.3. The statisticians said that they expect a magnesium-adjustment to behave similarly to a calcium-adjustment.

2.6.5. Comments from Lubrizol:

2.6.5.1. The impact of engine age is an engineering issue and not a statistical issue.
2.6.5.2. It is not appropriate to expect the Statistics Group to provide a solution.

2.6.6. Comments from Afton:

2.6.6.1. There are two separate issues being discussed at the same time.
2.6.6.2. The 1st issue is the calcium correction.
2.6.6.3. The 2nd issue is the engine hour adjustment.
2.6.6.4. The integrity of this test should take priority over concerns about complexity.

2.6.7. Ford argued that neither adjustment (calcium or engine hours) showed any major change in the data, so there is no need to discuss them separately.

2.6.8. Comments from Intertek:

2.6.8.1. The ACC PAPTG is concerned about ICP variability among the labs.
2.6.8.2. The reproducibility of the D5185 test suggests that adding a calcium adjustment will add variability to the measurement of iron.

2.6.9. General Motors:

2.6.9.1. Why go down the path of a calcium adjustment if it does not negate water and fuel variation?
2.6.9.2. Ford agreed with General Motor's concern.

2.6.10. Comments from Afton:

2.6.10.1. The end-of-test viscosity numbers vary greatly from lab-to-lab.
2.6.10.2. Those viscosity numbers include the impact of fuel and water.
2.6.10.3. The calcium adjustment helps to account for this fuel and water.
2.6.10.4. The calcium adjustment is needed to establish a "level playing field" among the labs.
2.6.10.5. However, an engine hour adjustment is more important than a calcium adjustment.

2.6.11. Infineum is now of the opinion that the calcium adjustment should be dropped.
2.6.12. Afton would like the Panel to consider whether the "field" is level with a calcium adjustment before there is any decision to discontinue it.

2.7. Motion for Calcium Adjustment:

2.7.1. A motion was introduced to remove the calcium adjustment from the iron pass/fail parameter.

2.7.2. **Motion:** *"Sequence IV Surveillance Panel approves using Fe at EOT without detergent metal ratio adjustment for the Sequence IVB FEWMEOT pass parameter and for LTMS charting. The detergent metal ratio adjustment will continue to be performed on Fe at EOT and reported as a rate and report parameter. Effective for all Sequence IVB candidate and reference oil tests started on or after 11/1/18."*

2.7.3. Explanation of Motion:

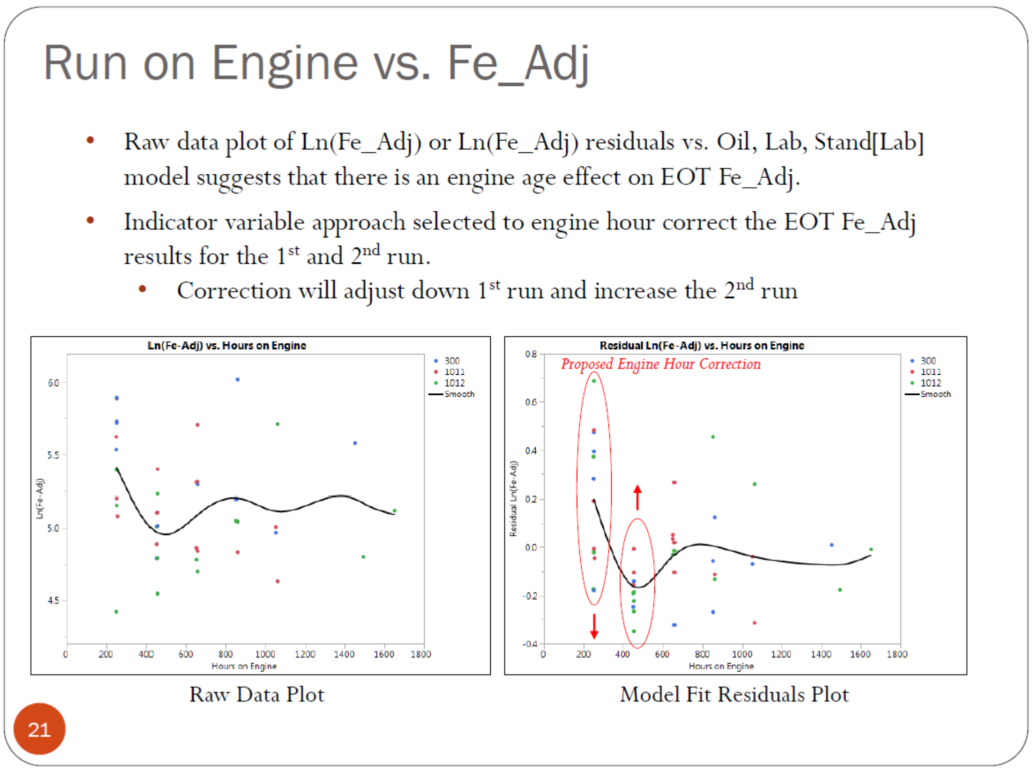
2.7.3.1. The calcium adjustment would be used for a rate-and-report iron parameter and not the pass/fail iron parameter.

2.7.3.2. This parameter will be monitored as more data is collected.

2.7.4. Toyota made the motion and it was seconded by Oronite.

2.7.5. It passed with (18) approves, (0) negatives and (1) waive.

2.8. Slide #21:



2.8.1. Lubrizol is concerned by the large spread in results for Run #1.

2.8.2. Afton believes that some of the spread with Run #1 is due to a "flyer".

2.8.2.1. However, there is clearly a difference between Run #1 and Run #2.

2.8.3. Comments from Intertek:

2.8.3.1. The test cycle probably does a better job at breaking-in an engine than the current break-in/aging cycle.

2.8.3.2. The current 50HR aging cycle could be replaced with the test cycle.

2.8.3.3. The oil gallery temperature setpoint could be increased.

2.8.4. Many of the Surveillance Panel members questioned whether a change to the break-in cycle would result in a new test.

2.8.5. Toyota shares the concern that the current break-in cycle may be inadequate.

2.8.6. Comments from Lubrizol:

2.8.6.1. Another option would be to eliminate the current break-in/aging cycle and use the first complete test on an engine as its "break-in".

2.8.6.2. Ford noted that this is like what is done on the LSPI test.

2.8.6.3. The TMC noted that this is like what is done on the Sequence VI.

2.8.6.4. Lubrizol also suggested taking this opportunity to replace REO1006-2 with REO300 as the Sequence IVB break-in oil.

2.8.6.4.1. The TMC is running out of REO1006-2 anyway.

2.9. Chart of Iron Data from N=44 Dataset:

2.9.1. O'Malley showed a chart of the iron data from the N=44 dataset.

2.9.2. The data is separated by the number of runs on the engine.

2.9.3. O'Malley initially only showed data for REO300.

2.9.4. Comments from Intertek on REO300 Data:

2.9.4.1. The data looks like a Sequence III viscosity curve.

2.9.4.2. Iron is steady for the first-half of the test while the oil is aging.

2.9.4.3. Iron begins to climb after the TAN-TBN crossover occurs.

2.9.4.4. The TAN-TBN crossover typically occurs between 100-125HRS.

2.9.4.5. Any new break-in cycle should not push the oil past its TAN-TBN crossover, otherwise the oil will not be able to adequately protect the engine.

2.9.5. REO1011:

2.9.5.1. O'Malley then only showed data for REO1011.

2.9.5.2. The iron trends looked like those for REO300.

2.9.6. REO1012:

2.9.6.1. O'Malley then only showed data for REO1012.

2.9.6.2. The iron level is not as pronounced as for the other two oils.

2.9.6.3. Afton added that REO300 has the most pronounced iron curve.

2.9.7. All Oils by Lab:

2.9.7.1. O'Malley then showed the data for all oils segregated by laboratory.

2.9.7.2. Southwest is different from the other four laboratories in that it does not show the high iron level during the first run on an engine.

2.9.7.3. The Panel members feel that the data in this chart is ambiguous.

2.9.7.3.1. Is the break-in cycle really the problem with iron predictability?

2.9.8. New Break-In Oil:

2.9.8.1. Lubrizol and Intertek again brought up the possibility of replacing REO1006-2 as the break-in oil.

2.9.8.2. Lubrizol and Shell both suggested using a high-moly formulation that is specifically designed for break-in.

2.9.8.3. <u>Shell Comments about Break-In Oils:</u>

2.9.8.3.1. Shell makes a break-in oil for a wide range of racing applications.

2.9.8.3.2. Shell noted that a break-in oil is designed to polish engine parts.

2.9.8.3.3. Break-in oils are not fully formulated and should only be used for 5,000-miles or 50HRS.

2.9.8.4. Lubrizol is willing to donate a break-in cycle using a Shell-supplied break-in oil.

2.9.8.4.1. It would then follow the break-in with an REO300 reference test.

2.9.8.5. Chadwick cautioned that running a special break-in oil could change the entire test.

2.9.8.6. <u>TMC Comments about REO1006-2:</u>

2.9.8.6.1. REO1006-2 uses older chemistry.

2.9.8.6.2. It has high levels of zinc and calcium.

2.9.8.6.3. The base stocks are also different than what is used today.

2.9.9. Iron as a Rate-and-Report:

2.9.9.1. Afton reiterated that iron is a redundant parameter.

2.9.9.1.1. Should it be made rate-and-report instead of pass/fail?

2.9.9.2. <u>Comments from Toyota:</u>

2.9.9.2.1. Iron was added as a pass/fail parameter to protect hybrids in the field that use start/stop technology.

2.9.9.2.2. It was also added to protect against corrosion resulting from high-ethanol fuels.

2.9.9.3. Chadwick again noted that AVLI and iron are highly correlated for the three reference oils.

2.9.10. Silicone Mitigation:

2.9.10.1. <u>Comments from Intertek:</u>

2.9.10.1.1. The break-in cycle can be improved.

2.9.10.1.2. REO1006-2 is probably not the best break-in oil.

2.9.10.1.3. The purpose of the current break-in/aging cycle is to mitigate silicone.

2.9.10.1.4. The current break-in cycle is based on the 90-minute break-in cycle from the Sequence IVA.

2.9.10.1.5. The Sequence IVA engine was not sensitive to beak-in conditions.

2.9.10.1.6. It was determined early in IVB test development that 50HRS was necessary to adequately mitigate silicone.

2.10. "Burning" the First Test:

2.10.1. Lubrizol again suggested using the 1st run on an engine as the "break-in".

2.10.2. Shell agreed that the first test should be "burned".

2.10.2.1. This issue can be revisited once more data is available for review.

2.10.3. Comments from Intertek:

2.10.3.1. Intertek is concerned with using the 1st test as the break-in.

2.10.3.2. This could severely limit test capacity in the industry.

2.10.3.3. Two different break-in cycles may be needed; with one cycle being used for new engines and another cycle being used after a camshaft lobe failure or cylinder head change.

2.10.4. Comments from Infineum:

2.10.4.1. They would like to keep REO1006-2 but utilize a longer break-in cycle.

2.10.4.2. Improvements to the break-in cycle should be made incrementally.

2.10.5. Lubrizol would like the statisticians to repeat their analysis without the Run #1 data.

2.10.6. Toyota believes that an engine hour adjustment may not be needed once more data becomes available.

2.10.7. Ford agrees that the 1st test should be "burned" as a reference.

2.10.8. Toyota believes that using the 1st test as a reference may be detrimental to the lifespan of the IVB.

2.10.9. Afton noted that the test price will have to go up if the 1st run on an engine is used for a break-in or reference test.

2.10.10. Comments from Intertek (Continued):

2.10.10.1. Apply an engine hour adjustment to the 1st and 2nd run on an engine.

2.10.10.2. Oil temperature is critical to pacifying silicon.

2.10.10.3. "Burning" the 1st run on an engine means that the test cycle will be used for break-in.

2.10.10.4. Will the test cycle's oil temperature pacify silicon correctly?

2.10.10.5. Continue to use the current break-in/aging cycle with the addition of 50HRS of the test cycle.

2.10.11. The TMC stressed that any changes to the break-in should be done with a DOE and not a live experiment.

2.10.12. Comments from Exxon:

2.10.12.1. There are two options – use an engine age adjustment or change the break-in procedure.

2.10.12.2. The first option will allow the Surveillance Panel to move forward today.

2.10.12.3. The second option will require an additional month or more for data collection.

2.10.13. Comments from T. Kostan:

2.10.13.1. The engine hour correction being proposed by the statisticians for Run #1 is "not where the data is at."

2.10.13.2. The correction was established using an average calculated for the two groups of data.

2.10.13.3. The Panel needs to research what is causing the higher group of iron data for Run #1.

2.10.14. Comments from Lubrizol:

2.10.14.1. Referencing a test stand using the 1st run on an engine is risky.

2.10.14.2. An unusually high iron result could have a negative impact on the lab's severity adjustment.

2.10.14.3. An unusually high iron result could also impact a future data analysis performed by the Surveillance Panel.

2.10.15. Comments from M. Chadwick:

2.10.15.1. He reminded the Panel that the engine hour adjustment is not based on the number of runs.

2.10.15.2. Instead, it is based on a window of engine hours.

2.11. Engine Hour Adjustment with No Calcium Correction:

2.11.1. Comments from M. Chadwick:

2.11.1.1. An engine hour adjustment without a calcium correction gives REO300 the lowest standard deviation of the three oils.

2.11.1.2. The LTMS model without a calcium correction looks like the LTMS model with a calcium adjustment.

2.11.1.3. Run #1 is different from Run #2 on an engine.

2.11.1.4. An engine hour adjustment does lower the top of the yellow bars in LTMS.

2.11.2. Comments from Toyota:

2.11.2.1. Toyota does not want an engine hour adjustment.

2.11.2.2. More data needs to be gathered before an engine hour adjustment can be considered.

2.11.2.3. They also do not want to change the break-in procedure.

2.11.3. Follow-Up Comments from M. Chadwick:

2.11.3.1. The ACC Code of Practice prevents a lab from manipulating which engine (and its run number) a candidate oil is tested in.

2.11.3.2. However, the same controls are not in place to prevent a lab from manipulating which engine is used for reference testing.

2.11.3.3. The decision on how to move forward is an engineering decision and not a statistical one.

2.11.4. Comments from T. Kostan:

2.11.4.1. The average iron from Run #1 is clearly different.

2.11.4.2. The data for Run #1 is unusual.

2.11.4.2.1. The data is separated into two clusters.

2.11.4.3. There is no explanation for why the clusters occur.

2.11.4.4. It is not appropriate to apply an engine hour correction to data clusters.

2.11.4.5. Engines that are adequately broken-in by the first test will be considered "mild" by the engine hour correction and will receive an adverse severity adjustment.

2.11.5. Comments from K. O'Malley:

2.11.5.1. Something needs to be done about the iron variability on a 1st run engine.

2.11.5.2. Lubrizol favors not using the 1st run on an engine for candidate testing.

2.11.6. Comments from Intertek:

2.11.6.1. An increase in test cost that results from restricting the use of 1st run engines will be transferred to the end user.

2.11.6.2. The increase in test cost is expected to be around 20%.

2.11.6.3. This will also reduce the number of available candidate tests.

2.11.7. Comments from J. Martinez:

2.11.7.1. On Tuesday, her position was to use an engineering solution to address the Run #1 issue.

2.11.7.2. She is always in favor of an engineering solution instead of a mathematical solution.

2.11.7.3. However, an engineering solution no longer appears to be an option.

2.11.7.4. The engine hour adjustment is not perfect, and there are risks with using it and not using it.

2.11.8. Follow-Up Comments from Intertek:

2.11.8.1. The 2nd run on an engine has less variability than the 1st run, and the 2nd run is generally milder.

2.11.8.2. Should the Panel move forward without an engine hour adjustment, and then plan a break-in DOE?

2.11.9. Comments from Afton:

2.11.9.1. Should the Panel use an engine hour adjustment without a severity adjustment?

2.11.9.2. M. Chadwick responded that there are significant differences between labs and stands, so a severity adjustment is probably appropriate.

2.12. Revised Break-In Procedure (Discussion):

2.12.1. Comments from Southwest:

2.12.1.1. Should a 50HR segment of the test cycle be added to the existing 50HR stead-state break-in/aging cycle?

2.12.1.2. Lubrizol said that they are willing to try this idea.

2.12.1.3. Southwest suggests using the same oil for both 50HR segments.

2.12.1.4. A cylinder head change or camshaft lobe failure would only require the first 50HR segment (steady-state break-in/aging) and not the second 50HR segment (test cycle).

2.12.2. Will the ACC consider this a new test with the revised break-in procedure?

2.12.2.1. Afton would consider it the same test.

2.12.2.2. Infineum is more comfortable with changing the break-in procedure than adding an engine hour correction.

2.12.2.3. <u>Comments from Lubrizol:</u>

2.12.2.3.1. Lubrizol is also more comfortable with changing the break-in procedure than adding an engine hour correction.

2.12.2.3.2. The change to the break-in procedure is more appropriate because it is an engineering solution and not a statistical one.

2.12.2.3.3. However, Lubrizol stressed that its position may change if the revised break-in procedure proves to be ineffective.

2.12.2.4. <u>Comments from Oronite:</u>

2.12.2.4.1. They are comfortable with adding a 50HR test cycle to the end of the current break-in.

2.12.2.4.2. Something needs to be done because Run #1 is clearly different.

2.12.2.4.3. They would like to see the [iron vs. engine hour] curve smooth out once the longer break-in is implemented.

2.12.2.5. <u>Comments from Shell:</u>

2.12.2.5.1. The break-in problem needs to be addressed now, otherwise labs will use it to “game the system”.

2.12.2.5.2. For example, a candidate test could be started on a 1st run engine.

2.12.2.5.3. The candidate test could then be terminated at 50-100HRS.

2.12.2.5.4. A new candidate test could then be restarted on a 2nd run engine.

2.12.3. Intertek has two engines that can be used to evaluate the new break-in method.

2.12.4. Intertek recommended the continued use of stock intake camshafts and valve springs for the break-in.

2.12.5. Revised Break-In Procedure (Motion):

2.12.5.1. Oronite made a motion to implement a new break-in procedure, and the motion was seconded by Shell.

2.12.5.2. Discussion about Break-In Oil:

2.12.5.2.1. The Panel originally wanted to continue to use REO1006-2 for the initial 50HRS of the break-in, and then switch to REO300 for the final 50HRS.

2.12.5.2.2. However, the TMC noted that there is only 1400-gallons of REO1006-2 remaining.

2.12.5.2.3. They also said that REO300-1 will need to be used in place of REO300.

2.12.5.2.4. The Panel eventually agreed to use REO1012.

2.12.5.3. Four Pre-Test Flushes:

2.12.5.3.1. There was also discussion about whether the four pre-test flushes are needed prior to the final 50HR segment of the break-in.

2.12.5.3.2. Intertek conducts four new engine break-ins each month, and they are concerned that the flushes will add a tremendous amount of time to this process.

2.12.5.3.3. Afton would like the flushes to remain in place to mimic what is done during a normal test.

2.12.5.4. ***Motion:*** "*Sequence IV surveillance panel approves modifying the current Sequence IVB break-in/aging procedure, for new engine assemblies only, to add start of test flushing procedures and 50 hours of runtime on test conditions, using ASTM REO 1012, at the completion of the 50-hour aging portion of the break-in/aging cycle. Effective for all Sequence IVB new engine assembly break-in/aging started on or after 10/19/18.*"

2.12.5.5. The motion passed with (19) approves, (0) negatives and (1) waive.

2.12.6. BOI/VGRA Matrix:

2.12.6.1. The current plan is to install the engine, break-in the engine and then run the REO300 reference test.

2.12.6.2. The Panel will need to approach the BOI/VGRA committee to see how they want to proceed now that the break-in has been changed.

2.12.6.3. Southwest already broke-in at least one of their BOI/VGRA matrix engines using the legacy break-in procedure.

2.12.6.4. OHT needs to confirm that they have enough camshafts to have Southwest break-in another engine using the new procedure.

2.12.6.4.1. It may deplete the reserve of camshafts that they have available in the event of lobe failures.

2.12.7. Introducing New Engines with a Reference Test:

2.12.7.1. The Panel discussed how new engines (that use the revised break-in procedure) should be introduced.

2.12.7.2. Introducing new engines with a reference test essentially makes this an engine-based LTMS system (at least for a short period of time).

2.12.7.3. Lubrizol likes this idea because it will quickly generate data that can be used to evaluate the effectiveness of the new break-in procedure.

2.12.7.4. Some of the Panel members suggested running reference tests on the next two engines that are introduced on each new stand.

2.12.7.4.1. Lubrizol and Afton cautioned that it will take the dependent labs 6-months to collect this data.

- 2.12.7.5. The four BOI/VGRA matrix stands will need to be exempt if this becomes a passing motion.
- 2.12.8. M. Chadwick warned that bias can be introduced into LTMS if Run #1 engines are used exclusively for reference tests.
- ***2.12.9. Comments from Lubrizol:***
  - 2.12.9.1. Lubrizol suggested referencing each new engine (and not just the next two engines on each test stand).
  - 2.12.9.2. Intertek asked, "*What if the life of the engine is shortened by a lobe failure?*"
  - 2.12.9.3. Southwest is against this idea and wants to put a cap on the total number of reference tests that need to be run.
  - 2.12.9.4. Lubrizol feels that N=6 is too small of a dataset.
- 2.12.10. Afton wants to make sure that no candidates are evaluated on a 1st run engine.
  - 2.12.10.1. Intertek cannot agree to Afton's position.
  - 2.12.10.2. Lubrizol and Shell agree with Afton, no formulator will want to run an oil on a 1st run engine.
- 2.12.11. Intertek made a motion that was seconded by Ford.
- 2.12.12. ***Motion:*** "*Sequence IV surveillance panel requires that the next new engine assembly that is introduced at each lab will be introduced using the new break-in/aging procedure, followed by a calibration test, conducted on ASTM REO 1012, and the next calibration test on each subsequent test stand at multiple stand labs, will be conducted as the first run on a test engine assembly using the new break-in/aging procedure.*"
- 2.12.13. The motion passed with (11) approves, (1) negative and (2) waives.

2.13. Vote to Cancel 2nd Motion of the Day:

- 2.13.1. This motion was originally proposed by Oronite and seconded by Shell.
- 2.13.2. There is no agreement within the Panel regarding how to implement it.
- 2.13.3. Lubrizol stressed that all Panel decisions should be made based on technical merit and not cost.
- 2.13.4. Oronite and Shell withdrew Motion #2.

2.14. Introduce FEWMEOT into LTMS:

- ***2.14.1. Comments from Afton:***
  - 2.14.1.1. Afton is worried that the LTMS targets may need to be changed because of the new break-in procedure.
  - *2.14.1.2. Should 1st run data be ignored when setting targets?*
  - 2.14.1.3. Some of the possible severity adjustments are huge (up to 50% of the original result).
  - *2.14.1.4. How far can these results be adjusted before people start getting uncomfortable?*
- 2.14.2. Lubrizol has similar concerns as Afton and does not know what should be done with the 1st run data.
- 2.14.3. Intertek noted that the severity adjustments were bigger when the engine hour adjustments were in place.
- ***2.14.4. Comments from Lubrizol:***
  - *2.14.4.1. Why is the Panel ignoring that there is a Run #1 anomaly, and assuming the new break-in procedure will be effective?*
  - 2.14.4.2. Voting on motions is premature.
  - 2.14.4.3. The statisticians have not yet had time to review the full master database.
  - 2.14.4.4. They may discover something during their full analysis that could impact the LTMS model.
  - 2.14.4.5. The five laboratories spent much of the summer compiling the master database with the intention that the statisticians would be able to analyze it as they saw fit.

2.14.5. Southwest noted that this date (October 18th) was selected to vote on LTMS because it gives the Surveillance Panel time to address issues before the end of the month.

2.14.6. Comments from TMC:

2.14.6.1. Southwest is correct, the intent was to have a time "cushion" to address any negative votes.

2.14.6.2. It appears as if Lubrizol will vote negatively on the LTMS motion.

2.14.6.3. If they do, the Panel will have two weeks to address this negative vote.

2.14.7. Comments from Afton:

2.14.7.1. This Panel needs to develop a "finished product" before the November AOAP meeting.

2.14.7.2. This Panel would be best served by giving the Statistics Group more time to review the database.

2.14.7.3. Afton and Intertek would much rather vote when they have more confidence that there will not be any negatives.

2.14.8. Recent Correspondence from the ACC:

2.14.8.1. Intertek noted that the Surveillance Panel has not yet had time to review recent correspondence from the ACC.

2.14.8.2. The ACC wants the Surveillance Panel to review a letter that was recently sent to them.

2.14.8.3. The ACC is going to have a meeting on October 26th, and a review of the Sequence IVB is on the agenda.

2.14.8.4. They do not feel there was enough time to review a letter recently sent to them by the chairman of the Sequence IV Surveillance Panel.

2.14.8.5. The ACC does not agree with how the Surveillance Panel has classified action items as "critical" and "non-critical".

2.14.9. Comments from Infineum:

2.14.9.1. It is standard practice to approve targets first and then go back to revise the LTMS system.

2.14.9.2. The change in protocol being discussed now is due to the compressed timeline that the Panel is working under.

2.14.10. Discussion Between Ford and Lubrizol:

2.14.10.1. Ford does not understand Lubrizol's reluctance about the upcoming LTMS vote.

2.14.10.2. Lubrizol's concerns are the result of the statisticians not being given the opportunity to fully review master database.

2.14.10.3. The Surveillance Panel and its sub-groups have always intended to allow the statisticians to perform their analysis as they see fit.

2.14.10.4. The meeting minutes reflect this.

2.14.11. Comments from M. Chadwick:

2.14.11.1. Even though the master database contains a lot of tests, most of the data is still from the Precision Matrix.

2.14.11.2. Any additional analysis of this database is not going to have a big impact on the iron parameter (in the aggregate).

2.14.11.3. B. Buscher added that eliminating the 1st run data from the LTMS analysis sounds like "cherry picking".

2.14.12. Ford made a motion for LTMS and it was seconded by Oronite.

2.14.13. ***Motion:*** "*Sequence IV surveillance panel approves the introduction of a Sequence IVB FEWMEOT LTMS, based on the N = 44 dataset, without the use of a detergent metal ratio adjustment or an engine hour correction factor, as per details included in document "IVB EOT Fe LTMS Final Summary 20181018.docx". Effective 11/1/18.*"

2.14.14. This motion passes with (6) approves, (2) negatives and (4) waives.

2.14.15. Comments from TMC:

2.14.15.1. The TMC noted that the negative votes will need to be addressed within two weeks.

2.14.15.2. This is required because the motion deals with LTMS.

2.14.16. The Surveillance Panel members that cast the negative votes, Lubrizol and Afton, agreed to provide documentation (to the Panel) explaining their votes by next Monday.

2.14.17. Comments from Lubrizol:

2.14.17.1. It is a mistake to proceed with voting before all the issues related to Run #1 have been addressed.

2.14.17.2. It was also a mistake to dictate to the ACC which action items are critical and which are continuous improvement.

2.14.17.2.1. The original plan was to solicit feedback from the ACC regarding what action items they deem critical.

2.14.17.2.2. In other words, "*What does the ACC want from the Surveillance Panel to be comfortable enough to start registration?*"

2.14.17.3. Lubrizol's primary goal is to complete the development of this test so that ACC registration and the BOI/VGRA matrix can begin.

2.14.17.3.1. Leaving issues unresolved will just prolong this effort.

Action Items	Person responsible	Completion Date

Follow-up Notes/Updates	Initials	Date Added

Attendees	Organization	Contact Information

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October 18, 2018

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Sequence IV Surveillance Panel
September 26, 2018
9:00AM – 11:00AM
Conference Call
and
October 4, 2018
9:00AM – 5:00PM
Intertek
San Antonio, TX

Motions and Action Items
As Recorded at the Meeting by Bill Buscher

1. Action Item – Sequence IV surveillance panel directs the Industry Statisticians Group to proceed with the Sequence IVB FEWMEOT statistical analysis and LTMS development both with and without the application of an engine hour correction factor, with a completion date set at 10/18/18. A Sequence IV surveillance panel face-to-face meeting will be scheduled for 10/18/18 and a WEBEX conference call will be scheduled for 10/25/18 to resolve any follow-up FEWMEOT action items.
Completed. FEWMEOT analysis results and LTMS sent to Bill Buscher, Seq. IV surveillance panel chair, and distributed to ACC PAPTG and Seq. IV surveillance panel members on 10/16/18.

2. Action Item – Sequence IV surveillance panel chair to provide a surveillance panel response to the ACC, addressing their list of requested surveillance panel actions, by 10/12/18.
Completed. Response sent to Doug Anderson, ACC PAPTG manager, on 10/16/18.

3. Action Item – Sequence IV surveillance panel chair to request a reply from ACC PAPTG, by 10/18/18, on exactly what the ACC needs from the Sequence IV surveillance panel prior to the start of Sequence IVB ACC registration.
Completed. Request sent to Doug Anderson, ACC PAPTG manager, on 10/16/18.

4. Motion – Sequence IV surveillance panel approves the addition of the "IVB FEWMEOT measurement procedure R.1" to the Sequence IVB ASTM draft procedure. The Sequence IVB test report forms and data dictionary will be updated accordingly. Effective for all Sequence IVB candidate and reference oil tests started on or after 10/9/18.
   Teri Kowalski / Bill Buscher / Passed 17 – 0 – 1

5. Motion – Sequence IV surveillance panel approves establishing an oil consumption limit of 1,000 grams maximum for the Sequence IVB test. Any candidate or reference oil test exceeding oil consumption of 1,000 grams will be reported as Invalid "I" and "has not" on Form 1 and with "No" checked for declaration No. 1, with "No" checked for part 1 of declaration No. 2 and with either "Yes" or "No" checked for part 2 of declaration No. 2, as per the test engineer's discretion, on Form 14 of the Sequence IVB test report. The Sequence IVB ASTM draft procedure will be updated accordingly. Effective for all Sequence IVB candidate and reference oil tests started on or after 9/26/18.
   Chris Mileti / Teri Kowalski / Passed Unanimously 18 – 0 – 0

6. Motion – Sequence IV surveillance panel approves the definition of a camshaft lobe failure, as any camshaft lobe experiencing heel to toe wear greater than 20 µm. The Sequence IVB ASTM draft procedure will be updated accordingly. Effective for all Sequence IVB candidate and reference oil tests started on or after 9/26/18.
   Bill Buscher / Teri Kowalski / Passed 17 – 0 – 1

7. Motion – Sequence IV surveillance panel approves reporting any Sequence IVB candidate or reference oil test experiencing one or more camshaft lobe failures as non-interpretable. Any candidate or reference oil test experiencing one or more camshaft lobe failures will be reported as "N" and "has" if conducted full duration (200 hours), or "has not" if terminated early, on Form 1 and with "No" checked for declaration No. 1, with "Yes" or "No" checked for part 1 of declaration No. 2, depending on whether or not the test was conducted full duration, and with either "Yes" or "No" checked for part 2 of declaration No. 2, as per the test engineer's discretion, on Form 14 of the Sequence IVB test report. The Sequence IVB ASTM draft procedure will be updated accordingly. Effective for all Sequence IVB candidate and reference oil tests started on or after 9/26/18.
   Bill Buscher / Teri Kowalski / Passed 6 – 1 – 11

8. Motion – Sequence IV surveillance panel approves the addition of Section 4 (engine reconditioning after a lobe failure) to the Sequence IVB engine assembly manual (EAM). Effective for all Sequence IVB candidate and reference oil tests started on or after 10/4/18.
   Bill Buscher / Teri Kowalski / Passed Unanimously 18 – 0 – 0

9. Motion – Sequence IV surveillance panel approves the addition of the "test stand maintenance after a camshaft lobe failure procedure" to the Sequence IVB ASTM draft procedure. Effective for all Sequence IVB candidate and reference oil tests started on or after 10/4/18.
   Khaled Rais / Bill Buscher / Passed Unanimously 18 – 0 – 0

10. Motion – Sequence IV surveillance panel approves the addition of the "engine health checklist" to the Sequence IVB ASTM draft procedure. Effective for all Sequence IVB candidate and reference oil tests started on or after 10/4/18.
    Chris Mileti / Robert Stockwell / Passed Unanimously 18 – 0 – 0

11. Motion – Sequence IV surveillance panel approves the addition of the "extended downtime procedure R.1" to the Sequence IVB ASTM draft procedure. Effective for all Sequence IVB candidate and reference oil tests started on or after 10/4/18.
    Bill Buscher / Khaled Rais / Passed Unanimously 18 – 0 – 0

12. Motion – Sequence IV surveillance panel approves revising ANNEX A.5 of the Sequence IVB ASTM draft procedure to eliminate PDI pre-test lifter screening and replace it with Keyence pre-test lifter screening, and revising the intake lifter profile screening criteria, as per the Lubrizol, SwRI and Afton proposals supplied by the Sequence IVB metrology sub-group. Effective for all Sequence IVB candidate and reference oil tests started on or after 10/4/18.
    Chris Mileti / Ben Maddock / Passed Unanimously 18 – 0 – 0

Sequence IV Surveillance Panel
October 18, 2018
9:00AM – 5:00PM
Intertek
San Antonio, TX

Motions and Action Items
As Recorded at the Meeting by Bill Buscher

1. Motion – Sequence IV surveillance panel approves using Fe at EOT without detergent metal ratio adjustment for the Sequence IVB FEWMEOT pass parameter and for LTMS charting. The detergent metal ratio adjustment will continue to be performed on Fe at EOT and reported as a rate and report parameter. Effective for all Sequence IVB candidate and reference oil tests started on or after 11/1/18.
   Teri Kowalski / Robert Stockwell / Passed 18 – 0 – 1

2. Motion – Sequence IV surveillance panel approves modifying the current Sequence IVB break-in/aging procedure, for new engine assemblies only, to add start of test flushing procedures and 50 hours of runtime on test conditions, using ASTM REO 1012, at the completion of the 50 hour aging portion of the break-in/aging cycle. Effective for all Sequence IVB new engine assembly break-in/agings started on or after 10/19/18.
   Robert Stockwell / Jeff Hsu / Passed 19 – 0 – 1

3. Action Item – Sequence IV surveillance panel chair to inform the BOI/VGRA task force of the modification the surveillance panel approved for new engine assembly break-in/aging, to allow them to decide which break-in/aging procedure, modified or unmodified, should be used for the BOI/VGRA matrix engines. Sequence IV surveillance panel chair to also inform the BOI/VGRA task force that one of the four BOI/VGRA matrix engines has already been broken in, aged and referenced, using the old break-in/aging procedure.

4. Motion – Sequence IV surveillance panel requires that the next new engine assembly that is introduced at each lab will be introduced using the new break-in/aging procedure, followed by a calibration test, conducted on ASTM REO 1012, and the next calibration test on each

IVB EOT Fe LTMS Suggestion Summary – **Items in BOLD need particular attention from the SP**

1. **Select the parameter to be charted and the accompanying Reference Oil targets from presented n=44 or other model.**
    a. Unadjusted EOT Fe = FEWMEOT
        i. IND, LTMSLAB, LTMSLAP(LTMSAPP) w LN from N=44 Model Targets

IND	Mean ln(FEWMEOT)	Std dev ln(FEWMEOT)
300	5.2645	0.3842
1011	5.0266	0.3508
1012	4.8344	0.3747

        ii. Severity adjustment standard deviation (SA s) is RMSE from Oil only model ln(FEWMEOT) = 0.3688
2. All stands will be charted separately as already determined for AVLI.
    a. Severity adjustments will be calculated on a stand basis
3. Utilize limits on Z_i (EWMA of severity), e_i (prediction error), and the excessive influence calculation to determine acceptance and calculate severity adjustments.
    a. Z_i Lambda = **0.2**
    b. Z_0 = Average of first two tests in a stand. This was already determined for AVLI and should remain consistent.
    c. Z_i Limit = **+1.800/-1.800**; a stand that exceeds these limits requires additional references until it is within the limits. Do not update severity adjustments until after an acceptable reference is conducted.
    d. e_i Limit 1 = +/-1.351; this limit applies to previously calibrated stands that have not been calibrated for two reference periods and are attempting to calibrate again. The stand can calibrate with one test if the Level 1 limits are not exceeded. References after the first attempt will be judged against the level 3 ei limits.
    e. e_i Limit 2 = +/-1.734; this limit applies in situations pre-determined by the SP to have potential impact to severity. Some situations that warrant consideration include hardware changes or engine build changes in a currently calibrated stand. The stand can calibrate with one test if the Level 2 limits are not exceeded. References after the first attempt will be judged against the level 3 ei limits.
    f. e_i Limit 3 = +/-2.066; this limit applies to all other situations when determining an acceptable reference. If the limit is exceeded do not update control charts until after an additional reference is conducted and apply excessive influence calculations.
    g. The excessive influence calculation minimizes the impact of a failing reference test if the following reference test does not agree with the initial failing results and returns to historical severity performance (LTMS 1.A.5).
4. A minimum of two references will be required for each new stand. This was already determined for AVLI and should remain consistent.
5. The reference calibration period will expire after fifteen full length non-reference tests or 6 months, whichever comes first. This was already determined for AVLI and should remain consistent.
6. The TMC will plot industry Zi charts to identify potential shifts in industry wide performance.
    a. Lambda = 0.2

Sequence IVB Precision Matrix FEWMEOT_Ca_Adj Analysis

Statistics Group

Oct. 18, 2018

Statistics Group

- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Kevin O'Malley, Lubrizol
- Martin Chadwick, Intertek
- Min Chen, ExxonMobil
- Richard Grundza, TMC
- Lisa Dingwell, Afton
- Todd Dvorak, Afton
- Travis Kostan, SwRI

Executive Summary without EngHr Adjustment

Analysis Highlights:

- This analysis includes the results of 44 precision matrix and post-PM tests
- Data supports the use of Ln(FEWMEOT_Ca_Adj) transformation
  - Statistically significant oil difference: 1012 < 300
  - Marginal oil difference: 1012 < 1011
  - Marginal lab difference (F < B)
  - No statistically significant Stands within Lab differences
- Correlation between sqrt(AVLI) and Ln(FEWMEOT_Ca_Adj) is high (indicating parameter redundancy)
- Estimated within a stand test precision (r; ASTM repeatability)
  - Ln(FEWMEOT_Ca_Adj) = 0.7996
- Estimated test precision across labs and stands (R; ASTM reproducibility)
  - Ln(FEWMEOT_Ca_Adj) = 1.0081
- Oil means and standard deviations

Ref. Oil	Number of Tests	Target Mean Ln(FEWMEOT_Ca_Adj)	Target Mean FEWMEOT_Ca_Adj	Target Standard Deviation Ln(FEWMEOT_Ca_Adj)
300	12	5.3781	217	0.3921
1011	16	5.1677	176	0.3505
1012	16	4.9350	139	0.3548

Executive Summary with EngHr Adjustment

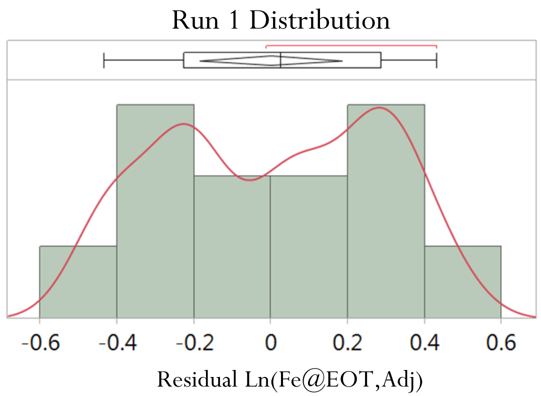
Analysis Highlights:

- This analysis includes the results of 44 precision matrix and post-PM tests
- Data supports the use of Ln(FEWMEOT_Ca_EngHr_Adj) transformation *(with Ca and EngHr Adjustments)*
  - Statistically significant oil difference: 1012 < 300 and 1012 < 1011
  - Statistically significant lab difference (F < B)
  - Statistically significant stand within lab differences:
    - B-2 is statistically different than B-3
- Correlation between sqrt(AVLI) and Ln(FEWMEOT_Ca_EngHr_Adj) is high (indicating parameter redundancy)
- Estimated within a stand test precision (r; ASTM repeatability)
  - Ln(FEWMEOT_Ca_Adj) = 0.6349
- Estimated test precision across labs and stands (R; ASTM reproducibility)
  - Ln(FEWMEOT_Ca_Adj) = 0.9052
- Oil means and standard deviations

Ref. Oil	Number of Tests	Target Mean Ln(FEWMEOT_Ca_EngHr_Adj)	Target Mean FEWMEOT_Ca_EngHr_Adj	Target Standard Deviation Ln(FEWMEOT_Ca_EngHr_Adj)
300	12	5.3062	202	0.3031
1011	16	5.1328	169	0.3226
1012	16	4.9072	135	0.3466

Caveats

- Run 1 exhibits bi-modal behavior
  - Break-in procedure improvement applied to the test in the future might impact LTMS targets based on no engine hour adjustment.
    - If this happens, targets maybe re-set for Fe
    - Need to check AVLI



- Severity adjustment might be biased by the run order
- Engine hour adjustment might "over-correct" future tests when break-in procedure improvement is implemented
- There are trade offs in test precision when comparing the two methods for determining the Fe parameter:
  - Ca Adjusted Fe data contains errors due to ICP measurements
    - This analysis includes ICP (Fe - Ca Adj) data from different labs
    - The inferences may differ if all ICP measurements were performed at the same lab
  - Unadjusted Fe data contains errors due to water and fuel dilution

Caveats

- To help clarify the differences between different modeling approaches (and their inherent error sources), the below summarizes the statistical significance for the contrasts, RMSE and repeatability
  - Overall, the Ln(Fe_Ca_EngHr_Adj) approach has advantages in terms of greater statistical significance between the contrasts and the lowest RMSE.

	Contrast *p*-values				
Model	300 vs. 1012	1011 vs. 1012	300 vs. 1011	RMSE	*r*
**Ln(Fe)	0.00	0.17	0.12	0.2869	0.7952
Ln(Fe_Ca_Adj)	0.00	0.08	0.18	0.2885	0.7996
**Ln(Fe_EngHr_Adj)	0.00	0.03	0.14	0.2323	0.6439
Ln(Fe_Ca_EngHr_Adj)	0.00	0.03	0.16	0.2291	0.6349

**Indicates it is not included in this analysis

- Additional analyses (engine life, break-in, hardware changes, etc.) could impact these conclusions.

Data Utilized

- Precision Matrix Data:
  - 4 Labs {A, B1, F and G}
  - 3 Reference Oils {300, 1012, and 1011}
  - 7 Stands {A-1, A-2, B-1, B-2, B-3, F-1 and G-1}
  - Number of tests = 28
- Post-Precision Matrix Data
  - 4 Labs {A, B, E, F}
  - 3 Reference Oils {300, 1012, and 1011}
  - 9 Stands {A-2, A-3, A-4, B-1, B-2, B-3, B-4, E-1, F-1}
  - Number of tests = 16
- Precision Matrix Data Table from Rich Grundza's 20180115 IVB Matrix update.

Run order	B-1	B-2	B-3	A-1	A-2	F-1	G-1	E-1
1	1012 127173-IVB	300 129759-IVB	1011 125879-IVB	300 129752-IVB	1012 125882-IVB	1012 125183-IVB	1012 130944-IVB	300
2	1011 129762-IVB	1012 129766-IVB	1012 129767-IVB	1011 109201-IVB 1011* 125881-IVB	300 130948-IVB	300 120739-IVB	1011 125184-IVB	1011
3	300 129760-IVB	1011 129763-IVB	300 129761-IVB 300 130939-IVB	1012 129755-IVB	1011 125880-IVB	1012 130945-IVB	1011 130943-IVB	300
4	1012 129768-IVB	300 130938-IVB	1011 129764-IVB	300 131277-IVB	1012 129756-IVB		300# 130940-IVB	
Reported			Invalid					

* Laboratory is running additional test because of Lean AFR and lower fuel flow on original matrix test

Additional test donated by lab

- Post-Precision Matrix Data

B-1	B-2	B-3	B-4	A-2	A-3	A-4	E-1	F-1
133499-IVB	133497-IVB	133498-IVB	129769-IVB	131278-IVB	133504-IVB	129753-IVB	132588-IVB	109205-IVB*
			129765-IVB		129757-IVB	137586-IVB	132592-IVB	110237-IVB
							132590-IVB	119629-IVB*

* Non-chartable

Reference Oil Discrimination Comparison

The table below compares the numbers of standard deviations of separation between the highest and lowest reference oil across GF-6 test types. The median of other tests is approx. 3.55 and the mean (without PHOS) is 3.99.

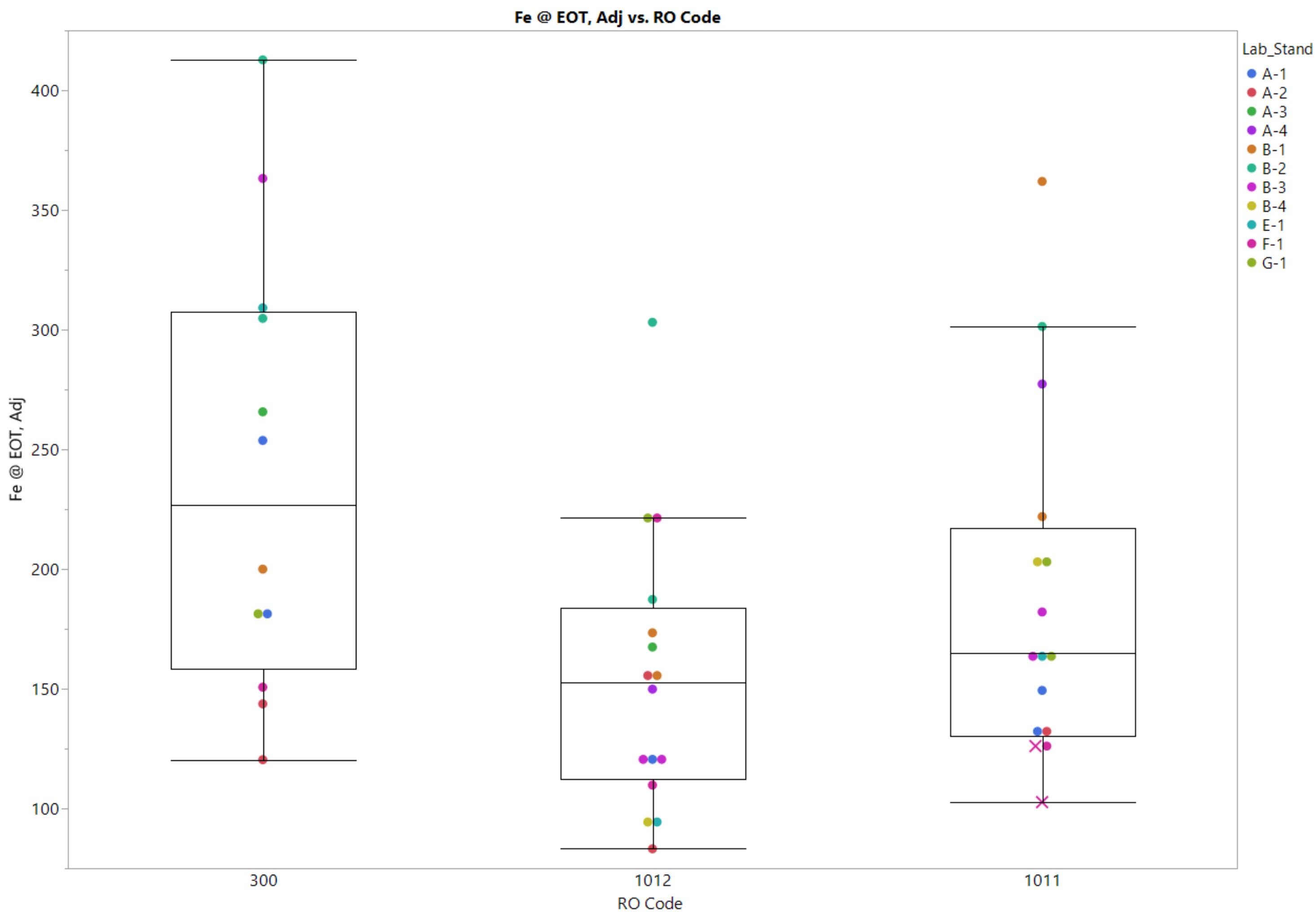
Test	Parameter	Oil 1	Oil 2	Range	Test s_r	SDs of Separation
IIIH	Ln(PVIS)	4.7191	3.3289	1.3902	0.4641	3
IIIH	WPD	4.63	3.66	0.97	0.47	2.1
IIIHA	Ln(MRV)	11.1107	9.7854	1.3253	0.4214	3.1
IIIHB	PHOS	94.15	78.92	15.23	1.53	10
VIE	FEI 1	2.56	1.3	1.26	0.29	4.3
VIE	FEI 2	1.82	1.41	0.41	0.12	3.4
VIF	FEI 1	2.23	1.45	0.78	0.21	3.7
VIF	FEI 2	2.25	1.41	0.84	0.19	4.4
IX (LSPI)	Sqrt(AvPIE + 0.5)	4.2644	3.3819	0.8825	0.2856	3.1*1
VH	AES	8.43	6.47	1.96	0.5	3.9
VH	Ln(10-RCS)	0.9155	-0.5294	1.4449	0.2194	6.6
VH	AEV50	9.26	8.77	0.49	0.25	2
VH	APV50	8.67	7.35	1.32	0.53	2.5
X (CW)	Ln(CHST)	-2.10574	-2.63174	0.526	0.14148	3.7*2
IVB (n=28)	Sqrt(AVLI)	1.3931	1.1543	0.2388	0.168	1.4
IVB (n=44)	Ln(FEWMEOT)	5.2645	4.8344	0.4301	0.2869	1.5
IVB (n=44)	Ln(FEWMEOT_Ca_Adj)	5.3781	4.935	0.4431	0.2885	1.5
IVB (n=44)	Ln(FEWMEOT_Ca_EngHr_Adj)	5.3062	4.9072	0.399	0.2291	1.7

*1: Oil 220 not used as a reference oil. Including this oil would yield approx. 12 SDs of separation between 220 and 222.
*2: 271 vs. 1011

Without Engine Hour Adjustment

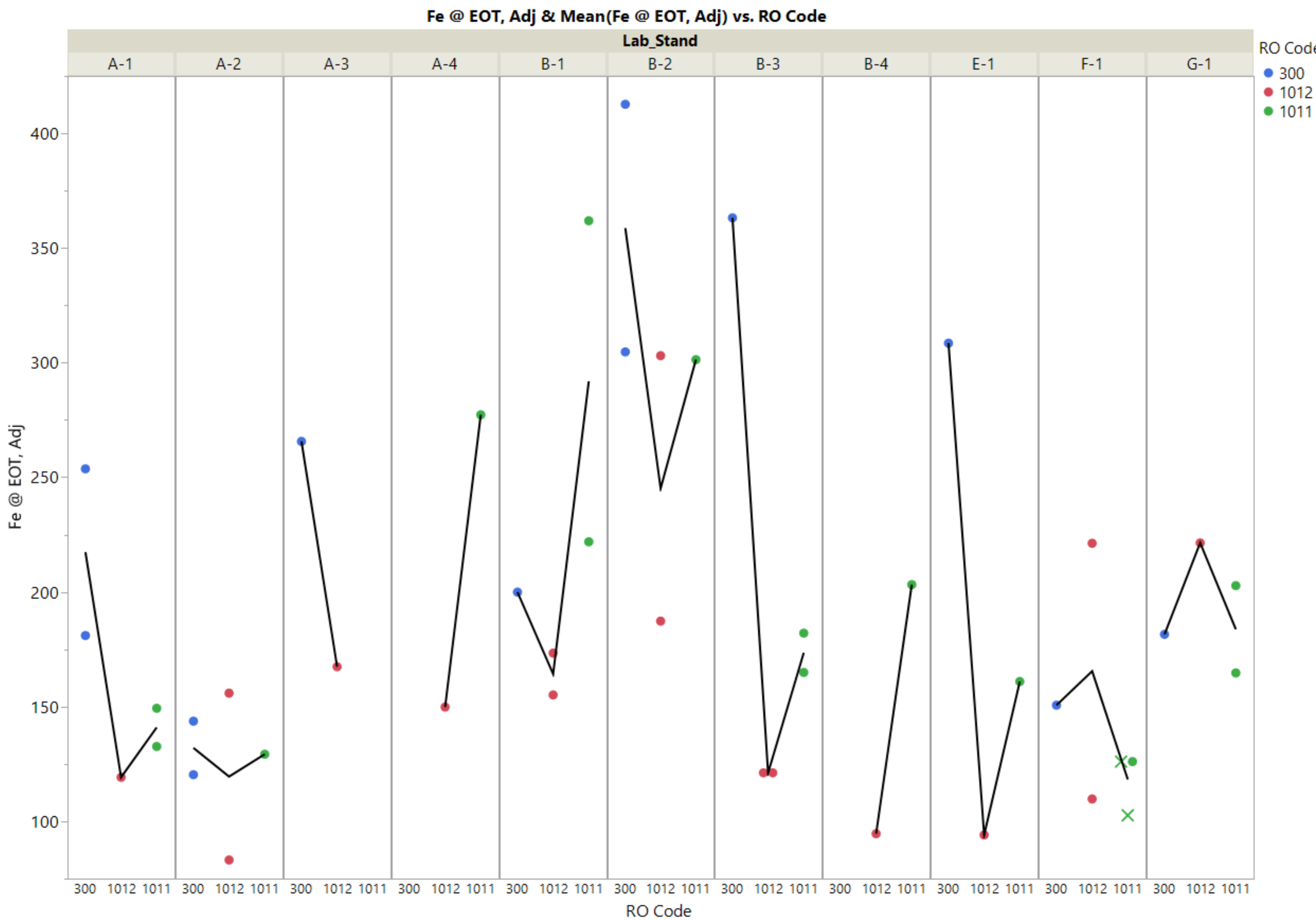
Calcium_Adj_Fe-Wear Metals at EOT by Oil

- There is considerable overlap among the oils.



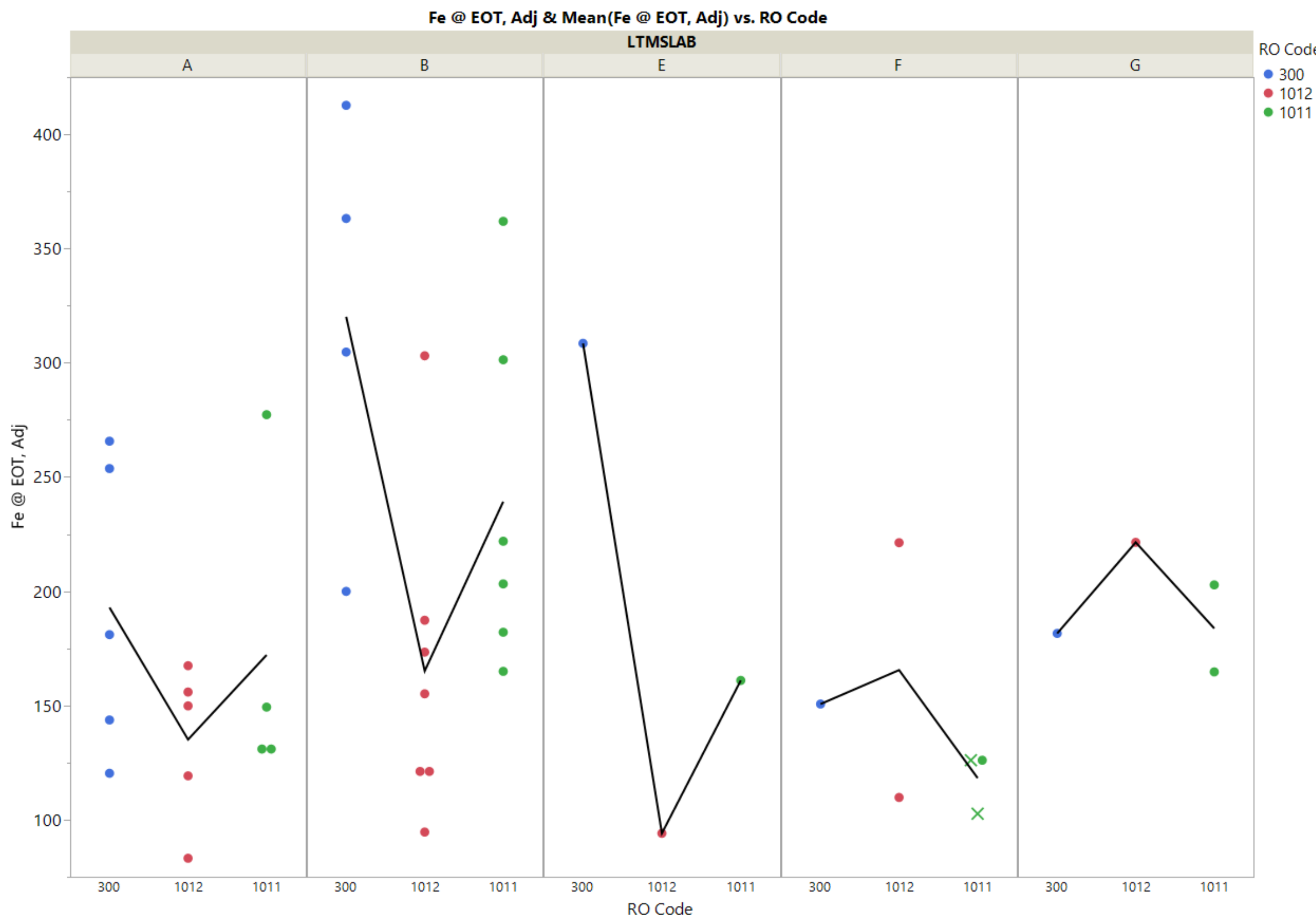
Calcium_Adj_Fe-Wear Metals at EOT by Stand

- It appears that oil discrimination is not consistent among the stands; Stands rank oils differently



Calcium_Adj_Fe-Wear Metals at EOT by Lab

- Below plot summarizes the FEWMEOT_Ca_Adj test result data by test Lab and reference oil



Ln(FEWMEOT_Ca_Adj) - ANOVA Full Model

Statistically significant differences:
- Oil
- Stands(Lab)

Marginally different:
- Lab

Summary of Fit

RSquare	0.614878
RSquare Adj	0.465799
Root Mean Square Error	0.288459
Mean of Response	5.170131
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	4.1183344	0.343195	4.1245
Error	31	2.5794677	0.083209	Prob > F
C. Total	43	6.6978021		0.0007*

Parameter Estimates

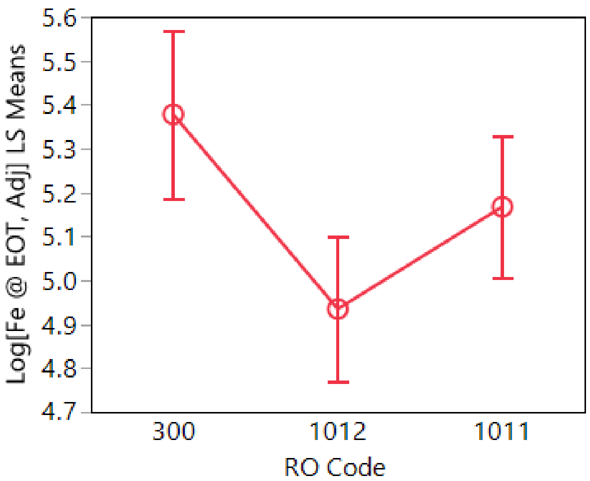
Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	5.1602737	0.055572	92.86	<.0001*	.
RO Code[300]	0.2178242	0.068237	3.19	0.0032*	1.5465006
RO Code[1012]	-0.22528	0.061527	-3.66	0.0009*	1.4558494
LTMSLAB[A]	-0.000742	0.086731	-0.01	0.9932	1.421776
LTMSLAB[B]	0.1716077	0.080653	2.13	0.0414*	1.3414426
LTMSLAB[E]	-0.041126	0.140463	-0.29	0.7716	1.6544119
LTMSLAB[F]	-0.222199	0.107054	-2.08	0.0463*	1.3648184
LTMSLAB[A]:LTMSAPP[1]	-0.122567	0.126258	-0.97	0.3392	1.3018682
LTMSLAB[A]:LTMSAPP[2]	-0.339924	0.125211	-2.71	0.0107*	1.2803682
LTMSLAB[A]:LTMSAPP[3]	0.1956923	0.169734	1.15	0.2578	1.3849423
LTMSLAB[B]:LTMSAPP[1]	0.0700732	0.118525	0.59	0.5587	1.1472908
LTMSLAB[B]:LTMSAPP[2]	0.3490788	0.120549	2.90	0.0069*	1.1867915
LTMSLAB[B]:LTMSAPP[3]	-0.128388	0.118525	-1.08	0.2871	1.1472908

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RO Code	2	2	1.2982579	7.8012	0.0018*
LTMSLAB	4	4	0.7114925	2.1377	0.0997
LTMSAPP[LTMSLAB]	6	6	1.5655723	3.1358	0.0161*

Ln(FEWMEOT_Ca_Adj) Oil Differences

- Model is Ln(FEWMEOT_Ca_Adj) ~ Oil, Lab, Stand(Lab)
- Oils significantly differ
  - Oil 300 is significantly different than oil 1012
  - Oil 1011 is marginally different than oil 1012
  - Oil 1011 is not significantly different than oil 300
- Plot shows Ln(FEWMEOT_Ca_Adj) LSMeans by Oil, with 95% Confidence Interval



LSMeans by Oil

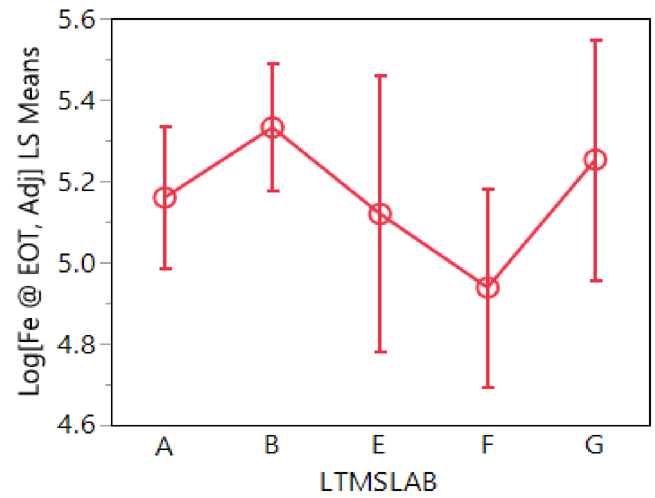
Oil	Ln(FEWMEOT_Ca_Adj) LSMean	FEWMEOT_Ca_Adj LSMean
300	5.3781	217
1011	5.1677	176
1012	4.9350	139

LSMeans Differences Between Oils

Oil1	Oil2	Ln(FEWMEOT_Ca_Adj) Difference	p-Value
300	1012	0.4431	0.00
1011	1012	0.2327	0.08
300	1011	0.2104	0.18

Ln(FEWMEOT_Ca_Adj) Lab Differences

- Model is Ln(FEWMEOT_Ca_Adj) ~ Oil, Lab, Stand(Lab)
- Plot shows Ln(FEWMEOT_Ca_Adj) LSMeans by Lab, with 95% confidence intervals
- Lab B is marginally different than Lab F.



LSMeans by Lab

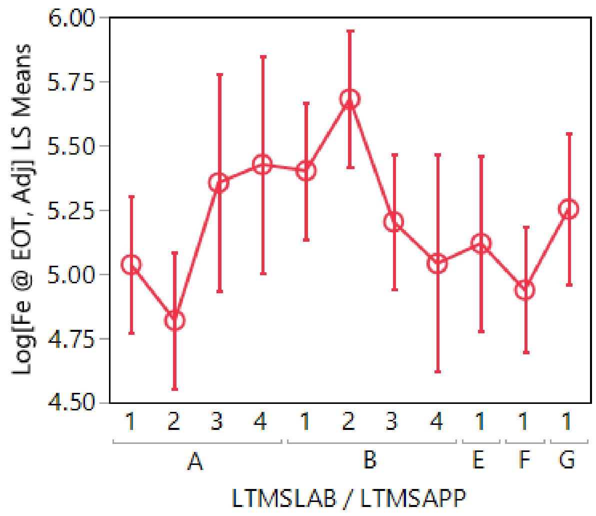
Lab	Ln(FEWMEOT_Ca_Adj) LSMean	FEWMEOT_Ca_Adj LSMean
A	5.1595	174
B	5.3319	207
E	5.1191	167
F	4.9381	140
G	5.2527	191

LSMeans Differences Between Labs

Lab1	Lab2	Ln(FEWMEOT_Ca_Adj) Difference	p-Value
B	F	0.3938	0.06
G	F	0.3147	0.46
A	F	0.2215	0.57
B	E	0.2127	0.77
E	F	0.1811	0.90
B	A	0.1723	0.57
G	E	0.1336	0.97
G	A	0.0932	0.98
B	G	0.0791	0.99
A	E	0.0404	1

Ln(FEWMEOT_Ca_Adj) Stand within Lab Differences

- Model is Ln(FEWMEOT_Ca_Adj) ~ Oil, Lab, Stand(Lab)
- Plot shows Ln(FEWMEOT_Ca_Adj) LSMeans by Stand, with 95% confidence intervals
- No statistically significant stands within lab differences (with Bonferroni adjustment for multiple contrasts within Lab A and G)



LSMeans by Stand

Lab[Stand]	Ln(FEWMEOT_Ca_Adj) LSMean	FEWMEOT_Ca_Adj LSMean
[A]1	5.0370	154
[A]2	4.8196	124
[A]3	5.3552	212
[A]4	5.4263	227
[B]1	5.4020	222
[B]2	5.6810	293
[B]3	5.2035	182
[B]4	5.0411	155
[E]1	5.1191	167
[F]1	4.9381	140
[G]1	5.2527	191

Ln(FEWMEOT_Ca_Adj) Precision

Repeatability Model: Ln(FEWMEOT_Ca_Adj) ~ Oil, Lab, Stand(Lab)
Reproducibility Model: Ln(FEWMEOT_Ca_Adj) ~ Oil

Model RMSE	Repeatability	Reproducibility
• $s_r = 0.2885$	• $s_r = 0.2885$ • r = 0.7996	• $s_R = 0.3637$ • R = 1.0081

Based upon the Ln(FEWMEOT_Ca_Adj) pooled standard deviation (s_r) and ASTM's repeatability (r), there is no significant difference between an FEWMEOT_Ca_Adj $result^1$ of 200 and 445.

Note 1: An FEWMEOT_Ca_Adj result of 200 was arbitrarily selected for comparison

Reference Oil Targets

Model: Ln(FEWMEOT_Ca_Adj) ~ Oil, Lab, Stand(Lab)

Iron at EOT (FEWMEOT_Ca_Adj)

Unit of Measure: Ln(FEWMEOT_Ca_Adj)

Ref. Oil (n)	Target Mean Ln(FEWMEOT_Ca_Adj)	Target Mean FEWMEOT_Ca_Adj	St. Dev
300 (12)	5.3781	217	0.3921
1011 (16)	5.1677	176	0.3505
1012 (16)	4.9350	139	0.3548

Target Means are the Oil LSMeans from the Model and Standard Deviations are calculated straight from Ln(FEWMEOT_Ca_Adj).

Correlation

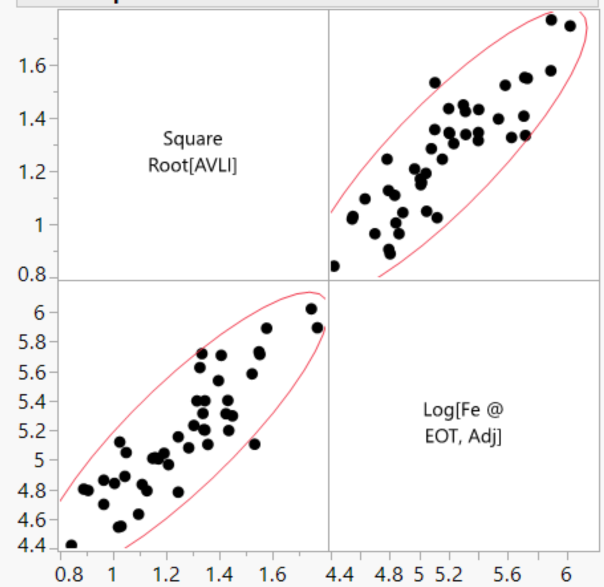
Appendix K Section A.3 Parameter Redundancy: Correlation between Sqrt(AVLI) and Ln(FEWMEOT_Ca_Adj) is statistically significant. These two parameters are closely related in repeat tests within oils.

Correlations

	Square Root[AVLI]	Log[Fe @ EOT, Adj]
Square Root[AVLI]	1.0000	0.8701
Log[Fe @ EOT, Adj]	0.8701	1.0000

The correlations are estimated by Row-wise method.

Scatterplot Matrix

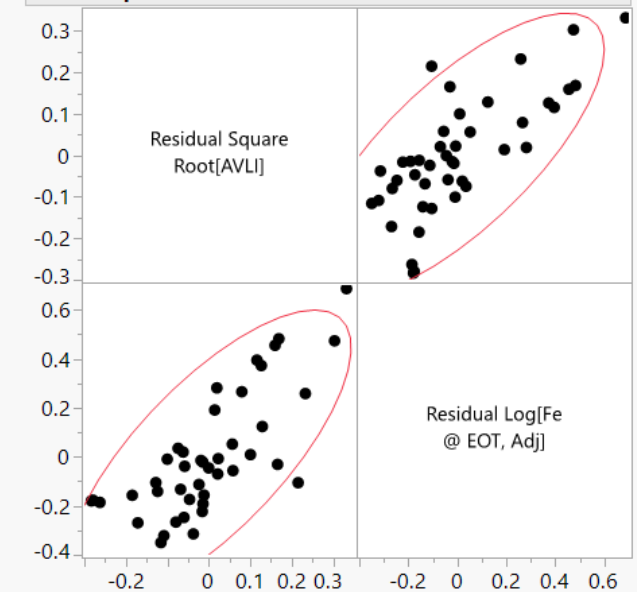


Correlations

	Residual Square Root[AVLI]	Residual Log[Fe @ EOT, Adj]
Residual Square Root[AVLI]	1.0000	0.7451
Residual Log[Fe @ EOT, Adj]	0.7451	1.0000

The correlations are estimated by Row-wise method.

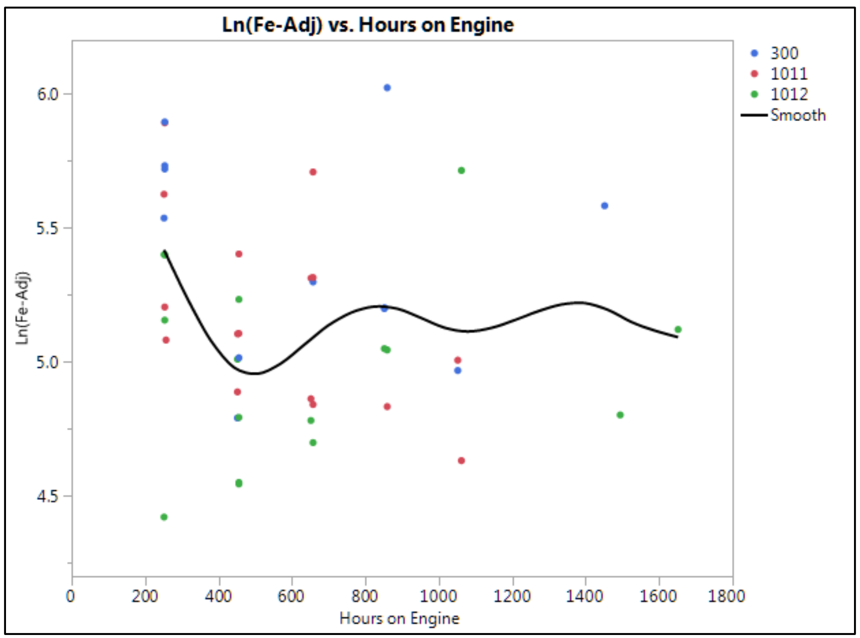
Scatterplot Matrix



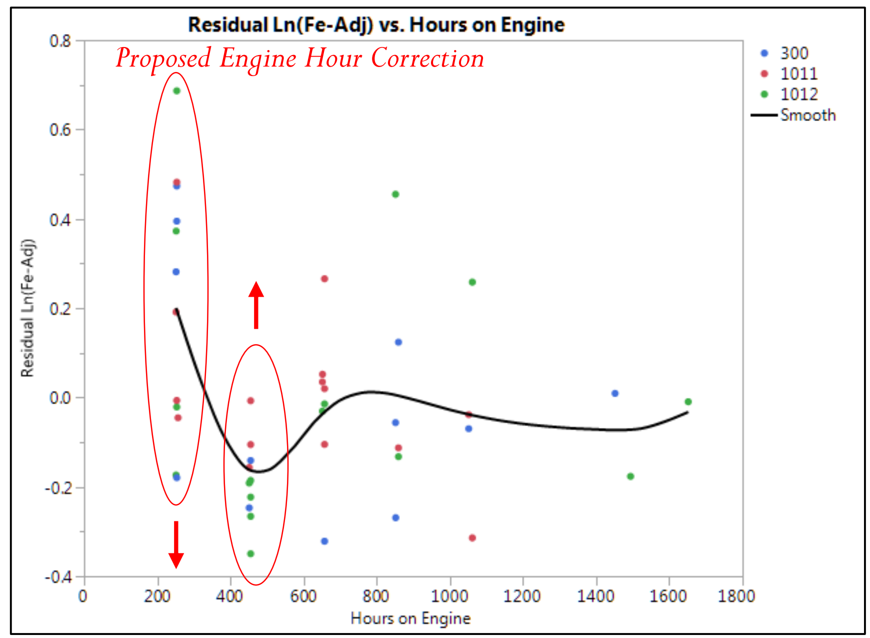
With Engine Hour Adjustment

Run on Engine vs. Fe_Adj

- Raw data plot of Ln(Fe_Adj) or Ln(Fe_Adj) residuals vs. Oil, Lab, Stand[Lab] model suggests that there is an engine age effect on EOT Fe_Adj.
- Indicator variable approach selected to engine hour correct the EOT Fe_Adj results for the 1st and 2nd run.
  - Correction will adjust down 1st run and increase the 2nd run



Raw Data Plot



Model Fit Residuals Plot

Ln(FEWMEOT_Ca_Adj) - ANOVA Full Model

<u>Statistically significant differences:</u>

- Oil
- Lab
- Stands(Lab)
- Hrs<350 vs Hrs≥550

<u>Marginally different:</u>

- 350 ≤ Hrs < 550 vs Hrs≥550

Summary of Fit

RSquare	0.757162
RSquare Adj	0.63993
Root Mean Square Error	0.236824
Mean of Response	5.170131
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	14	5.0713238	0.362237	6.4587
Error	29	1.6264783	0.056085	**Prob > F**
C. Total	43	6.6978021		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5.115387	0.06587	77.66	<.0001*
RO Code[300]	0.1907999	0.05643	3.38	0.0021*
RO Code[1012]	-0.208175	0.050788	-4.10	0.0003*
LTMSLAB[A]	0.0188175	0.072108	0.26	0.7960
LTMSLAB[B]	0.1950982	0.066468	2.94	0.0065*
LTMSLAB[E]	-0.119866	0.121211	-0.99	0.3309
LTMSLAB[F]	-0.201648	0.089888	-2.24	0.0327*
LTMSLAB[A]:LTMSAPP[1]	-0.115633	0.103712	-1.11	0.2740
LTMSLAB[A]:LTMSAPP[2]	-0.334426	0.102907	-3.25	0.0029*
LTMSLAB[A]:LTMSAPP[3]	0.2259795	0.144729	1.56	0.1293
LTMSLAB[B]:LTMSAPP[1]	0.0118884	0.098327	0.12	0.9046
LTMSLAB[B]:LTMSAPP[2]	0.350645	0.100234	3.50	0.0015*
LTMSLAB[B]:LTMSAPP[3]	-0.156025	0.099155	-1.57	0.1264
Hrs<350	0.2618114	0.096878	2.70	0.0114*
350<=Hrs<550	-0.152742	0.096081	-1.59	0.1227

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RO Code	2	2	1.0568213	9.4216	0.0007*
LTMSLAB	4	4	0.7873579	3.5096	0.0187*
LTMSAPP[LTMSLAB]	6	6	1.4740207	4.3803	0.0029*
Hrs<350	1	1	0.4096125	7.3034	0.0114*
350<=Hrs<550	1	1	0.1417408	2.5272	0.1227

Ln(FEWMEOT_Ca_Adj) - ANOVA Full Model

Engine Hour Correction:

- Rsquare Adj improved with engine hour factor in model (0.47 vs. 0.64)
- 1st Run results are reduced by -0.262 in transformed units
- 2nd Run Results are increased by 0.153 in transformed units
- No engine hour adjustment necessary for engine hours ≥ 550 (3rd or higher run)

Summary of Fit

RSquare	0.757162
RSquare Adj	0.63993
Root Mean Square Error	0.236824
Mean of Response	5.170131
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	14	5.0713238	0.362237	6.4587
Error	29	1.6264783	0.056085	Prob > F
C. Total	43	6.6978021		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5.115387	0.06587	77.66	<.0001*
RO Code[300]	0.1907999	0.05643	3.38	0.0021*
RO Code[1012]	-0.208175	0.050788	-4.10	0.0003*
LTMSLAB[A]	0.0188175	0.072108	0.26	0.7960
LTMSLAB[B]	0.1950982	0.066468	2.94	0.0065*
LTMSLAB[E]	-0.119866	0.121211	-0.99	0.3309
LTMSLAB[F]	-0.201648	0.089888	-2.24	0.0327*
LTMSLAB[A]:LTMSAPP[1]	-0.115633	0.103712	-1.11	0.2740
LTMSLAB[A]:LTMSAPP[2]	-0.334426	0.102907	-3.25	0.0029*
LTMSLAB[A]:LTMSAPP[3]	0.2259795	0.144729	1.56	0.1293
LTMSLAB[B]:LTMSAPP[1]	0.0118884	0.098327	0.12	0.9046
LTMSLAB[B]:LTMSAPP[2]	0.350645	0.100234	3.50	0.0015*
LTMSLAB[B]:LTMSAPP[3]	-0.156025	0.099155	-1.57	0.1264
Hrs<350	0.2618114	0.096878	2.70	0.0114*
350<=Hrs<550	-0.152742	0.096081	-1.59	0.1227

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RO Code	2	2	1.0568213	9.4215	0.0007*
LTMSLAB	4	4	0.7873579	3.5096	0.0187*
LTMSAPP[LTMSLAB]	6	6	1.4740207	4.3803	0.0029*
Hrs<350	1	1	0.4096125	7.3034	0.0114*
350<=Hrs<550	1	1	0.1417408	2.5272	0.1227

Ln(FEWMEOT_Ca_EngHr_Adj) - ANOVA Full Model

Statistically significant differences:

- Oil
- Lab
- Stands(Lab)

Summary of Fit

RSquare	0.69898
RSquare Adj	0.582457
Root Mean Square Error	0.229057
Mean of Response	5.136914
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	3.7767532	0.314729	5.9986
Error	31	1.6264783	0.052467	**Prob > F**
C. Total	43	5.4032315		<.0001*

Parameter Estimates

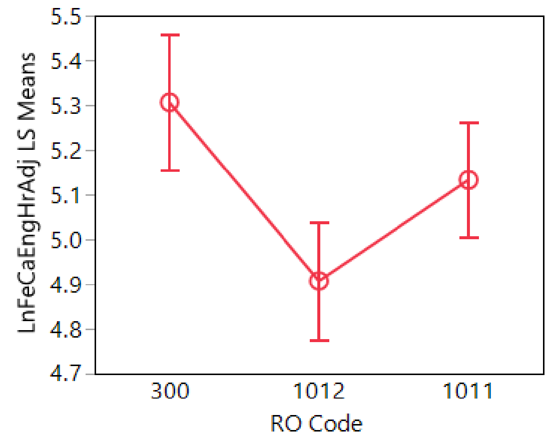
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5.115387	0.044128	115.92	<.0001*
RO Code[300]	0.1907999	0.054185	3.52	0.0014*
RO Code[1012]	-0.208175	0.048857	-4.26	0.0002*
LTMSLAB[A]	0.0188175	0.06887	0.27	0.7865
LTMSLAB[B]	0.1950982	0.064045	3.05	0.0047*
LTMSLAB[E]	-0.119866	0.111538	-1.07	0.2908
LTMSLAB[F]	-0.201648	0.085009	-2.37	0.0241*
LTMSLAB[A]:LTMSAPP[1]	-0.115633	0.100258	-1.15	0.2576
LTMSLAB[A]:LTMSAPP[2]	-0.334426	0.099426	-3.36	0.0021*
LTMSLAB[A]:LTMSAPP[3]	0.2259795	0.134781	1.68	0.1037
LTMSLAB[B]:LTMSAPP[1]	0.0118883	0.094118	0.13	0.9003
LTMSLAB[B]:LTMSAPP[2]	0.350645	0.095724	3.66	0.0009*
LTMSLAB[B]:LTMSAPP[3]	-0.156025	0.094118	-1.66	0.1075

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RO Code	2	2	1.0700807	10.1976	0.0004*
LTMSLAB	4	4	0.7947496	3.7869	0.0128*
LTMSAPP[LTMSLAB]	6	6	1.4869799	4.7235	0.0016*

Ln(FEWMEOT_Ca_EngHr_Adj) Oil Differences

- Model is Ln(FEWMEOT_Ca_EngHr_Adj) ~ Oil, Lab, Stand(Lab)
- Oils significantly differ
  - Oil 1012 is significantly different than oil 300 and oil 1011
  - Oil 1011 is not significantly different than oil 300
- Plot shows Ln(FEWMEOT_Ca_EngHr_Adj) LSMeans by Oil, with 95% Confidence Interval



LSMeans by Oil

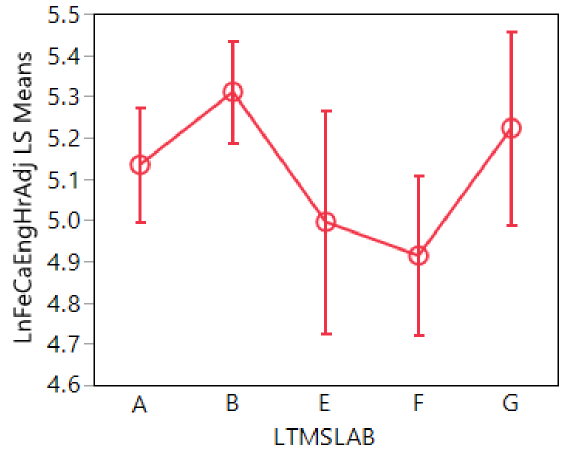
Oil	Ln(FEWMEOT_Ca_EngHr_Adj) LSMean	FEWMEOT_Ca_Eng_Hr_Adj LSMean
300	5.3062	202
1011	5.1328	169
1012	4.9072	135

LSMeans Differences Between Oils

Oil1	Oil2	Ln(FEWMEOT_Ca_EngHr_Adj) Difference	p-Value
300	1012	0.399	0.00
1011	1012	0.2256	0.03
300	1011	0.1734	0.16

Ln(FEWMEOT_Ca_EngHr_Adj) Lab Differences

- Model is Ln(FEWMEOT_Ca_EngHr_Adj) ~ Oil, Lab, and Stand(Lab)
- Plot shows Ln(FEWMEOT_Ca_EngHr_Adj) LSMeans by Lab, with 95% confidence intervals
- Lab B is statistically different than Lab F.



LSMeans by Lab

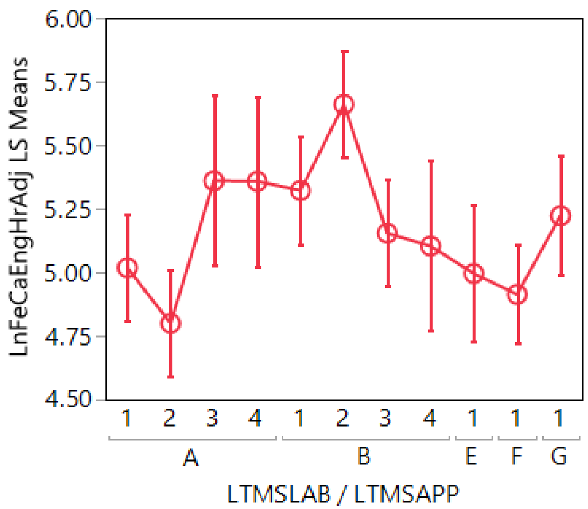
Lab	Ln(FEWMEOT_Ca_EngHr_Adj) LSMean	FEWMEOT_Ca_Eng_Hr_Adj LSMean
A	5.1342	170
B	5.3105	202
E	4.9955	148
F	4.9137	136
G	5.223	185

LSMeans Differences Between Labs

Lab1	Lab2	Ln(FEWMEOT_Ca_EngHr_Adj) Difference	p-Value
B	F	0.3967	0.01
B	E	0.315	0.22
G	F	0.3092	0.25
G	E	0.2275	0.70
A	F	0.2205	0.35
B	A	0.1763	0.32
A	E	0.1387	0.88
G	A	0.0888	0.96
B	G	0.0875	0.96
E	F	0.0818	0.99

Ln(FEWMEOT_Ca_Enghr_Adj) Stand within Lab Differences

- Model is Ln(FEWMEOT_Ca_EngHr_Adj) ~ Oil, Lab, and Stand(Lab)
- Plot shows Ln(FEWMEOT_Ca_EngHr_Adj) LSMeans by Stand, with 95% confidence intervals
- B-2 is statistically different than B-3 (with Bonferroni adjustment for multiple contrasts within Lab A and B)



<u>LSMeans by Stand</u>

Lab[Stand]	Ln(FEWMEOT_Ca_EngHr_Adj) LSMean	FEWMEOT_Ca_Eng_Hr_Adj LSMean
[A]1	5.0186	151
[A]2	4.7998	121
[A]3	5.3602	213
[A]4	5.3583	212
[B]1	5.3224	205
[B]2	5.6611	287
[B]3	5.1545	173
[B]4	5.104	165
[E]1	4.9955	148
[F]1	4.9137	136
[G]1	5.223	185

Ln(FEWMEOT_Ca_EngHr_Adj) Precision

Repeatability Model: Ln(FEWMEOT_Ca_EngHr_Adj) ~ Oil, Lab, Stand(Lab)
Reproducibility Model: Ln(FEWMEOT_Ca_EngHr_Adj) ~ Oil

Model RMSE	Repeatability	Reproducibility
• $s_r = 0.2291$	• $s_r = 0.2291$ • r = 0.6349	• $s_R = 0.3266$ • R = 0.9052

Based upon the Ln(FEWMEOT_Ca_EngHr_Adj) pooled standard deviation (s_r) and ASTM's repeatability (r), there is no significant difference between an FEWMEOT_Ca_EngHr_Adj *result*[1] of 200 and 377.

Note 1: An FEWMEOT_Ca_EngHr_Adj result of 200 was arbitrarily selected for comparison

Reference Oil Targets

Model: Ln(FEWMEOT_Ca_EngHr_Adj) ~ Oil, Lab, Stand(Lab)

Iron at EOT (FEWMEOT_Ca_EngHr_Adj)

Unit of Measure: Ln(FEWMEOT_Ca_Adj)

Ref. Oil (n)	Target Mean Ln(FEWMEOT_Ca_EngHr_Adj)	Target Mean FEWMEOT_Ca_EngHr_Adj	St. Dev
300 (12)	5.3062	202	0.3031
1011 (16)	5.1328	169	0.3226
1012 (16)	4.9072	135	0.3466

Target Means are the Oil LSMeans from the Model and Standard Deviations are calculated straight from Ln(FEWMEOT_Ca_EngHr_Adj)

Correlation

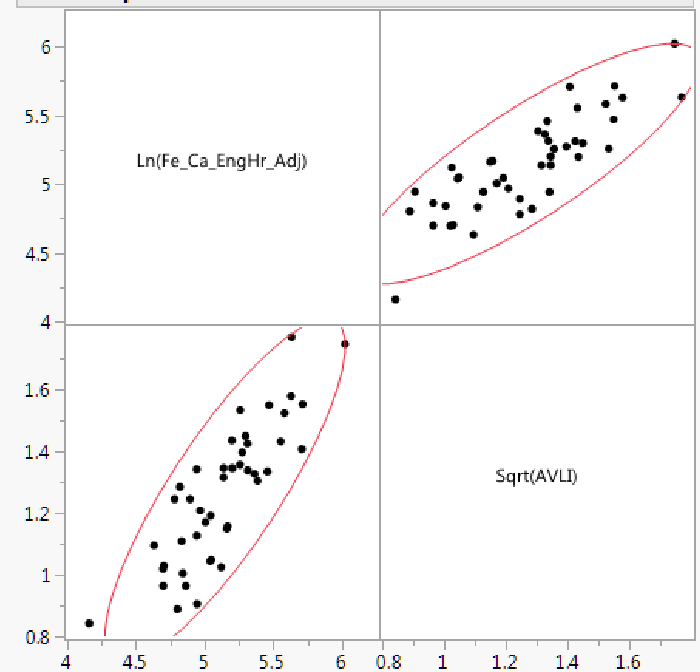
Appendix K Section A.3 Parameter Redundancy: Correlation between Sqrt(AVLI) and Ln(FEWMEOT_Ca_EngHr_Adj) is statistically significant. These two parameters are closely related in repeat tests within oils.

Correlations

	Ln(Fe_Ca_EngHr_Adj)	Sqrt(AVLI)
Ln(Fe_Ca_EngHr_Adj)	1.0000	0.8446
Sqrt(AVLI)	0.8446	1.0000

There are 6 missing values. The correlations are estimated by REML method.

Scatterplot Matrix

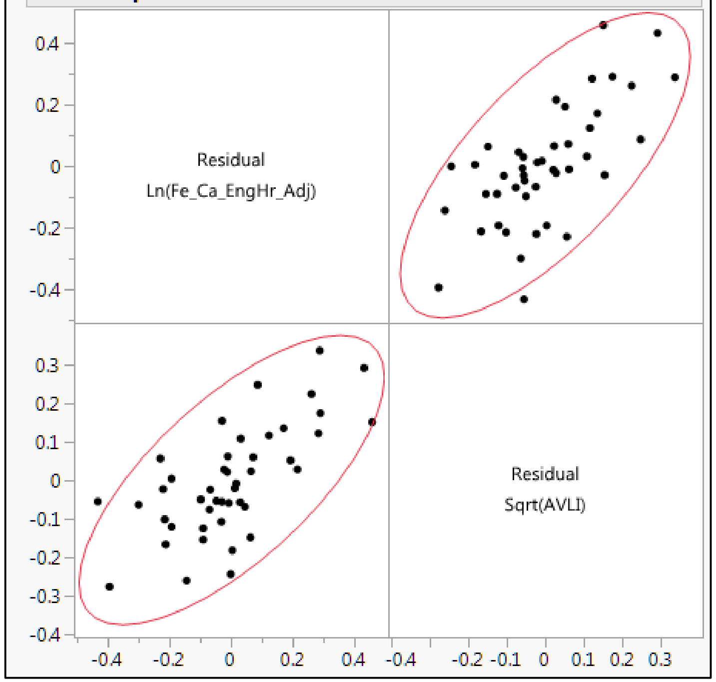


Correlations

	Residual Ln(Fe_Ca_EngHr_Adj)	Residual Sqrt(AVLI)
Residual Ln(Fe_Ca_EngHr_Adj)	1.0000	0.7117
Residual Sqrt(AVLI)	0.7117	1.0000

There are 6 missing values. The correlations are estimated by REML method.

Scatterplot Matrix



Appendix A

FEWMEOT Models

Ln(FEWMEOT_Ca_Adj) Model with Engine Run

Summary of Fit

RSquare	0.757162
RSquare Adj	0.63993
Root Mean Square Error	0.236824
Mean of Response	5.170131
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	14	5.0713238	0.362237	6.4587
Error	29	1.6264783	0.056085	**Prob > F**
C. Total	43	6.6978021		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5.1517435	0.046314	111.24	<.0001*
RO Code[300]	0.1907999	0.05643	3.38	0.0021*
RO Code[1012]	-0.208175	0.050788	-4.10	0.0003*
LTMSLAB[A]	0.0188175	0.072108	0.26	0.7960
LTMSLAB[B]	0.1950982	0.066468	2.94	0.0065*
LTMSLAB[E]	-0.119866	0.121211	-0.99	0.3309
LTMSLAB[F]	-0.201648	0.089888	-2.24	0.0327*
LTMSLAB[A]:LTMSAPP[1]	-0.115633	0.103712	-1.11	0.2740
LTMSLAB[A]:LTMSAPP[2]	-0.334426	0.102907	-3.25	0.0029*
LTMSLAB[A]:LTMSAPP[3]	0.2259795	0.144729	1.56	0.1293
LTMSLAB[B]:LTMSAPP[1]	0.0118884	0.098327	0.12	0.9046
LTMSLAB[B]:LTMSAPP[2]	0.350645	0.100234	3.50	0.0015*
LTMSLAB[B]:LTMSAPP[3]	-0.156025	0.099155	-1.57	0.1264
Engine Run[1]	0.2254549	0.057973	3.89	0.0005*
Engine Run[2]	-0.189098	0.057528	-3.29	0.0027*

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RO Code	2	2	1.0568213	9.4215	0.0007*
LTMSLAB	4	4	0.7873579	3.5096	0.0187*
LTMSAPP[LTMSLAB]	6	6	1.4740207	4.3803	0.0029*
Engine Run	2	2	0.9529894	8.4959	0.0012*

$$+\mathrm{Match}\left(\text{Engine Run}\right)\begin{pmatrix} \text{"1"} & \Rightarrow 0.2254548602 \\ \text{"2"} & \Rightarrow -0.189098328 \\ \text{"3+"} & \Rightarrow -0.036356532 \\ \text{else} & \Rightarrow . \end{pmatrix}$$

Ln(FEWMEOT) Unadjusted for Ca

Summary of Fit

RSquare	0.623439
RSquare Adj	0.477674
Root Mean Square Error	0.286922
Mean of Response	5.056658
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	4.2252039	0.352100	4.2770
Error	31	2.5520459	0.082324	**Prob > F**
C. Total	43	6.7772498		0.0005*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5.041826	0.055276	91.21	<.0001*
RO Code[300]	0.2226995	0.067873	3.28	0.0026*
RO Code[1012]	-0.207469	0.061199	-3.39	0.0019*
LTMSLAB[A]	-0.006434	0.086269	-0.07	0.9410
LTMSLAB[B]	0.1801148	0.080224	2.25	0.0320*
LTMSLAB[E]	-0.11319	0.139715	-0.81	0.4240
LTMSLAB[F]	-0.215617	0.106484	-2.02	0.0516
LTMSLAB[A]:LTMSAPP[1]	-0.110221	0.125585	-0.88	0.3869
LTMSLAB[A]:LTMSAPP[2]	-0.338021	0.124544	-2.71	0.0108*
LTMSLAB[A]:LTMSAPP[3]	0.1768954	0.16883	1.05	0.3028
LTMSLAB[B]:LTMSAPP[1]	0.0772888	0.117894	0.66	0.5169
LTMSLAB[B]:LTMSAPP[2]	0.3551694	0.119906	2.96	0.0058*
LTMSLAB[B]:LTMSAPP[3]	-0.122788	0.117894	-1.04	0.3057

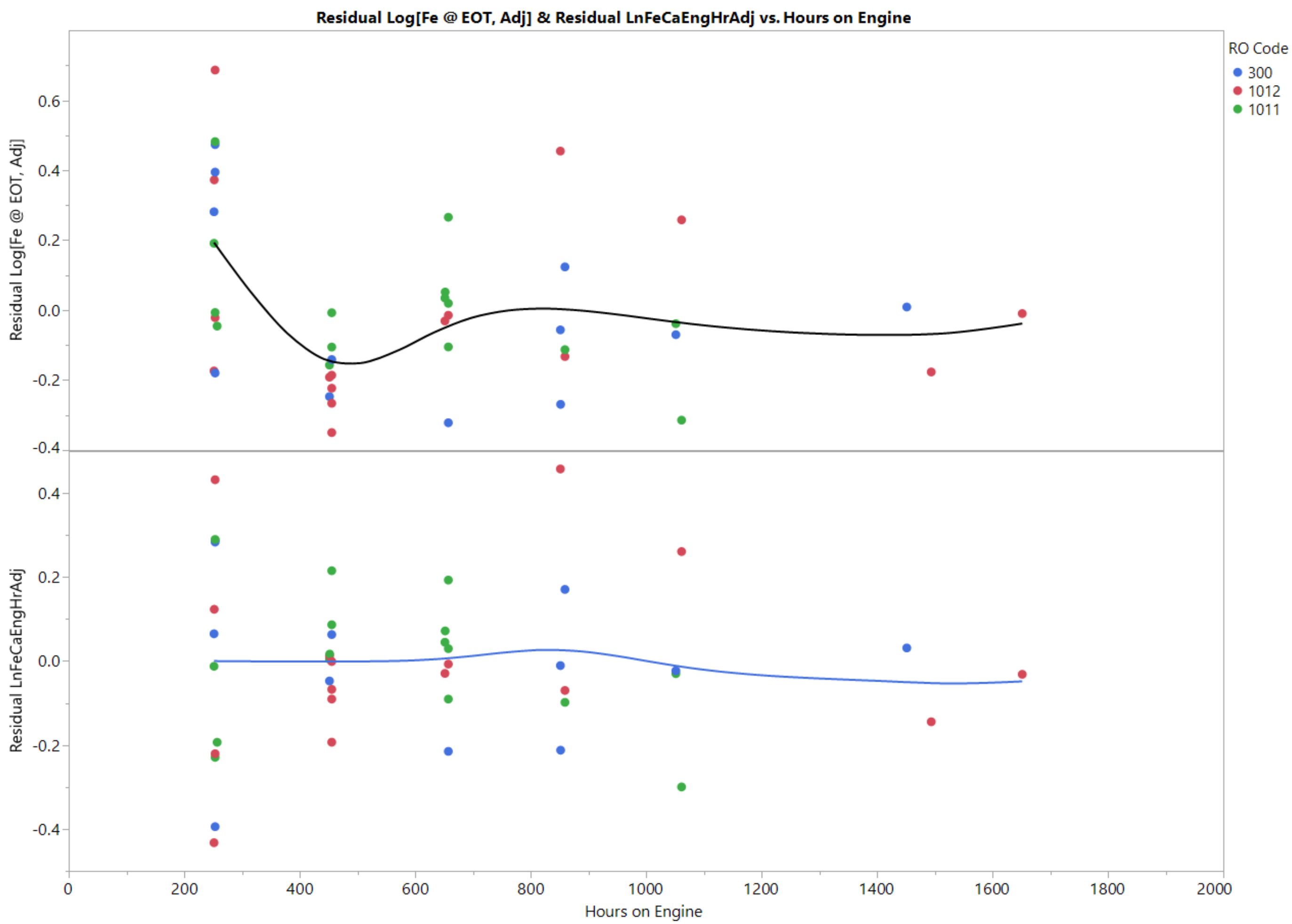
Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RO Code	2	2	1.1998018	7.2871	0.0025*
LTMSLAB	4	4	0.8243301	2.5033	0.0625
LTMSAPP[LTMSLAB]	6	6	1.5807985	3.2004	0.0146*

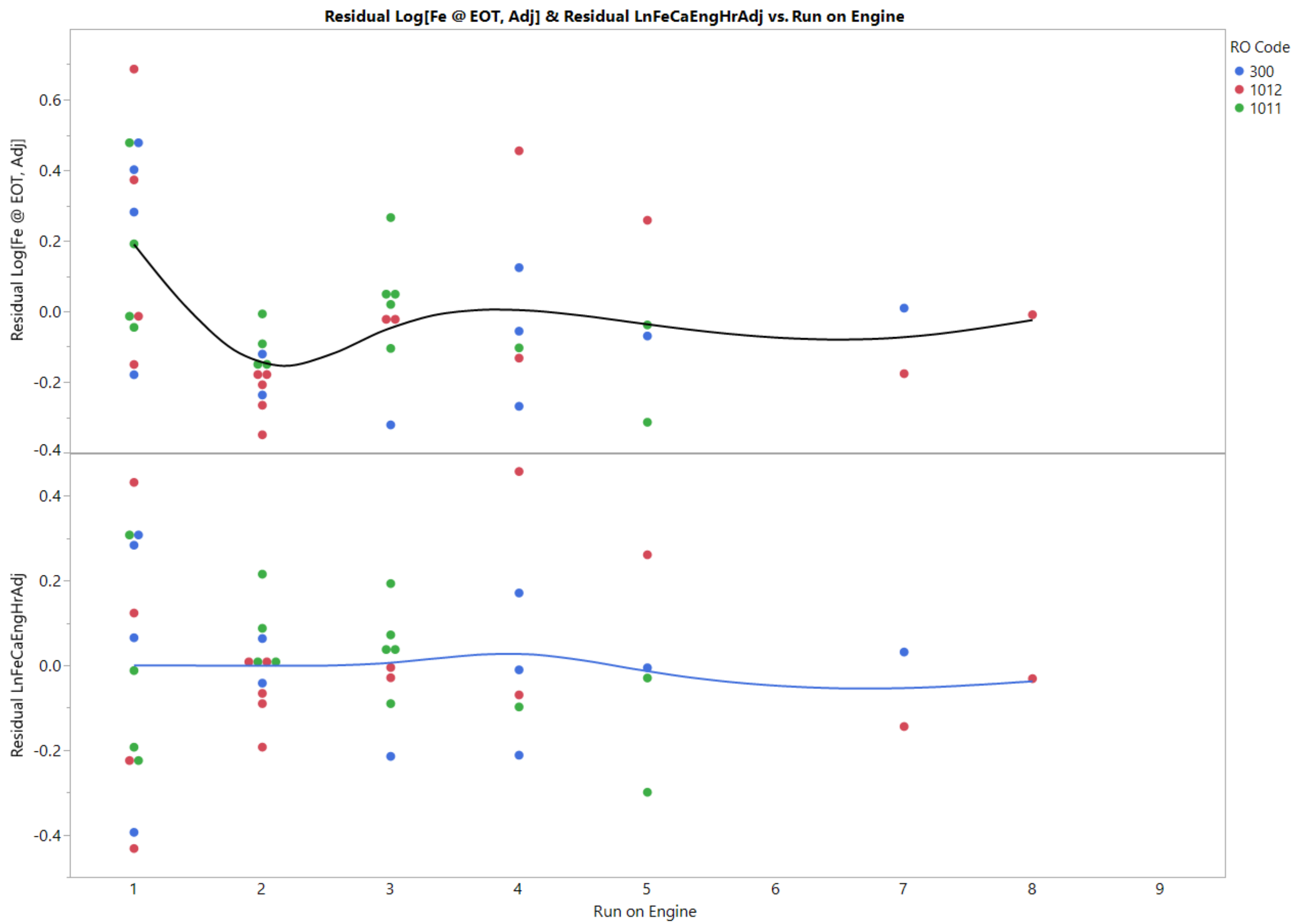
Appendix B

Residual Plots from Calcium Adjusted FEWMEOT No Engine Hour Adjustment and With Engine Hour Adjustment Models

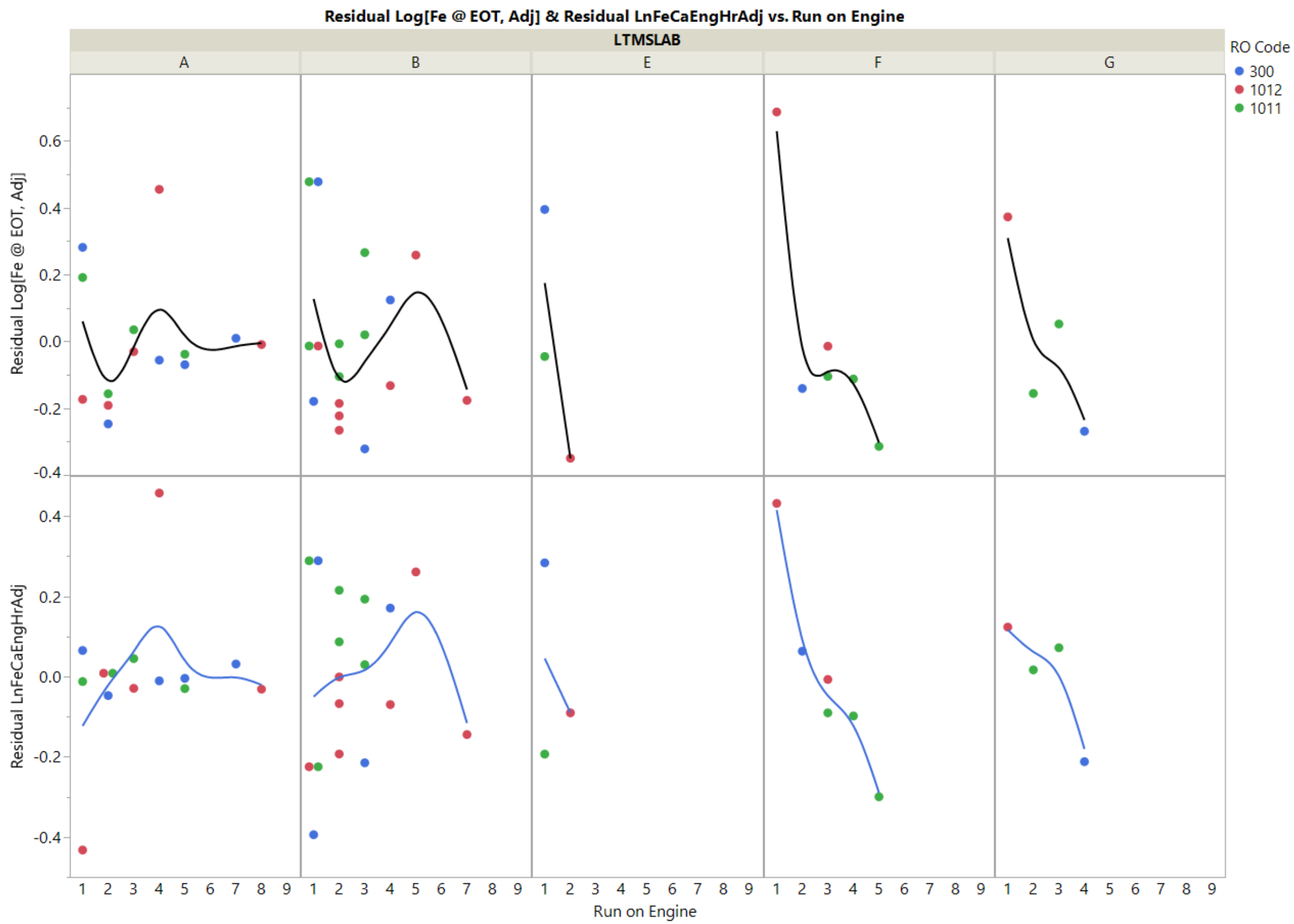
Engine Hours



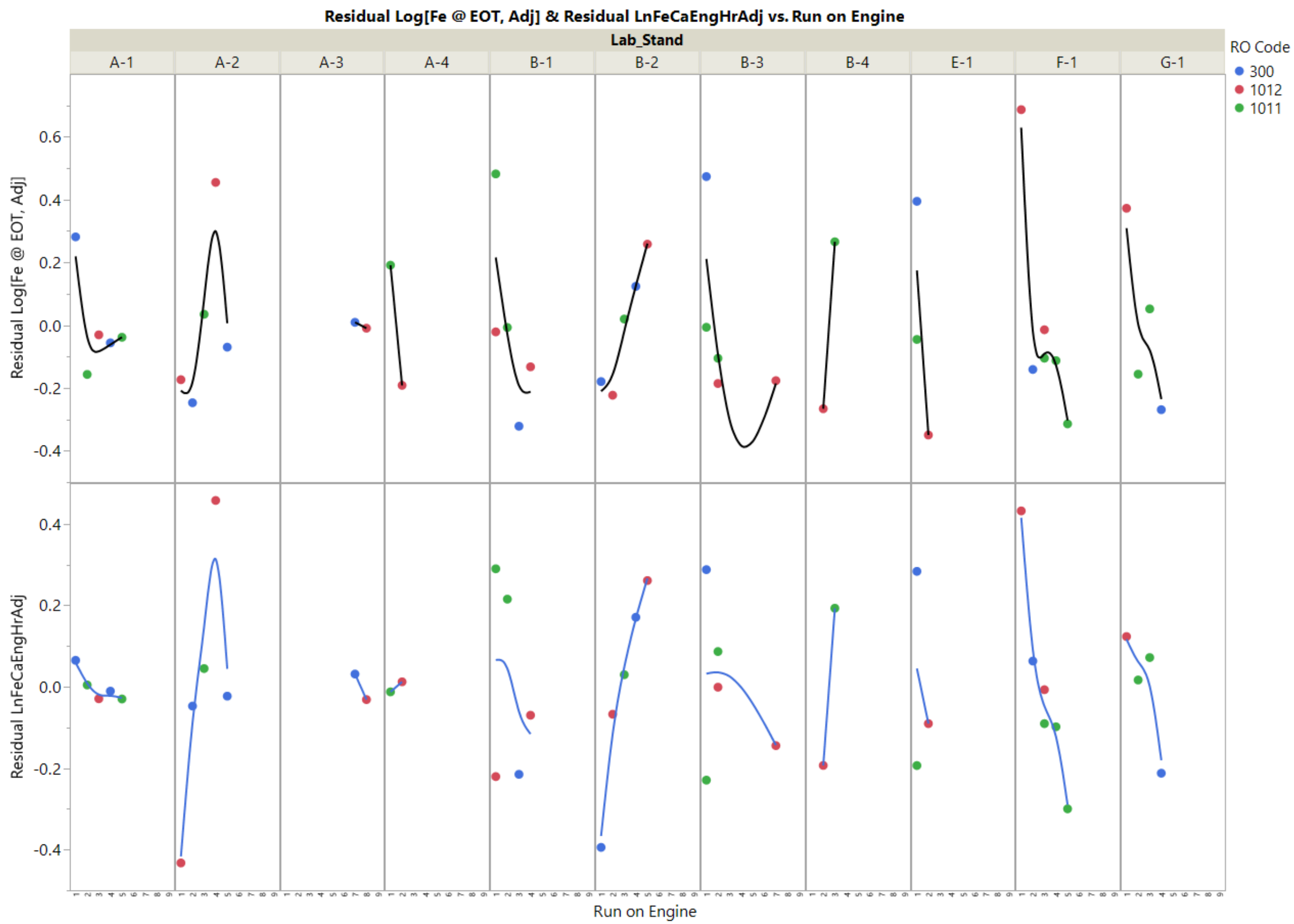
Run on Engine



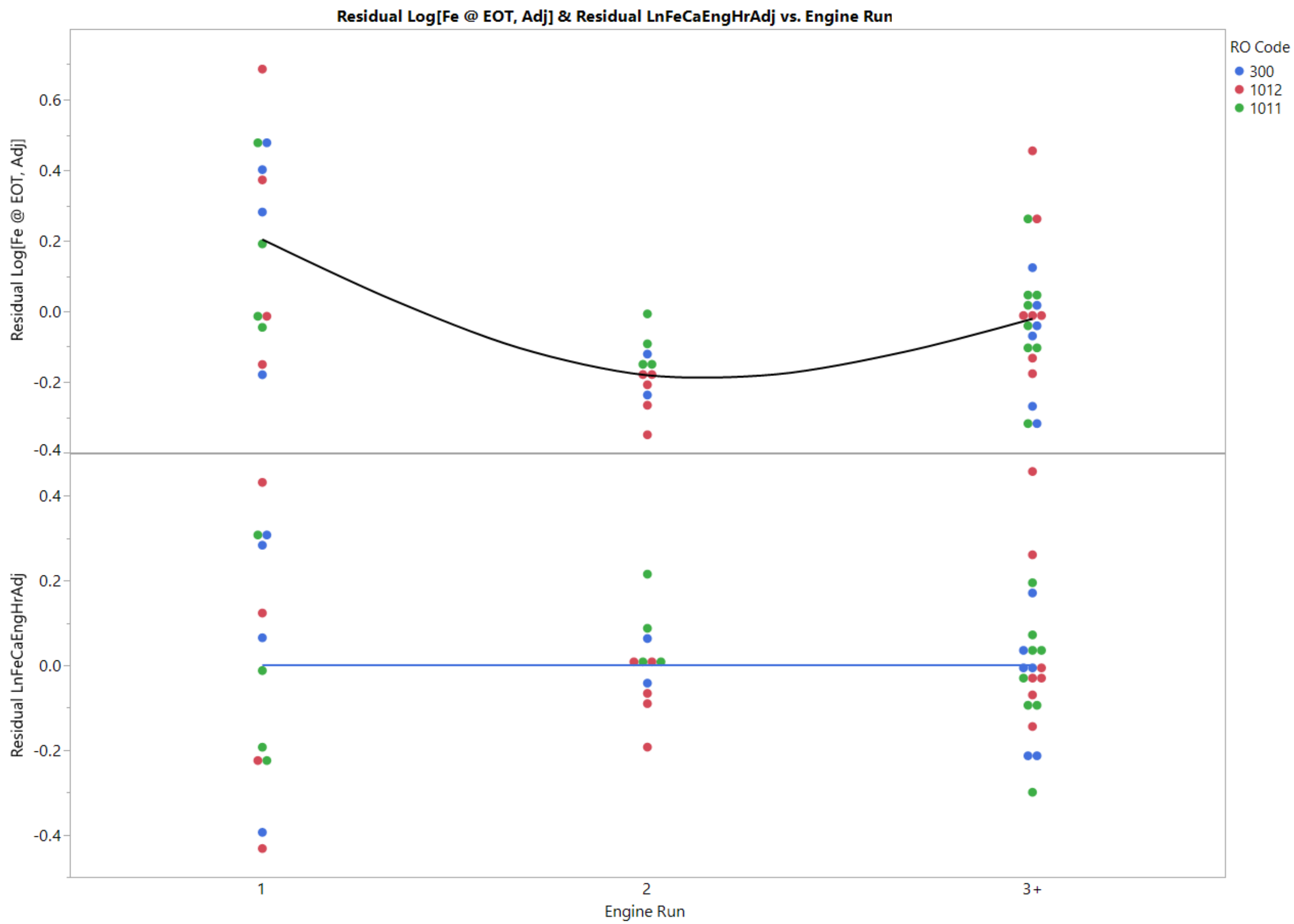
Run on Engine by Lab



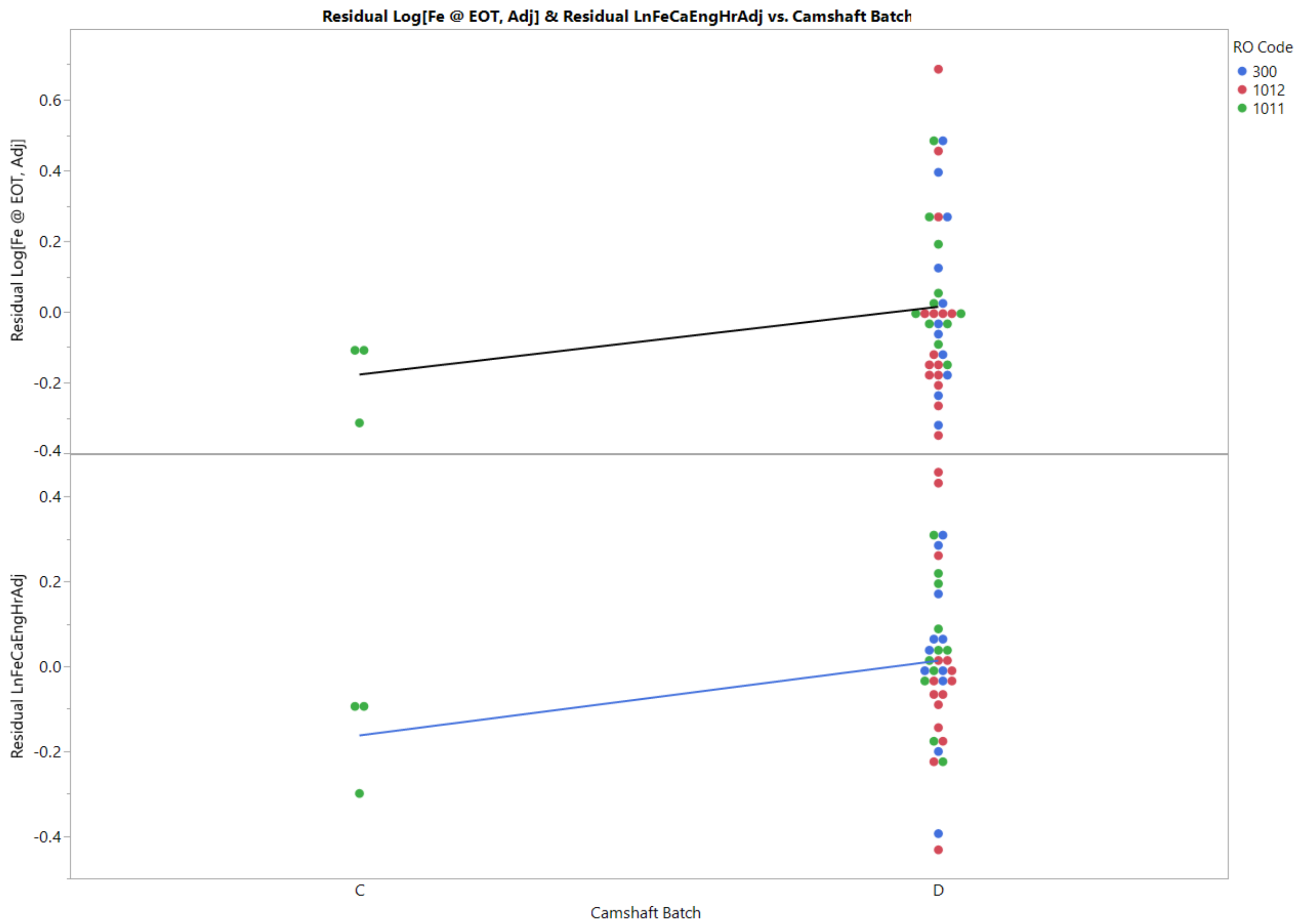
Run on Engine by Stand



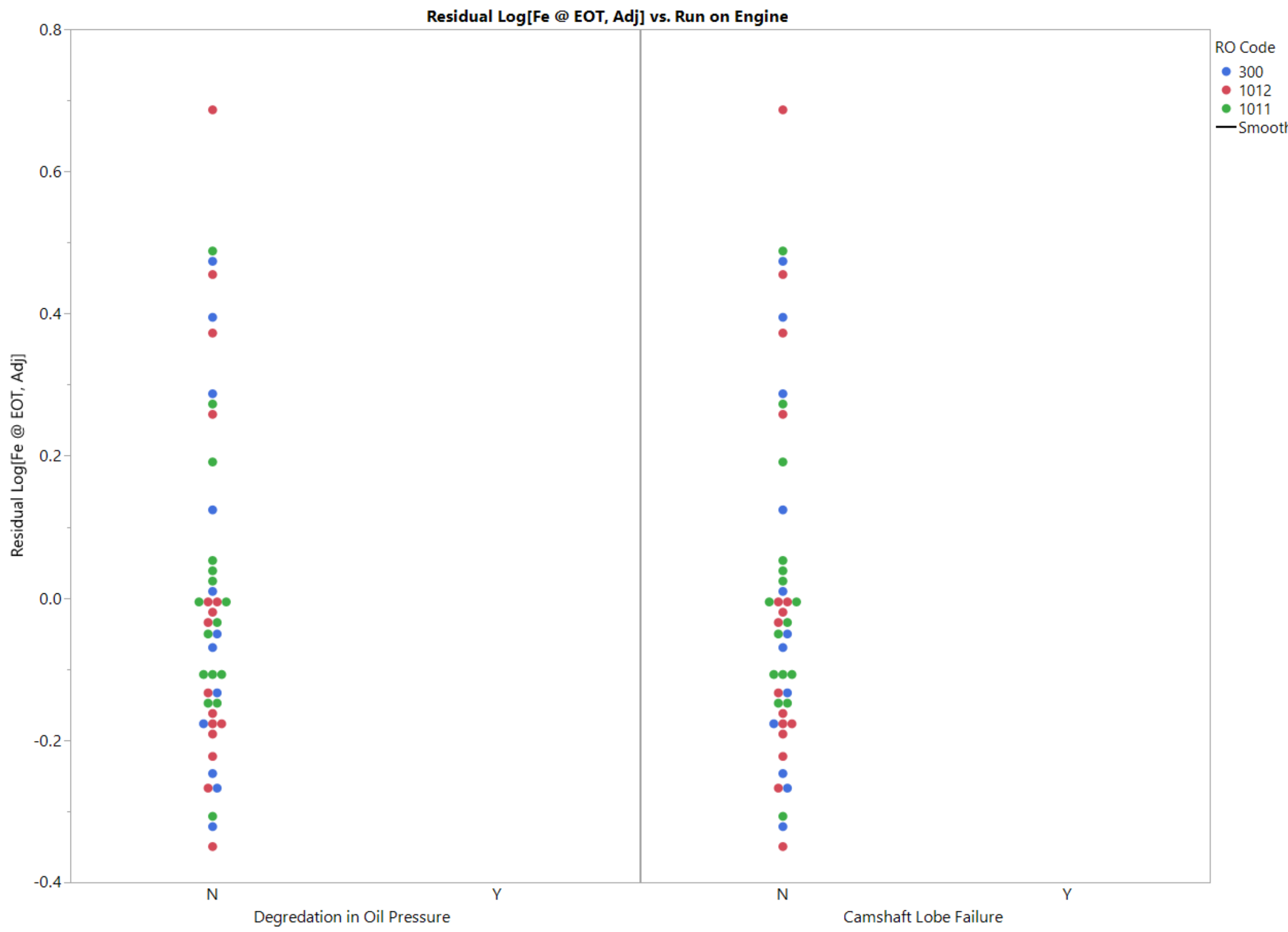
Engine Run


Residual Log[Fe @ EOT, Adj] & Residual LnFeCaEngHrAdj vs. Engine Run
RO Code
300
1012
1011
Residual Log[Fe @ EOT, Adj]
0.6
0.4
0.2
0.0
-0.2
-0.4
Residual LnFeCaEngHrAdj
0.4
0.2
0.0
-0.2
-0.4
1
2
3+
Engine Run

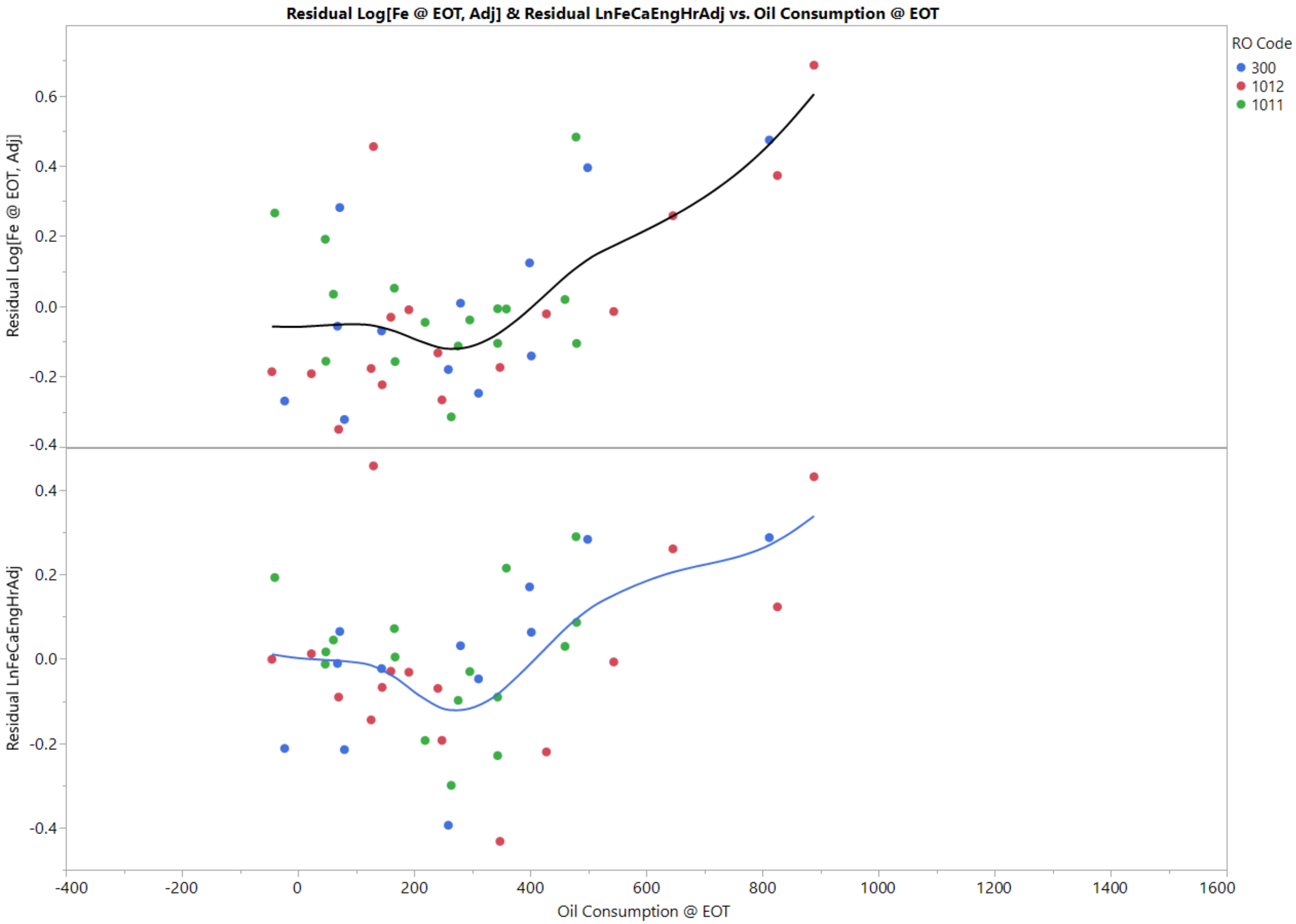
Camshaft Batch



Oil Pressure Degradation and Cam Lobe Failure



Oil Consumption



b. $Z_0 = 0.000$

c. Z_i Limit 1 = +/-0.775

    i. When industry level one limits are exceeded the TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

d. Z_i Limit 2 = +/-0.859

    i. When industry level two limits are exceeded the TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

subsequent test stand at multiple stand labs, will be conducted as the first run on a test engine assembly using the new break-in/aging procedure.
Bill Buscher / Ron Romano / Passed 11 – 1 – 2

5. Motion – Sequence IV surveillance panel approves the introduction of a Sequence IVB FEWMEOT LTMS, based on the N = 44 dataset, without the use of a detergent metal ratio adjustment or an engine hour correction factor, as per details included in document "IVB EOT Fe LTMS Final Summary 20181018.docx". Effective 11/1/18.
   Ron Romano / Robert Stockwell / Passed 6 – 2 – 4

6. Action Item – Negative voters on Motion 4 to provide comments to Sequence IV surveillance panel chair by end of business on Tuesday, 10/23/18.

7. Action Item – Sequence IV surveillance panel members to review the surveillance panel response to ACC PAPTG and have feedback prepared by end of business on Wednesday, 10/24/18,