Sequence IV Surveillance Panel | MINUTES

REVISION DATE: 1/30/2018 4:37:00 PM

Relevant Test:	Sequence IVA and IVB
Note Taker:	Chris Mileti
Meeting Date:	01-25-2018
Comments:	Sequence IV Surveillance Panel meeting hosted by Intertek. The purpose of this meeting was to review the results of the 2nd IVB Precision Matrix.

1. SUMMARY OF MOTIONS AND ACTION ITEMS:

1.1. Background:

1.1.1. This summary of motions and action items was provided by Bill Buscher (Intertek) via email on 01-26-2018.

1.2. Motions:

1.2.1. The Surveillance Panel recommends to Toyota that a 0W-16 or higher viscosity grade, high-wear Sequence IVB oil, targeting an expected average intake lifter volume loss greater than 3.50mm^3, be identified and tested, so that it can be used in conjunction with the Precision Matrix #2 dataset to demonstrate better oil discrimination with the Sequence IVB test. The Surveillance Panel chair to issue the request to the AOAP distribution, and will request a response back to Toyota by February 1, 2018.

1.2.1.1. The motion was made by Lubrizol and seconded by Intertek.

1.2.1.2. The motion passed unanimously (13 affirmatives, 0 negatives, 0 waives).

1.3. Action Items:

1.3.1. The Statistics Group is to perform additional analysis on the Precision Matrix #2 dataset, including:

1.3.1.1. Higher and lower weighting of lifters #1, #2 and #3.

1.3.1.2. Other weighting strategies deemed suitable or valuable.

1.3.2. All laboratories to provide an 8oz end-of-test (200HR) oil sample from each Precision Matrix test to Intertek. Intertek will then run all the required oil drain analysis on all (28) samples.

1.3.3. Statistics Group to perform analysis on all operational data included in the Sequence IVB data dictionary, the end-of-test oil analysis performed at a single lab (Intertek), lifter grade data and additional 1-hour datasets from 10-11HRS and 195-196HRS, to identify root causes for laboratory differences.

1.3.4. The laboratories are to provide two additional 1-hour datasets, 10-11HRS and 195-196HRS, of operational data, using the updated operational review Excel template, from all Precision Matrix #2 tests, so that an additional operational data analysis can be performed.

1.3.4.1. The labs can use their discretion to select a subsequent hour of data if an unscheduled shutdown occurred between the hours specified by the Surveillance Panel.

1.3.4.2. The labs should have this data uploaded to the TMC website by the end of business on February 1, 2018.

1.3.5. Each laboratory is to generate its own 200-hour operational data plots from their Precision Matrix #2 test and distribute for Surveillance Panel review.

1.3.6. Each laboratory is to summarize its notes from the recent IVB Engine Build Workshop and distribute for Surveillance Panel review.

1.3.7. Standardize and draft a procedure for protecting against oxidation of the camshafts and lifters during unscheduled shutdowns.

2. DISCUSSION ABOUT DISPLAY HARDWARE PRIOR TO MEETING:

2.1. Background:

2.1.1. Intertek had a cylinder head and two connecting rod bearing sets on display in the conference rooms.

2.2. Connecting Rod Bearings:

2.2.1. ***1st Bearing Set:***

2.2.1.1. *Number of runs before camshaft failure:* 1

2.2.1.2. *Initial Oil Charge:* 2400mL

2.2.1.3. The bearings are heavily pitted and scuffed.

2.2.2. ***2nd Bearing Set:***

2.2.2.1. *Number of runs before camshaft failure: 6*

2.2.2.2. *Initial Oil Charge:* 3000mL

2.2.2.3. The bearings had no obvious signs of damage or excessive wear.

2.2.3. ***Photograph:***

2.3. Intertek Comments about Bore Polishing:

2.3.1. Intertek has observed a drastic reduction in bore polishing since the larger initial oil charge was introduced.

2.3.2. A relatively large area of the bore would become polished (with no remnants of honing) when the 2400mL initial oil charge was used.

2.3.3. They are only observing a small area of polish, approximately the width of a pencil, with the larger 3000mL initial oil charge.

3. STATISTICS PRESENTATION (K. O'MALLEY):

3.1. Opening Comments by Bill Buscher:

3.1.1. The Surveillance Panel will no longer hold a vote regarding the readiness of the Sequence IVB test.

3.1.2. The vote is being postponed in response to a letter sent by the ACC to Toyota.

3.1.2.1. The ACC is requesting more time for the statisticians and engineers to review the data from the 2^{nd} Precision Matrix.

3.1.3. The Surveillance Panel will probably need to hold another face-to-face meeting on or around February 13^{th} to conduct this vote.

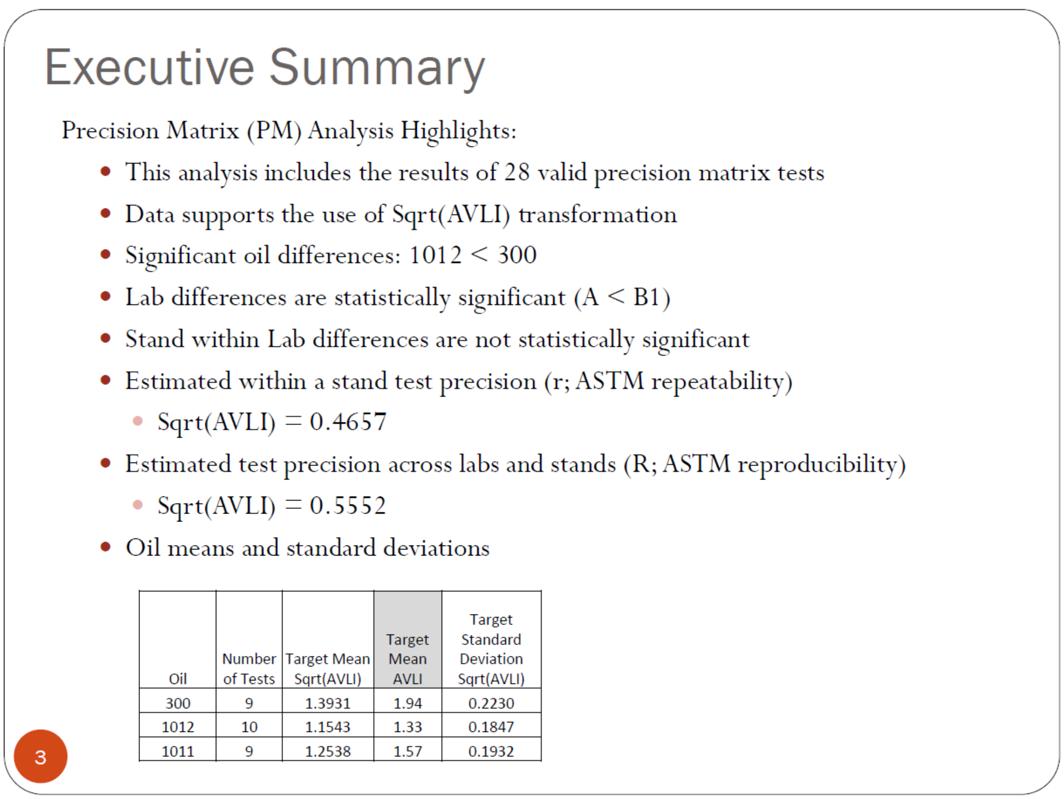
3.1.4. Buscher thanked the Statistics Group for the analysis that they conducted over the last few weeks.

3.1.5. The Surveillance Panel will need to discuss potential causes for the loss of test precision during the 2^{nd} Precision Matrix.

3.2. Background on Statistics Presentation:

3.2.1. ***File:*** Sequence IVB PM Analysis Final 012518.pdf

3.3. Slide #3 – Executive Summary:



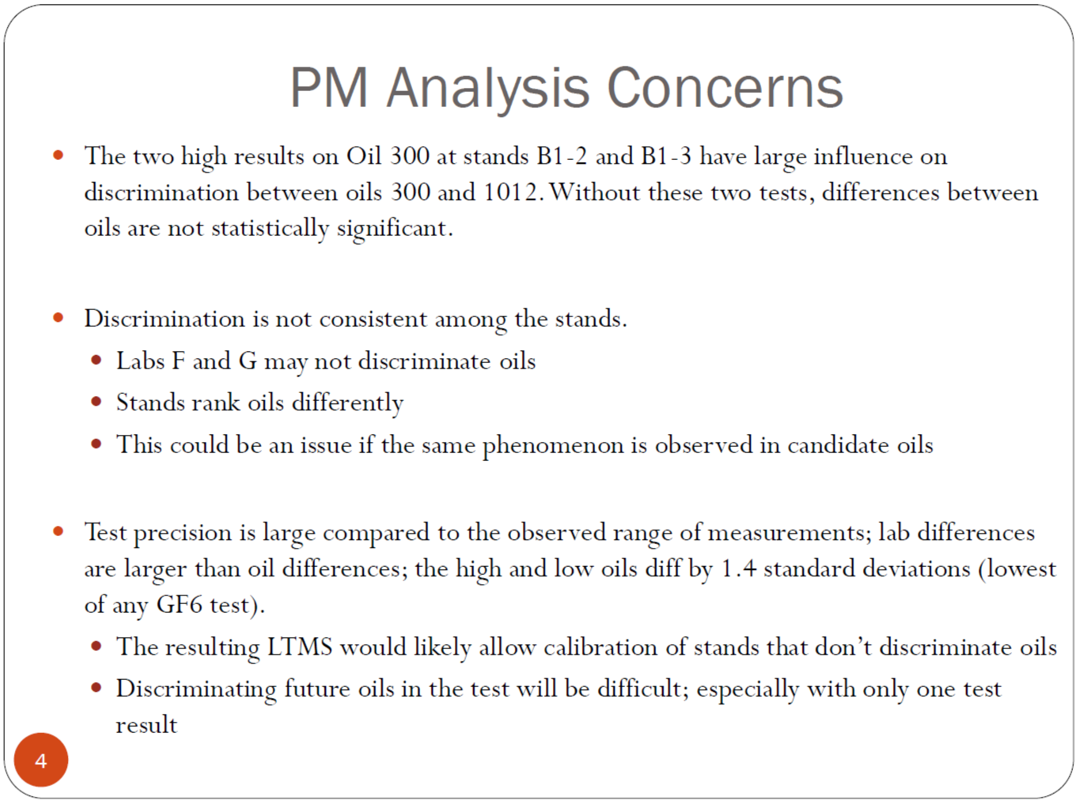
3.3.1. This summary was compiled using the average intake lifter volume loss (i.e. AVLI) data.

3.3.2. The results are showing both oil differences and laboratory differences.

3.3.3. The stand differences within a lab are not <u>statistically</u> significant.

3.3.3.1. However, this issue needs to be discussed further because there are visual differences in the results from some stands.

3.4. Slide #4 – PM Analysis Concerns:



3.4.1. ***List of Concerns:***

3.4.1.1. Two data points at Lab B are driving the discrimination between REO300 and REO1012.

3.4.1.2. There is some evidence that suggests oil discrimination is not consistent from stand-to-stand.

3.4.1.3. Some labs are not discriminating oils.

3.4.1.4. There is not a consistent ranking of oils across all stands.

3.4.1.5. Lab differences are larger than oil differences.

3.4.2. The lack of a consistent ranking of the reference oils across all stands may create problems when candidate oils are tested.

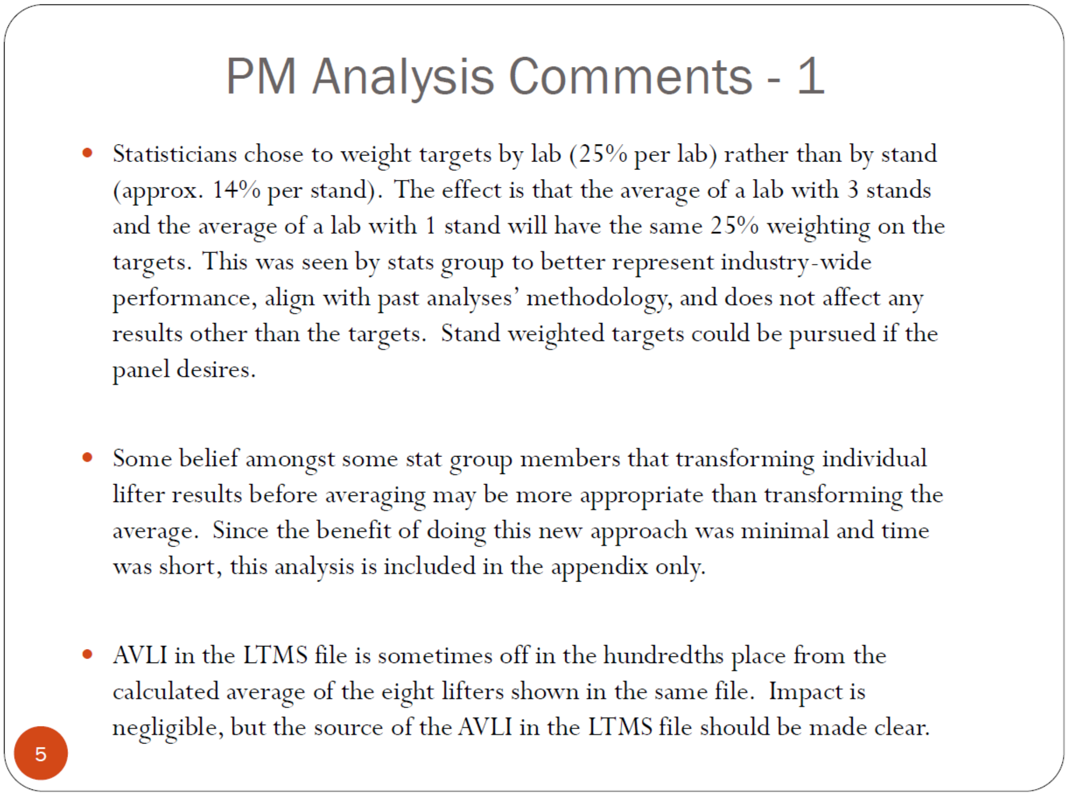
3.4.3. The averages of REO300 and REO1012 (the highest and lowest wear oils, respectively) differ by 1.4 standard deviations.

3.4.3.1. This is the lowest standard deviation of any GF-6 test.

3.4.4. The lack of oil discrimination has resulted in a situation where laboratories can potentially reference their test stands too easily.

3.4.4.1. The proposed LTMS system would allow all Precision Matrix stands to easily calibrate – even the two stands that did not show discrimination.

3.5. Slide #5 – PM Analysis Comments 1:



3.5.1. The Statistics Group chose to weigh targets by lab instead of by individual test stand.

3.5.2. The Statistics Group had a lengthy internal discussion about appropriate transformation strategies.

3.5.2.1. Some statisticians preferred transforming the average intake lifter volume loss, while other statisticians preferred transforming the individual lifter wear measurements.

3.5.2.2. The two approaches do yield different results.

3.5.3. The statisticians are also concerned about how the average lifter volume loss is being calculated in the LTMS file.

3.5.3.1. They believe that rounding errors may result in a difference between the actual average of the lifter measurements and the number that is being reported in the LTMS file.

3.6. Slide #6 – PM Analysis Comments 2:

PM Analysis Comments - 2

- Based on analysis conducted, there is no additional benefit in using parameters other than AVLI
- Additional tests could help better understand discrimination and precision of the test.
- Statistical analyses have not yet been completed to assess the impact of operational differences on test severity. The outcome of such analyses and discussions could ultimately affect oil targets. Given the differences noted in the surveillance panel call on January 11^{th}, the panel may find it helpful to review the full datafiles for all tests.

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3.6.1. There is no additional benefit in using parameters other than AVLI (such as mass loss and end-of-test iron) to discriminate between oils.
3.6.2. The statisticians agree that additional test results (possibly with a different oil) will aid their analysis.
3.6.3. The Surveillance Panel needs to spend more time reviewing the operational data.
  3.6.3.1. Lab-to-lab differences in specific operational parameters have been known for over a year.
  3.6.3.2. These operational parameters need to be correlated to test severity.
  3.6.3.3. Is a one-hour snapshot of operational data appropriate for comparison?
  3.6.3.4. Should the statisticians look at a larger sample of data?
3.6.4. ***Afton's Comments:***
  3.6.4.1. The operational data (101-102HR) that has been used during previous reviews is from the halfway point of each test.
  3.6.4.2. This operation of the engine probably changes over the course of the test.
  3.6.4.3. So, this 1-hour segment of data may not be appropriate.

3.7. Trends in Test Results:

3.7.1. ***Lifter Bias:***
  3.7.1.1. O'Malley noted that there is a lifter bias in almost all the test results.
    3.7.1.1.1. Lifter #2 frequently exhibits the highest wear.
    3.7.1.1.2. Lifter #1 frequently exhibits high wear as well.
  3.7.1.2. Buscher noted that the engineers are aware of this lifter bias and can explain it.
    3.7.1.2.1. For example, the individual lifter wear measurements for a test kit that has a 3.0mm^3 average volume loss can range between 0.5-4.0mm^3.
3.7.2. ***Camshaft Lobe Failures (Buscher):***
  3.7.2.1. Single camshaft lobe failures are not usually isolated to a single intake valve location.
  3.7.2.2. An engine can operate for 20 to 30 hours after a lobe fails.

3.7.2.3. The lifter associated with a camshaft lobe failure generally has a lower than expected volume loss.

3.7.3. ***Oil Consumption (Buscher):***

3.7.3.1. Intertek has seen end-of-test oil consumption levels range between 0g to 900g.

3.7.3.2. There has been no indication of oil pump starvation since the initial oil charge was increased.

3.7.4. ***Water Content (Buscher):***

3.7.4.1. The water content does seem to differ with reference oils.

3.7.4.2. Intertek has seen end-of-test water content measurements that range between 1600ppm and 4300ppm.

3.7.4.3. The Karl Fischer test was added to the IVB oil analysis test schedule after 2015.

3.7.4.4. There is one end-of-test Karl Fischer data point from the IVB DOE, and it was around 3000ppm.

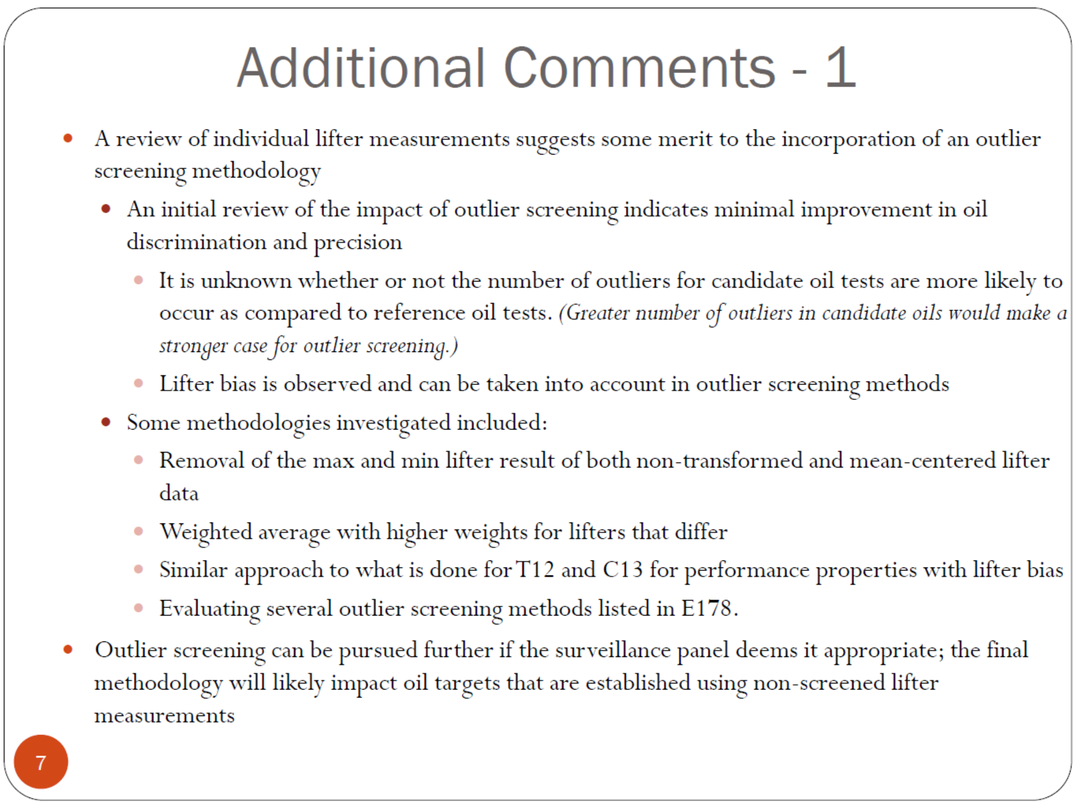
3.7.4.5. K. O'Malley's Comments:

3.7.4.5.1. The statisticians did identify laboratory and stand differences with the Karl Fischer measurements.

3.7.4.5.2. In general, Lab A had lower water contents than the other labs.

3.7.4.5.3. Lab A is also somewhat milder than the others.

3.8. Slide #7 – Additional Comments 1:



3.8.1. There is some merit in applying outlier screening to individual lifter measurements.

3.8.1.1. However, this outlier screening will not have a big impact on oil discrimination or test precision.

3.8.1.2. The Surveillance Panel will need to discuss the merits of outlier screening further.

3.8.1.3. Outlier screening <u>may</u> benefit candidate oils more than reference oils, but more data is needed to make a definitive judgement on this.

3.8.2. Several outlier screening strategies were evaluated.

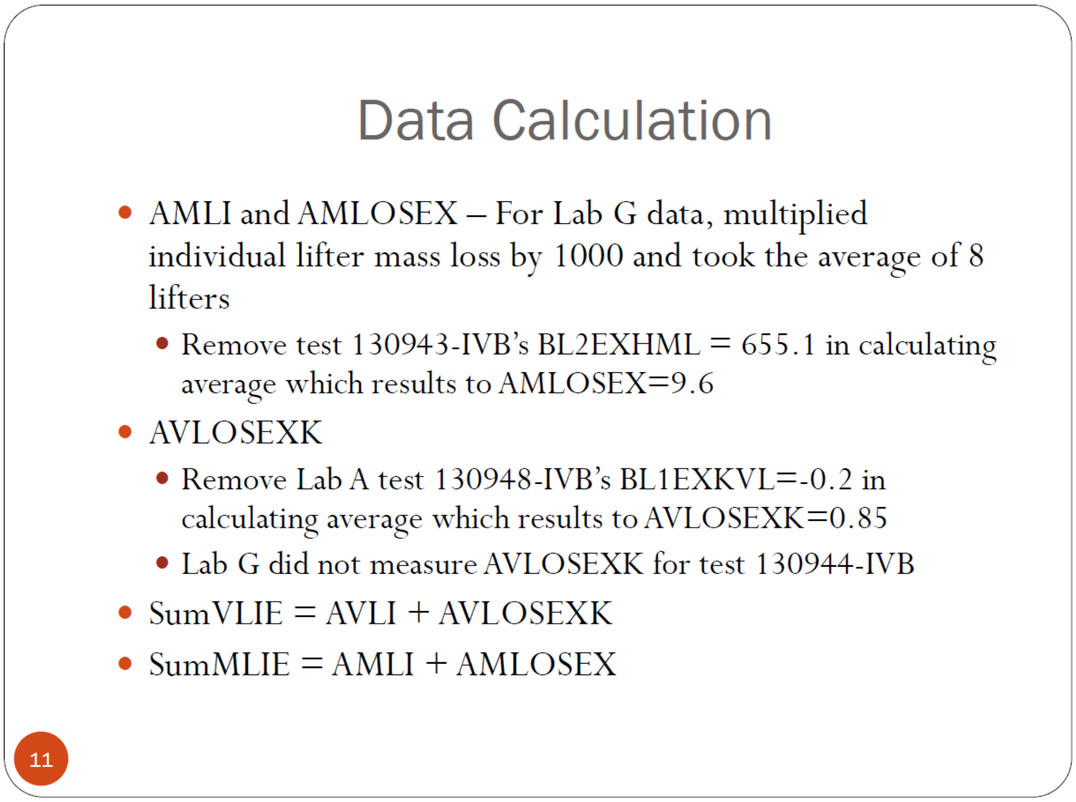
3.8.2.1. Comments from M. Chadwick:

3.8.2.1.1. The improvement gained from each outlier screening method is marginal.
3.8.2.1.2. The best outlier screening method would increase the difference in oil averages from 1.4 to 1.9 standard deviations.
3.8.2.1.3. Even after this increase, the Sequence IVB would still have the lowest standard deviation of any GF-6 test.

3.8.2.2. Comments from D. Boese:

3.8.2.2.1. The Surveillance Panel needs to be aware that there is a risk associated with fitting a complicated model to a relatively small dataset.

3.9. Slide #11 – Data Calculation:



3.9.1. The AMLI and AMLOSEX parameters had to be converted for Lab G.
3.9.2. One test from Lab G did not have exhaust lifter volume loss measurements.
3.9.3. One of the individual lifter measurements from Lab A had a negative magnitude.
3.9.3.1. This measurement was removed from the dataset.

3.10. Slide #12 – Summary of Model Results:

Summary of Model Results

Model P-values	Sqrt(AVLI)	AMLI	Sqrt(AVLOSEXK)	Ln(AMLOSEX)	Ln(SumVLIE)	Sqrt(SumMLIE)	Ln(FEWMEOT)	Sqrt(AVLIS)	Sqrt(AVLIOS)
IND	0.02	0.02	0.05	0.04	0.01	0.01	0.06	0.04	0.02
LTMSLAB	0.01	0.05	0.00	0.00	0.00	0.01	0.01	0.01	0.01
LTMSAPP[LTMSLAB]	0.34	0.02	0.56	0.04	0.15	0.01	0.13	0.40	0.34
Oil Discrimination, in standard deviation units, red means difference is statistically significant									
300-1012	1.4	1.4	1.3	1.3	1.7	1.6	1.2	1.3	1.5
300-1011	0.8	0.8	0.9	0.8	1.0	0.8	0.8	0.8	0.9
1011-1012	0.6	0.6	0.4	0.5	0.8	0.8	0.4	0.5	0.6
Precision									
RMSE, sr	0.1680	3.83	0.0979	0.1891	0.1903	0.4861	0.2701	0.1537	0.1647
Repeatability, r	0.4657	10.61	0.2714	0.5242	0.5275	1.3474	0.7487	0.4260	0.4565
Parameter Result	2.00	20.00	1.20	10.00	3.00	30.00	200	2.00	2.00
No significant difference	3.53	30.61	1.87	16.89	5.08	46.58	423	3.39	3.50

Most parameters except AMLI show that lab difference is greater than oil difference. The Volume Loss parameters showed no significant difference between stands within the lab.

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Note: n-size for these models is 28 except for SumVLIE and AVLOSEXK which has 27

3.10.1. The first row in the Oil Discrimination table shows the standard deviations between the REO300 and REO1012 mean results.

3.10.1.1. The p-values in this row are relatively consistent across the columns.

3.10.1.2. This shows that no single parameter offers a drastic improvement in oil separation.

3.11. Slide #13 – Reference Oil Discrimination Comparison:

3.11.1. This table shows the standard deviation between the highest and lowest reference oil for other GF-6 tests.

3.11.2. Most of these other tests have "SD's of Separation" that range between 2.0 and 4.0 standard deviations.

3.11.3. Intertek noted that one driver of the low standard deviation for the Sequence IVB test may be the reference oils that were selected.

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 is approx. 3.3 and the mean (without PHOS) is 3.4.

Test	Parameter	Oil 1	Oil 2	Range	Test s_r	SDs of Separation
IIIH	Ln(PVIS)	4.7191	3.3289	1.3902	0.4641	**3.0**
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	**10.0**
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	**2.0**
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	Sqrt(AVLI)	1.3931	1.1543	0.2388	0.1680	**1.4**

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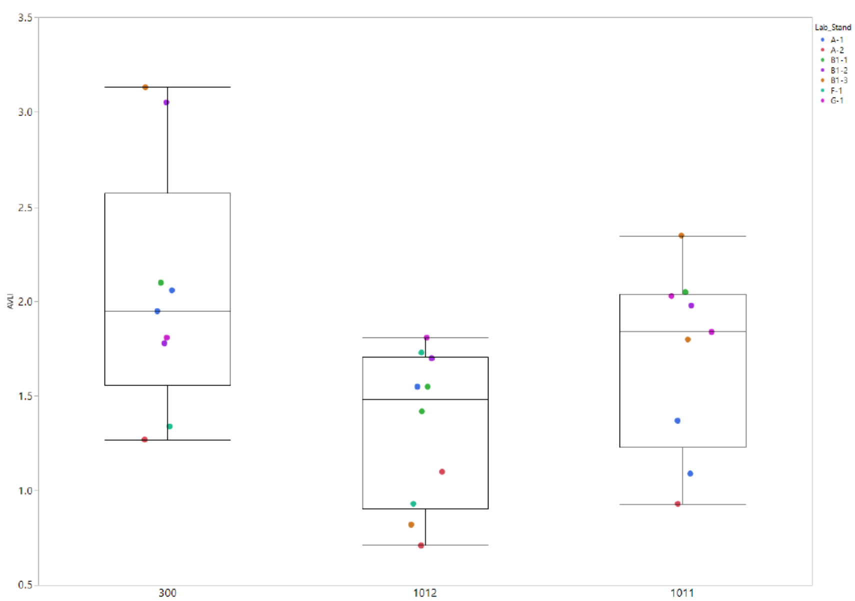
*1: Oil 220 not used as a reference oil. Including this oil would yield approx. 12 SDs of separation between 220 and 222.
*2: 271 vs. 1011

3.12. Slide #15 – Average Intake Volume Loss by Oil:

Average Intake Volume Loss by Oil

- The below plot summarizes the AVLI test result data by reference oil.



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3.12.1. The two "severe" results for REO300 are driving the separation between oils.

3.12.1.1. One of these "severe" results had a lifter wear profile in which all the individual lifter wear measurements were shifted upward.

3.12.1.2. The second "severe" result had a lifter wear profile that was different than the other Precision Matrix tests.

3.12.1.2.1. The first three lifters had extremely high wear measurements.

3.12.2. **Afton's Comments:**

3.12.2.1. The Surveillance Panel reviewed the operational data from these two "severe" tests and could not find a reason to invalidate the results.

3.12.2.2. Continuing to run tests without changing something will not improve discrimination or precision.

3.12.2.3. Is there another severity "lever" to pull?

3.12.2.4. Are the labs encountering engine bias instead of a lack of test precision?

3.12.3. ***Intertek's Comments:***

3.12.3.1. One of these "severe" results followed a camshaft lobe failure, so the engine was new.

3.12.3.2. The second "severe" result was on an engine that had 3 or 4 previous runs.

3.12.3.3. Intertek plotted every controlled and uncontrolled parameter from these two tests (over the full 200-hours) and did not identify any anomalies.

3.12.3.4. The only difference that they identified in the two tests was the exhaust temperature, but this difference did not correlate to severity.

3.12.3.5. They even reviewed the build data from each engine.

3.12.4. ***Status of REO300:***

3.12.4.1. The TMC has almost depleted its current blend of REO300.

3.12.4.1.1. There is enough REO300 oil at the laboratories for approximately (6) additional Sequence IVB tests.

3.12.4.2. A re-blend was scheduled and is available.

3.12.4.2.1. However, there is no guarantee that the re-blend will perform similarly to the original batch.

3.12.4.3. Intertek and OHT noted that it may be desirable to replace REO300 with an oil that provides better discrimination.

3.12.4.4. Intertek noted that REO300 delivers highly variable lifter-to-lifter wear.

3.12.4.4.1. REO300 also delivered highly variable results when it was tested in the Sequence IVA engine.

3.12.4.4.2. REO300 is a GF-5 oil that is down-treated to promote wear.

3.12.5. ***Lubrizol's Comments:***

3.12.5.1. There is no evidence suggesting that the lack of precision is due to hardware or engine variability.

3.12.5.1.1. In fact, Lubrizol has extensively reviewed the IVB hardware and found almost no part-to-part variation.

3.12.5.2. It is possible that the lack of precision is due to emulsion on the valve deck.

3.12.5.2.1. A varnish deposit is forming around the perimeter of the lifters that may be interfering with their rotation and/or movement in the bore.

3.12.5.2.2. In some cases, a rectangular wear pattern forms on the top of the lifter because it stopped rotating at some point in the test.

3.12.5.3. Lubrizol is suspicious that the external blowby system (particularly the expansion tank and one-way check valve) is contributing to this variability in emulsion formation.

3.12.5.4. Intertek noted that a similar problem of varnish deposits interfering with lifter movement may have occurred early in test development with the Ford 2.0L engine.

3.12.6. ***Frequency of Lobe Failures:***

3.12.6.1. Intertek reported that they continue to experience camshaft lobe failures.

3.12.6.2. Their failure rate with candidate oils is around 10%.

3.12.6.3. They noted that many of these failures occurred with 0W-8 oils.

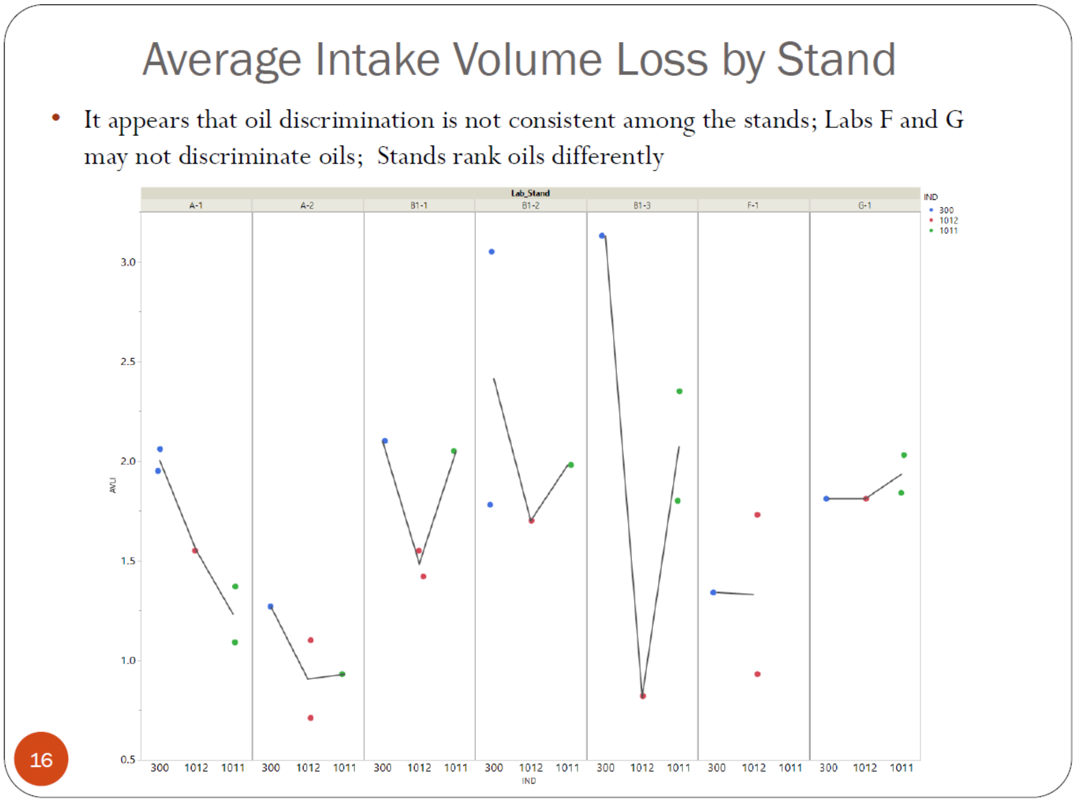
3.12.6.4. Lubrizol expressed disappointment that the low-sulfur fuel, modified oil pan and larger initial oil charge did not eliminate these failures.

3.12.6.5. Southwest is not currently running candidate oils.

3.12.6.5.1. They did note that the high-event camshaft lobe failure proof-of-performance oils were run at both Intertek and Southwest with no issues.

3.12.6.5.2. So, it is possible the changes listed by Lubrizol did, in fact, reduce the likelihood of a failure.

3.13. Slide #16 – Average Intake Volume Loss by Stand:



3.13.1. This slide presents the Precision Matrix data by test stand.

3.13.2. The p-values do not indicate significant differences between the test stands, but a visual analysis clearly shows differences.

3.13.2.1. The p-values probably due not indicate stand differences because of the overall lack of test precision.

3.13.3. ***Afton's Comments about Each Stand:***

3.13.3.1. A-1:

3.13.3.1.1. REO300 is more severe than REO1012.

3.13.3.2. A-2:

3.13.3.2.1. There is a small difference between reference oils.

3.13.3.2.2. REO1011 and REO1012 look the same.

3.13.3.3. B1-1:

3.13.3.3.1. REO300 is more severe than REO1012.

3.13.3.3.2. REO1011 and REO300 look the same.

3.13.3.4. B1-2:

3.13.3.4.1. There is a large range in REO300 results.

3.13.3.5. B1-3:

3.13.3.5.1. The data for this stand looks good.

3.13.3.6. F-1:

3.13.3.6.1. This stand is not discriminating between oils.

3.13.3.7. G-1:

3.13.3.7.1. This stand is not discriminating between oils.

3.13.4. M. Chadwick cautioned that the Surveillance Panel is operating under the assumption that REO300 and REO1012 should separate.

3.13.5. T. Kostan cautioned that nobody knows how REO1011 should rank against REO300 and REO1012.

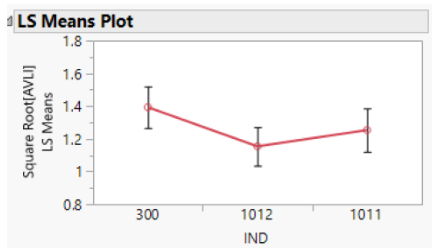
3.13.5.1. It is concerning that the stands and laboratories rank REO1011 differently.

3.13.6. Exxon noted that it is possible that these oils are performing the same, and the spread in results is due to stand-to-stand variation.

3.14. Slide #19 – Sqrt(AVLI) Oil Differences:

Sqrt(AVLI) Oil Differences

- Model is Sqrt(AVLI) ~ Oil, Lab, Stand(Lab)
- Oils significantly differ
  - Oil 300 is statistically significantly different than oil 1012
  - Oil 1011 is not statistically significantly different than oils 300 and 1012
- Plot shows Sqrt(AVLI) LSMeans by Oil, with 95% confidence intervals



LSMeans by Oil

Oil	Sqrt(AVLI) LSMean	AVLI LSMean
300	1.3931	1.94
1012	1.1543	1.33
1011	1.2538	1.57

LSMeans Differences Between Oils

Oil1	Oil2	Sqrt(AVLI) LSMean Difference	p-Value
300	1012	0.2387	0.02
300	1011	0.1393	0.23
1011	1012	0.0994	0.47

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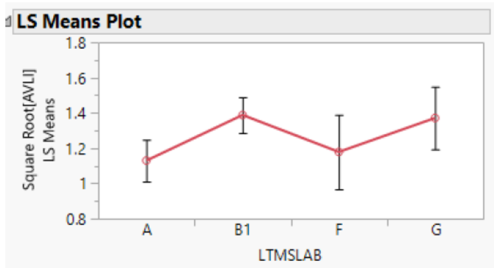
3.14.1. The plot in the upper right-hand corner shows the modeled differences between oils.

3.14.2. On average, REO300 and REO1012 differ from each other.

3.15. Slide #20 – Sqrt(AVLI) Lab Differences:

Sqrt(AVLI) Lab Differences

- Model is Sqrt(AVLI) ~ Oil, Lab, Stand(Lab)
- Plot below of Sqrt(AVLI) LSMeans by Lab, with 95% confidence intervals
- Lab A is statistically significantly different than Lab B1.



LSMeans by Lab

Lab	Sqrt(AVLI) LSMean	AVLI LSMean
A	1.1298	1.28
B1	1.3882	1.93
F	1.1789	1.39
G	1.3713	1.88

LSMeans Differences Between Labs

Lab1	Lab2	Sqrt(AVLI) LSMean Difference	p-Value
B1	A	0.2584	0.01
G	A	0.2415	0.12
B1	F	0.2093	0.27
G	F	0.1924	0.49
F	A	0.0491	0.97
B1	G	0.0169	1

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3.15.1. This plot summarizes the severity differences between labs.

3.16. Slide #24 – PM Data Ranges Overlap:

PM Data Ranges Overlap

	% of Observed Measurement Range						
Oil	FEWMEOT	Average Intake Volume Loss	Average Exhaust Volume Loss	Average Intake Mass Loss	Average Exhaust Mass Loss	Sum Intake & Exhaust Volume Loss	Sum Intake & Exhaust Mass Loss
1011	54.17	58.68	73.53	55.28	63.48	57.19	60.91
1012	47.92	45.45	52.94	61.73	47.95	47.71	55.33
300	87.85	76.45	77.45	69.86	83.48	76.76	72.34

	FEWMEOT			Average Intake Volume Loss			Average Exhaust Volume Loss			Average Intake Mass Loss			Average Exhaust Mass Loss			Sum Intake & Exhaust Volume Loss			Sum Intake & Exhaust Mass Loss		
Oil	Minimum	Maximum	Range	Minimum	Maximum	Range	Minimum	Maximum	Range	Minimum	Maximum	Range	Minimum	Maximum	Range	Minimum	Maximum	Range	Minimum	Maximum	Range
1011	113	269	156	0.93	2.35	1.42	0.57	1.32	0.75	11.58	24.09	12.51	6.13	13.24	7.11	1.5	3.37	1.87	18.24	37.33	19.09
1012	74	212	138	0.71	1.81	1.1	0.66	1.2	0.54	6.11	20.08	13.97	5.18	10.55	5.37	1.37	2.93	1.56	11.29	28.63	17.34
300	109	362	253	1.28	3.13	1.85	0.8	1.59	0.79	12.93	28.74	15.81	7.03	16.38	9.35	2.13	4.64	2.51	19.96	42.63	22.67
All oils	74	362	288	0.71	3.13	2.42	0.57	1.59	1.02	6.11	28.74	22.63	5.18	16.38	11.2	1.37	4.64	3.27	11.29	42.63	31.34

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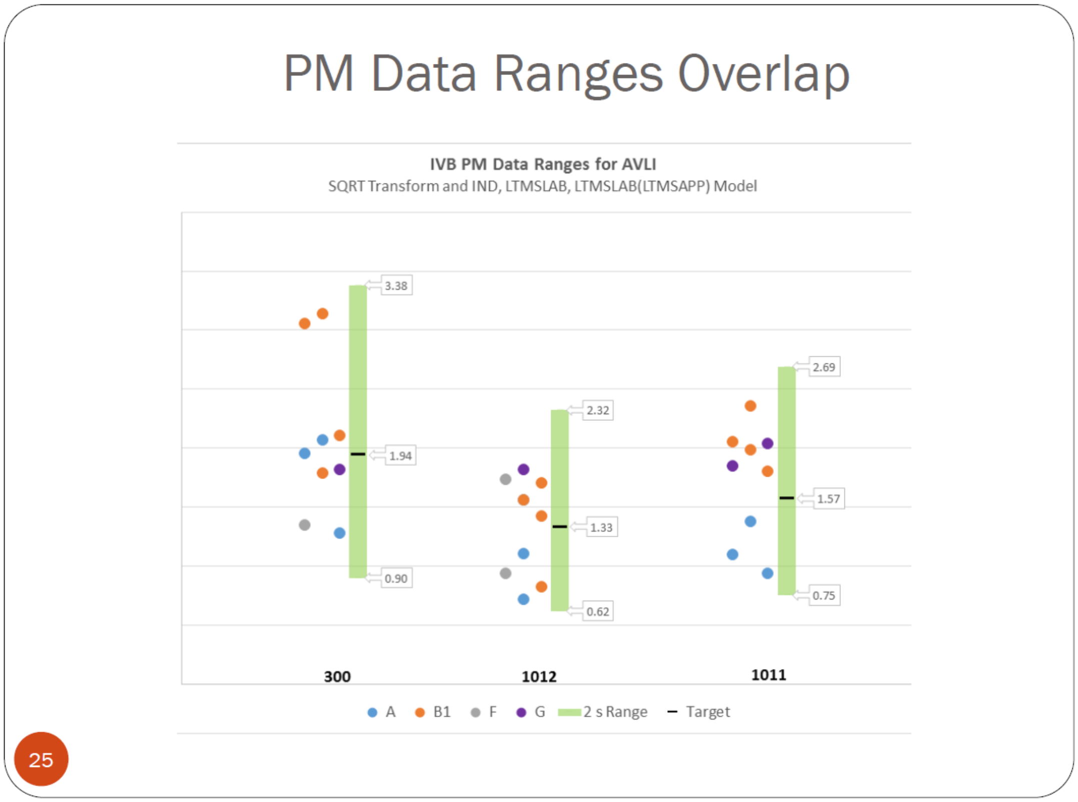
3.16.1. This slide shows the unmodeled raw data.
3.16.2. This slide can be used to establish the range of results for each oil.

3.16.3. REO1011 spans 59% of the overall range of measurements for the full Precision Matrix dataset.
3.16.4. REO300 spans 76% of the overall range of measurements for the full Precision Matrix dataset.
3.16.5. The statisticians are concerned that these large spans will complicate the stand calibration/referencing process.

3.17. Slide #25 – PM Data Ranges Overlap:



3.17.1. A lab can have a large range of test results on a single stand and will still be able to calibrate that stand.
3.17.2. In other words, a lab can get any result within the overall range of results from the Precision Matrix and will still be able to calibrate.
3.17.2.1. Even stands that cannot discriminate oils will have no problem referencing.
3.17.3. The plot in Slide #25 clearly shows that the two "severe" REO300 results are responsible for the apparent separation in oils.

4. DISCUSSION AFTER THE STATISTICIAN PRESENTATION:

4.1. Test Length (Buscher):

4.1.1. Several test lengths were evaluated during the IVB DOE matrix.
4.1.1.1. There was no discrimination in oils when the test length was 150-hours.
4.1.1.2. There was a small discrimination in oils when the test length was 175-hours.
4.1.1.3. There was not significant oil separation until the test length was extended to 200-hours.
4.1.2. The Surveillance Panel did the right thing by implementing several changes to the test procedure to eliminate oil pump starvation.

4.1.2.1. However, the larger initial oil charge appears to have pushed wear back by approximately 25-hours.

4.1.3. Toyota is leery of extending the test length by 25-hours because it would invalidate the data collected during the 2nd Precision Matrix.

4.2. Adding a High-Wear Proof-of-Performance Oil:

4.2.1. ***OHT's Comments:***

4.2.1.1. OHT recommended having each lab test a specially formulated high-wear [proof-of-performance] oil.

4.2.1.2. This additional oil should improve the statistical analysis without invalidating any existing Precision Matrix data.

4.2.2. ***Afton's Comments:***

4.2.2.1. Their recollection is that REO300 was a high-wear oil on the Sequence IVA, and REO1012 has historically been a good wearing oil [during IVB development].

4.2.2.2. They suggested that the Surveillance Panel needs to gather historical data on these two oils two confirm whether they should be high-wear or low-wear.

4.2.2.3. The ACC stated that they are not comfortable with the level of discrimination and precision with this test.

4.2.2.3.1. It will help the Surveillance Panel's position if it documents the scope of this test.

4.2.2.3.2. Is it a Sequence IVA replacement?

4.2.2.3.3. How much of a corrosive aspect do we want it to have?

4.2.2.3.4. Is this test attempting to correct an existing problem in the field, or is the goal to prevent a problem from developing in the future?

4.2.3. Buscher said that Toyota is willing to evaluate an additional reference oil.

4.2.3.1. They may be interested in testing a GF-6 prototype oil.

4.2.4. ***Historical Review of Test Development (Buscher):***

4.2.4.1. The Sequence IVB was intended to be a direct replacement for the Sequence IVA until 2013.

4.2.4.2. Toyota and the development labs eventually concluded that developing a direct replacement for the IVA would not be possible.

4.2.4.3. The emphasis then shifted towards developing a low temperature test (with an oil degradation component) that can screen "good" and "bad" oils.

4.2.4.3.1. Historically, the Sequence IVA was a true wear/scuffing test while the Sequence VE had a corrosive element.

4.2.4.3.2. Toyota wanted the Sequence IVB to replace both the IVA and VE tests.

4.2.4.3.3. However, Toyota does not want the corrosive component of the Sequence IVB to outweigh its traditional wear component.

4.2.4.4. There was a period during the development of the Sequence IVB in which the development labs were seeing considerable cylinder bore and piston ring wear.

4.2.4.4.1. This ring and bore wear was substantially reduced when the fuel sulfur specification was introduced into the test procedure.

4.2.4.4.2. This is an indication that corrosion was significantly reduced.

4.2.4.5. There was also a period during which the development labs were seeing considerable bearing damage.

4.2.4.5.1. This bearing damage was eliminated when the larger initial oil charge and modified oil pan were introduced into the test procedure.

4.2.4.5.2. This is an indication that the engine is no longer experiencing oil pump starvation.

4.2.4.6. The five development laboratories now need to work on improving test precision.

4.2.5. ***TMC's Comments:***

4.2.5.1. They are willing to solicit their suppliers for information on current reference oils.

4.2.5.2. They cautioned that suppliers are sometimes reluctant to give information on oils that will be used as poor performing reference oils.

4.2.6. ***Comments from M. Chadwick:***

4.2.6.1. A poor performing reference oil will need to deliver an average intake volume loss around 3.5-4.0mm^3.

4.2.6.2. The current IVB reference oils may not discriminate enough measure stand performance with one test (i.e. a reference test).

4.2.6.3. The Surveillance Panel should also consider finding a reference oil that offers exceptional performance.

4.2.7. ***Intertek's Comments:***

4.2.7.1. The poor performing Chain Wear reference oil (REO271) could be an option for the Sequence IVB.

4.2.7.1.1. Ford confirmed that the poor performing Chain Wear reference oil uses GF-5 chemistry.

4.2.7.1.2. It is a fully formulated commercial oil.

4.2.7.2. Another option would be to use the low-event LSPI reference oil (REO220).

4.2.8. ***Toyota's Comments:***

4.2.8.1. They want to run scoping tests with a new reference oil now, and worry about the TMC rules regarding the introduction of new reference oil later.

4.2.8.2. Ideally, the new reference oil will deliver significantly more wear than REO300.

4.2.8.3. They would like to avoid 0W-8 viscosities because that could lead to some complaints within the Industry.

4.3. Improving Test Precision:

4.3.1. ***Comments from D. Boese:***

4.3.1.1. The purpose of the [recently completed] Precision Matrix was to measure the precision of the test.

4.3.1.2. The Surveillance Panel is now talking about changing the precision of the test.

4.3.2. ***Comments from Buscher:***

4.3.2.1. It is not unprecedented for a Surveillance Panel to attempt to improve test precision after a Precision Matrix.

4.3.2.2. This has occurred with most of the GF-6 tests.

4.3.3. ***Comments from Southwest:***

4.3.3.1. This Surveillance Panel has reviewed operational data several times already.

4.3.3.2. Another operational data review may improve precision, but it will not yield a "slam dunk".

4.3.3.3. One option may be to lower the initial oil charge.

4.3.4. ***Comments from Exxon:***

4.3.4.1. They are hesitant to reduce the initial oil charge.

4.3.4.1.1. The current initial oil charge is already below the factory oil charge.

4.3.4.2. They also do not want to adjust the fuel sulfur specification.

4.3.4.3. Adding an additional reference oil may provide the "biggest bang for the buck."

4.3.4.4. Southwest added that it would be much easier to add an existing reference oil from another test.

4.4. Shifts in Stand Severity? (Lubrizol):

4.4.1. Lubrizol does not believe that there is a problem with the test procedure, per se.

4.4.2. Instead, Lubrizol believes that the apparent lack of precision is due to inexplicable shifts in stand severity.

4.4.3. For instance, Intertek clearly experienced an increase in severity with REO300 near the end of the Precision Matrix.

4.4.4. Lubrizol is even questioning the performance of its own stand.

4.4.4.1. The stand is delivering much milder results than it has in the past.

4.4.5. Analysis of oil samples (i.e. water content) is not necessarily a reliable indicator of emulsion formation on the valve deck.

4.4.5.1. Lubrizol has collected data showing large differences in fuel dilution, wear metals and water concentrations between oil from the sump and emulsion from the valve deck.

4.4.5.2. It is possible that test stands are generating different amounts of emulsion.

4.4.5.3. These differences in emulsion are changing the corrosive severity of the stand.

4.4.6. Lubrizol suspects that the blowby expansion chamber and one-way check valve may be responsible for the stand-to-stand variation.

4.4.6.1. Crankcase pressures have increased significantly since this hardware was added to the Golden Stand.

4.4.6.2. There may be anomalies in the blowby flow that the labs are not yet aware of.

4.4.7. Intertek noted that the expansion chamber and one-way check valve were added to prevent the crankcase pressure from becoming negative.

4.4.8. ***Exxon's Comments:***

4.4.8.1. Is there more consistency among individual lifter wear measurements if the expansion chamber and one-way check valve are removed?

4.4.8.2. Southwest said that this can be determined by reviewing historical data that was collected before these additions were made to the Golden Stand.

4.4.9. ***Historical Review:***

4.4.9.1. Lubrizol also called on the Surveillance Panel to perform a historical review of changes made to the test over the last three years.

4.4.9.2. At one point, there was adequate separation between these reference oils.

4.4.9.3. The original Golden Stands did exhibit good repeatability and precision.

4.4.9.4. Precision started to degrade when efforts were made to align the performance of all the Golden Stands.

4.4.9.4.1. This loss of precision occurred in conjunction with an Industry-wide reduction in test severity.

4.5. Precision Matrix #1:

4.5.1. The Surveillance Panel has operated under the assumption that test precision was adequate during the 1st Precision Matrix.

4.5.2. However, a brief review of the results from the 1st Precision Matrix indicated that this may not have been the case.

4.5.3. The Statistics Group was asked to compare the precision of Precision Matrix #1 to that of Precision Matrix #2.

4.6. ACC Letter to Surveillance Panel:

4.6.1. Afton read the ACC letter that was sent to the Sequence IV Surveillance Panel.

4.6.2. The ACC has requested that the Surveillance Panel continue its analysis of the Precision Matrix data.

4.6.3. The TMC will expand the LTMS file as needed.

4.6.4. ***Should the Surveillance Panel review 200-hour operational data files?***

4.6.4.1. Analyzing the extremely large 200-hour operational data files will pose significant logistical challenges.

4.6.4.2. A recent analysis performed by Southwest suggests that 1-hour data files are a good representation of the 200-hour data.

4.6.5. ***Afton's Comments:***

4.6.5.1. They would like to have data analyzed from both early and late in the test.

4.6.5.2. They would also like to have data analyzed from day and night.

4.6.5.3. Afton is concerned that the TAN measurements from each lab are significantly different.

4.6.6. ***End-of-Test Oil Analysis:***

4.6.6.1. The Surveillance Panel agreed that it needs to reconcile the end-of-test oil measurements taken at each lab.

4.6.6.2. This may help identify differences between labs.

4.6.6.3. Intertek agreed to perform an oil analysis on each end-of-test oil sample from the Precision Matrix.

4.6.6.4. Southwest, Lubrizol and Exxon are to send Intertek 8oz end-of-test samples from each Precision Matrix test.

4.6.7. **Forward Action Plan:**

4.6.7.1. Add a Poor Reference Oil:

4.6.7.1.1. The Surveillance Panel agreed that the best course of action at this point is to add a poor performing proof-of-performance oil to the Precision Matrix dataset.

4.6.7.1.2. Lubrizol made the following motion: "*The Surveillance Panel recommends to Toyota that a 0W-16 or higher viscosity grade, high-wear Sequence IVB oil, targeting an expected average intake lifter volume loss greater than 3.50mm^3, be identified and tested, so that it can be used in conjunction with the Precision Matrix #2 dataset to demonstrate better oil discrimination with the Sequence IVB test. The Surveillance Panel chair to issue the request to the AOAP distribution, and will request a response back to Toyota by February 1, 2018.*"

4.6.7.1.3. This motion was seconded by Intertek.

4.6.7.1.4. The motion passed unanimously (13 approves, 0 negatives and 0 waives).

4.6.7.2. Expand Operational Data Review:

4.6.7.2.1. The engineers and statisticians will review operational data from the following time segments of each Precision Matrix test.

4.6.7.2.1.1. 10HR-11HR

4.6.7.2.1.2. 101HR-102HR

4.6.7.2.1.3. 195HR-196HR

4.6.7.2.2. Each lab will be responsible for reviewing its full 200-hour data file, and comparing daytime performance to nighttime performance.

4.6.7.2.3. All this operational data will need to be made available on the TMC website by February 1st.

4.6.8. **OHT Hardware Update:**

4.6.8.1. OHT has (150) Batch-D intake camshafts in their inventory.

5. SOUTHWEST PRESENTATION:

5.1. Operational Differences:

5.1.1. Southwest continued to identify differences in operational parameters between labs.

5.1.2. ***Intake Manifold Pressure:***

5.1.2.1. The intake manifold pressure increases more aggressively at Intertek than at the other labs.

5.1.2.2. Lubrizol appears to have a 1-second delay in its intake manifold pressure ramps.

5.1.3. ***ECM Spark Timing:***

5.1.3.1. There are substantial differences in spark timing between the labs.

5.1.4. ***Crankcase Pressure:***

5.1.4.1. There are substantial differences in crankcase pressure between the labs.

5.2. Final Requests from Afton:

5.2.1. They requested that each lab compile their notes from the recent Sequence IVB engine build workshop.

5.2.2. They also requested that the labs standardize and draft a procedure for protecting test hardware from rust during extended unscheduled shutdowns.

Action Items	Person responsible	Completion Date

Follow-up Notes/Updates	Initials	Date Added

Attendees	Organization	Contact Information