Sequence VH Conference Call | MINUTES

Revision Date *7/18/2017 1:34:00 PM*

Relevant Test:	Sequence VH
Note Taker:	Chris Mileti
Meeting Date:	06-22-2017
Comments:	Statistician review of Sequence VH operational data analysis and LTMS model.

1. OPERATIONAL DATA REVIEW:

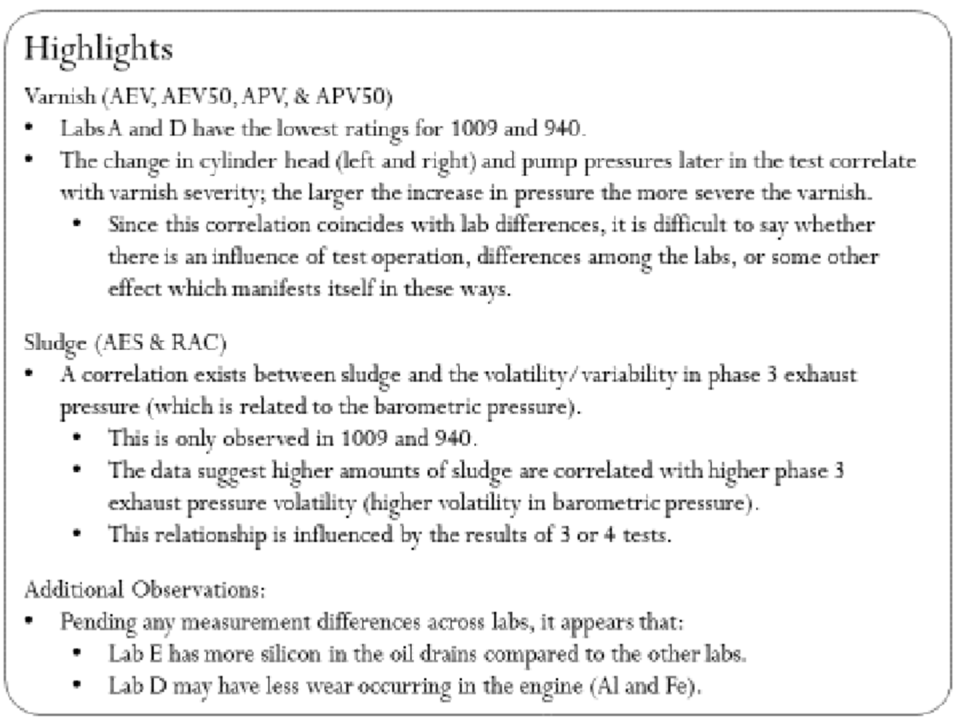
a) Background:

i) The ***VH PM Operational Data Analysis June 2017 without Appendix A,B,C,D and E….pptx*** file was presented by Kevin O'Malley.

ii) The full version of this presentation has been posted to the TMC website.
  (1) Unfortunately, this file is too large to distribute by email.

iii) A condensed version of this presentation was emailed to the Sequence V Surveillance Panel by A. Ritchie on 06-21-2017 at 9:26AM EST.
  (1) The condensed version only has (21) slides.
  (2) The appendices have been removed.

b) Slide #4:



i) Varnish Parameters:

(1) There is a correlation between the varnish parameters and the three oil pressure measurements (left cylinder head oil pressure, right cylinder head oil pressure and oil pump pressure).

(2) This correlation was established after removing the first few hours of oil pressure data from the beginning of each test's data set.

(a) The data was removed because oil pressure changes drastically within the first two days of testing as a result of rising fuel dilution levels.

(3) The statistical analysis suggests that a larger increase in oil pressure (later in the test) correlates to more severe varnish ratings.

ii) Sludge Parameters:

(1) There is a correlation between the sludge parameters and the Stage 3 exhaust backpressure.

(a) The statistical analysis suggests that more sludge is generated when the backpressure measurements are more variable.

(2) Exhaust backpressure is controlled during Stage 1 and Stage 2, but not during Stage 3.

(a) The exhaust valve is locked in an "open" position during Stage 3.

(b) As a result, the Stage 3 exhaust backpressure should be very close to the barometric pressure (and subject to the same variability).

(c) In other words, the statistical analysis suggests that there is a correlation between sludge generation and barometric pressure.

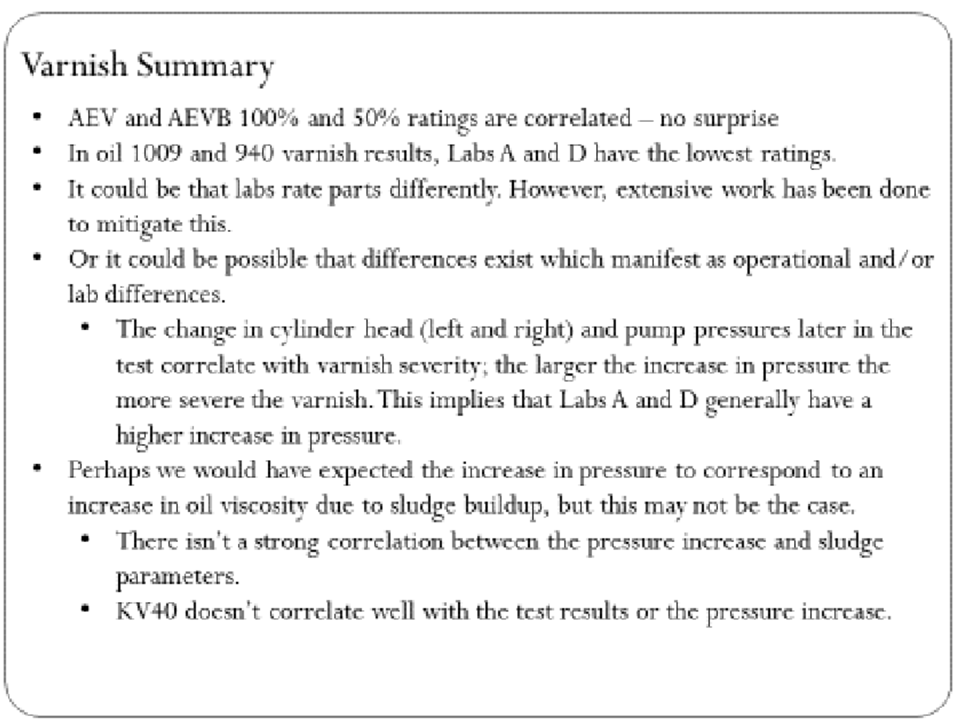
(3) The statisticians warned that this correlation is based on only a few data points (so additional analysis is needed).

(4) Afton's Comments:

(a) A relationship between sludge and barometric pressure could lead to lab-to-lab differences in test severity.

(b) The barometric pressure in Texas is undoubtedly lower than in Richmond or Ashland.

c) Slide #6:



i) Lab A and Lab D have the lowest varnish ratings with REO940 and REO1009.

(1) This may be due to lab-to-lab differences in ratings.

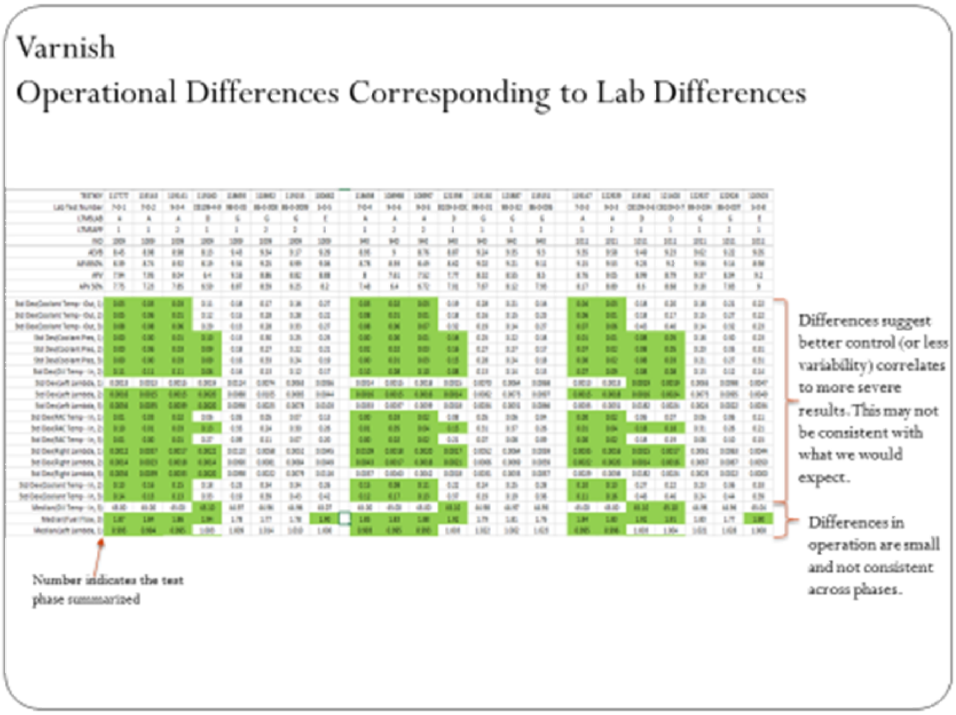
(2) However, this is unlikely because the labs have done a lot of work to mitigate rating differences.

ii) Interestingly, changes in oil pressure correlate to varnish and not sludge.

(1) This <u>contradicts</u> the widely held notion that oil pressure increases later in a test as a result of sludge build-up within the engine.

iii) It is also interesting that KV40 does not correlate well with the increase in oil pressure.

d) Slide #9:



i) The top two rows of data match the test key to the lab and test stand.

ii) The columns have been grouped according to the reference oil.

iii) The subsequent rows of data have been summarized according to the measured parameters.

(1) The measured parameters have been further divided according to stage/phase.

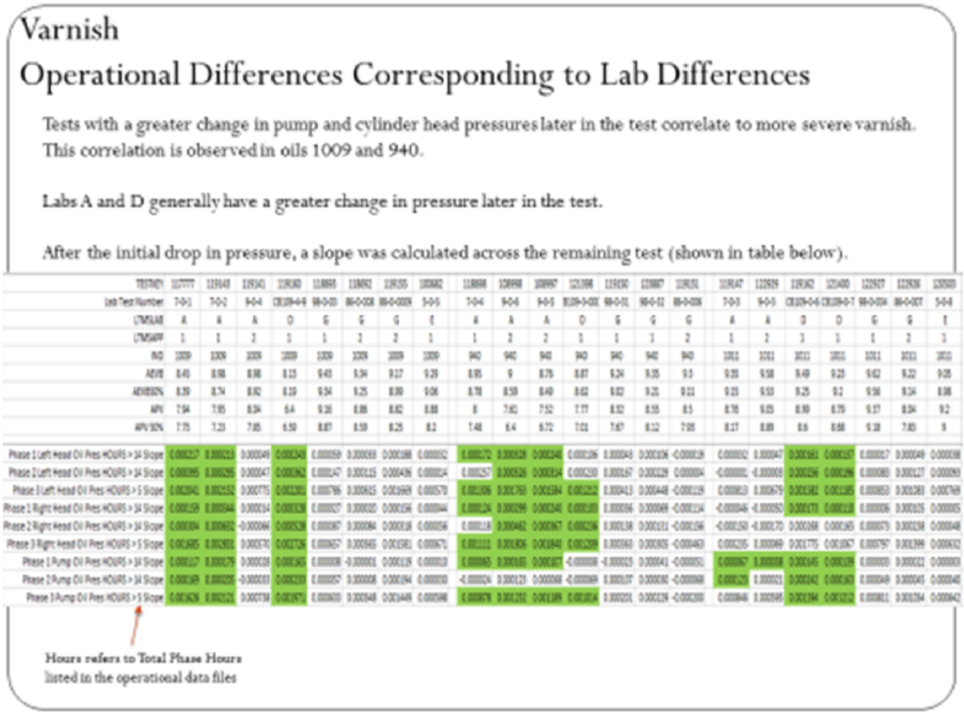
iv) The data suggests that better control of the operational parameters correlates to more severe test results.

(1) Does this make sense to the engineers?

(2) Could this be related to data filtering?

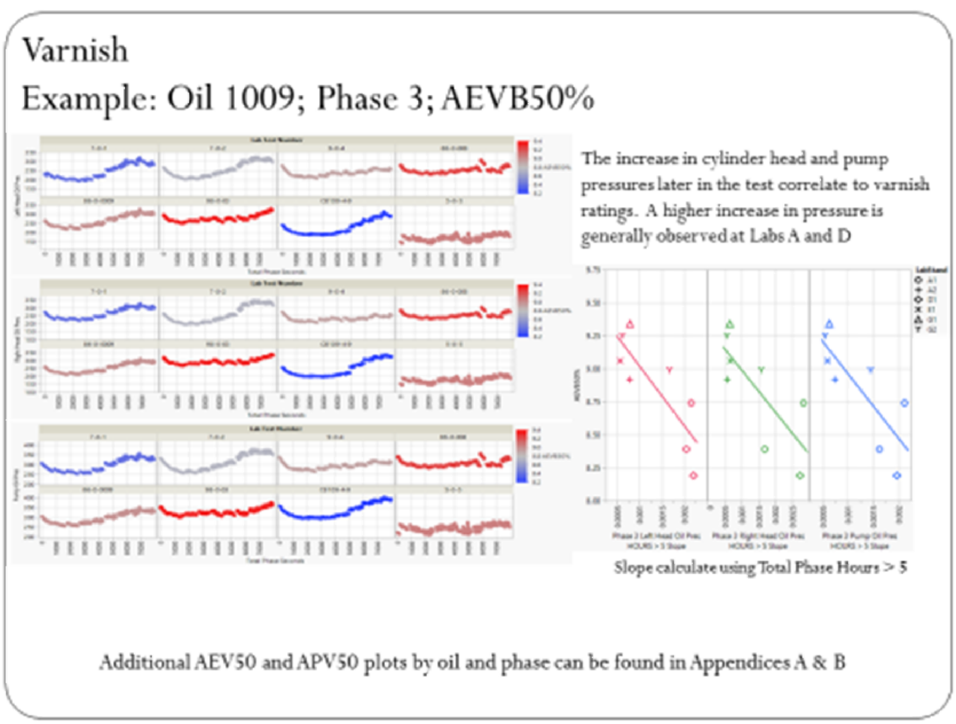
v) The engineers noted that the standard deviations for oil temperature, fuel flow and the left-side lambda are not particularly large.

e) Slide #10:



i) Tests with a greater change in oil pump and cylinder head oil pressure generally have more severe varnish.
   (1) The initial drop in oil pressure that occurred early during each test was excluded from the correlation.
   (2) Basically, the initial 14-hours of test data was removed.
ii) The correlation was made using a calculated slope for the oil pressure.
iii) Lab A and Lab D generally have larger changes in oil pressure late in the test.
iv) Slide #10 contains a tabular summary of the oil pressure versus varnish severity analysis.

f) Slide #11:



i) The operational data in this slide is limited to the Stage/Phase 3 oil pressure data for REO1009.
ii) The test results are limited to the AEV50 rating.
iii) Even though this slide illustrates an isolated case, it can be generalized to other cases.
iv) This slide shows a graphical representation of the analysis, and it <u>includes</u> the first 14-hours of data.
v) The graphs on the left-side of the slide show that a lower (i.e. more severe) AEV50 result is generally associated with a larger increase in oil pressure.
vi) The graphs on the right-side of the slide summarize the slopes of the oil pressure data from later in the test.
   (1) Higher slopes correlate to lower varnish.
vii) The oil pressures for the tests that use the same oil appear to start at the same point.
   (1) How do oil pressure differences affect varnish?
   (2) And why is there no correlation between oil pressure and sludge?
viii) Sludge is a cumulative deposit that forms over the course of the test.
   (1) Could the varnish be forming more quickly than the sludge?

ix) Infineum's Comments:
   (1) It is generally believed that the varnish mechanism stops once sludge is deposited on the part.

x) Afton's Comments:
   (1) The pistons appear to be contributing to the overall varnish more than the camshaft baffles.
      (a) This indicates that something in the crankcase is driving varnish severity.
   (2) Also, the oil pump pressures are more stable than the cylinder head pressures.
      (a) This indicates that the cylinder heads are contributing more to the oil pressure changes.

xi) Ford's Comments:
   (1) This engine does not have piston cooling jets.
   (2) This engine also does not have oil ports in the connecting rods.
   (3) The pistons and connecting rods are both splash lubricated.

xii) TMC's Comments:
   (1) REO940 does not exhibit the oil pressure increase of REO1009.
   (2) This is interesting because REO940 is the "dirtier" of the two reference oils.
      (a) This supports the theory that the oil pressure increase is <u>not</u> being driven by sludge thickening.

g) Fuel Dilution:

i) Intertek reminded the group that fuel dilution is an important variable that can influence the relationship between oil pressure and varnish.

ii) O'Malley's Comments:
   (1) The statisticians discussed fuel dilution at length.
   (2) They questioned whether the Sequence V test is collecting the "right" fuel dilution data.
   (3) The oil samples used for the fuel dilution measurements are taken at the start of Stage/Phase 3.
      (a) Is this the best time to take the samples?
      (b) Is there a more appropriate time to measure fuel dilution in the engine?

iii) Infineum's Comments:
   (1) Historically, the Sequence V needs some oil viscosity increase near the end of the test in order to generate sludge.
   (2) O'Malley noted that the oil viscosity data in Slide #13 does not support this historical observation.

(a) There is not a statistical correlation between an increase in oil viscosity and an increase in oil pressure.

iv) Has there been a recent change in the fuel dilution components with this test?

(1) The Sequence V does not currently measure the components of fuel dilution.

(2) Haltermann stressed that the formulation of the fuel has not changed.

v) Infineum's Comments:

(1) The Sequence VH generates a more "liquid" sludge.

(2) Could this difference in sludge consistency be the result of a different level of fuel dilution?

vi) Ford's Comments:

(1) It is possible that the VH engine generates similar fuel dilution levels [as the VG engine] at the end of Stage/Phase 2, but very different fuel dilution levels during Stage/Phase 1 and 3.

(2) The VH engine may have a different operating temperature during these two "cold" stages.

vii) Intertek's Comments:

(1) Fuel dilution does not typically increase significantly during Stage/Phase 3.

(2) The theory is that even though there is a lot of fuel enrichment, the combustion pressures are not high enough to push the unburned fuel into the crankcase.

(3) The VH engine does not exhibit the same drastic increase in oil viscosity during sludge formation as the VG engine did.

(a) As a result, kinematic viscosity is not as good of an indicator of sludge formation as it was with the VG test.

viii) Could the oil pressure increase be the result of more sludge suspended in the oil as a result of higher Stage/Phase 1 fuel dilutions?

(1) The higher fuel dilution could be "washing" more sludge off of hardware surfaces and into the oil sump.

(2) SWRI noted that there are significant differences in fuel dilution between the VG and VH engines:

(a) *Sequence VG fuel dilution:* 5%-10%

(b) *Sequence VH fuel dilution:* 11%-15%

(3) SWRI also suggested that the viscosity increase may, in fact, still be correlated to sludge.

(a) It is possible that the current sludge rating methods are not sensitive to some new type of sludge being generated by the engine.

(b) In other words, the current varnish rating methods may be more sensitive than the current sludge rating methods.

ix) Lubrizol's Comments:

(1) Could the number of runs on engine hardware be playing a role in this?

(a) Intertek noted that the Precision Matrix was run on all new hardware, so this factor should not be playing a role.

(2) Variability in cylinder head oil pressures may also be the result of assembly techniques.

(a) Ashland noted that there are differences in cylinder head assembly techniques.

(b) For instance, some labs seal their camshaft tie-downs while other labs do not.

x) Afton's Comments:

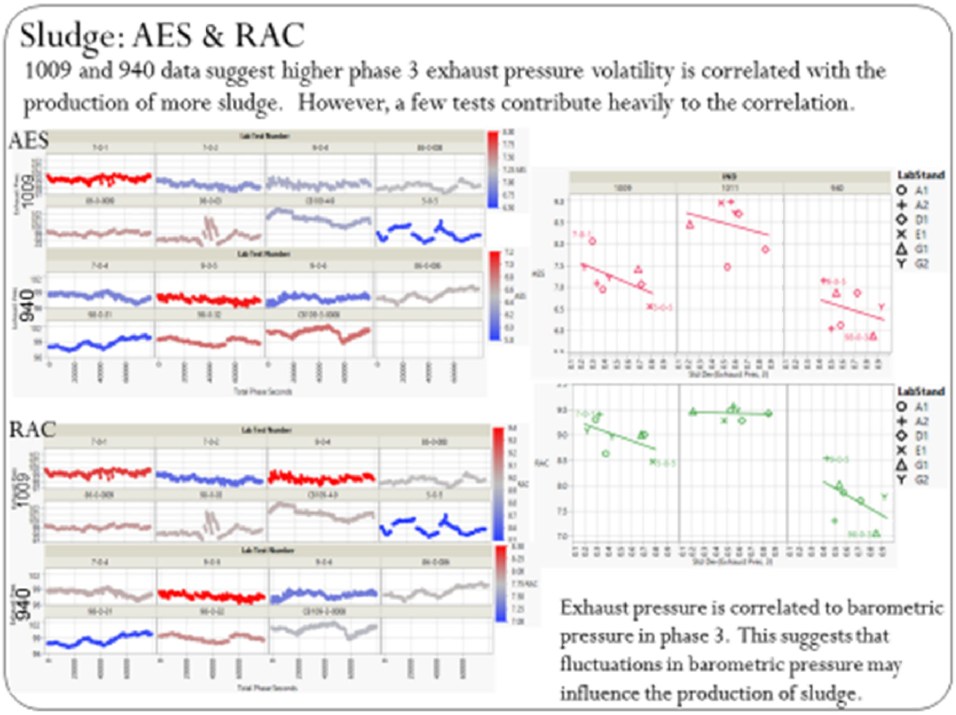
(1) Afton would like the statisticians to analyze how the left-side and right-side camshaft baffle varnish parameters correlate to oil pressure.

xi) SWRI's Comments:

(1) The oil pump pressure relief valves should be inspected for varnish or excessive wear.

(2) This could definitely impact how the oil pressure changes over the course of a test.

h) Slide #17:



i) The variability in exhaust backpressure is represented by standard deviations in this slide.

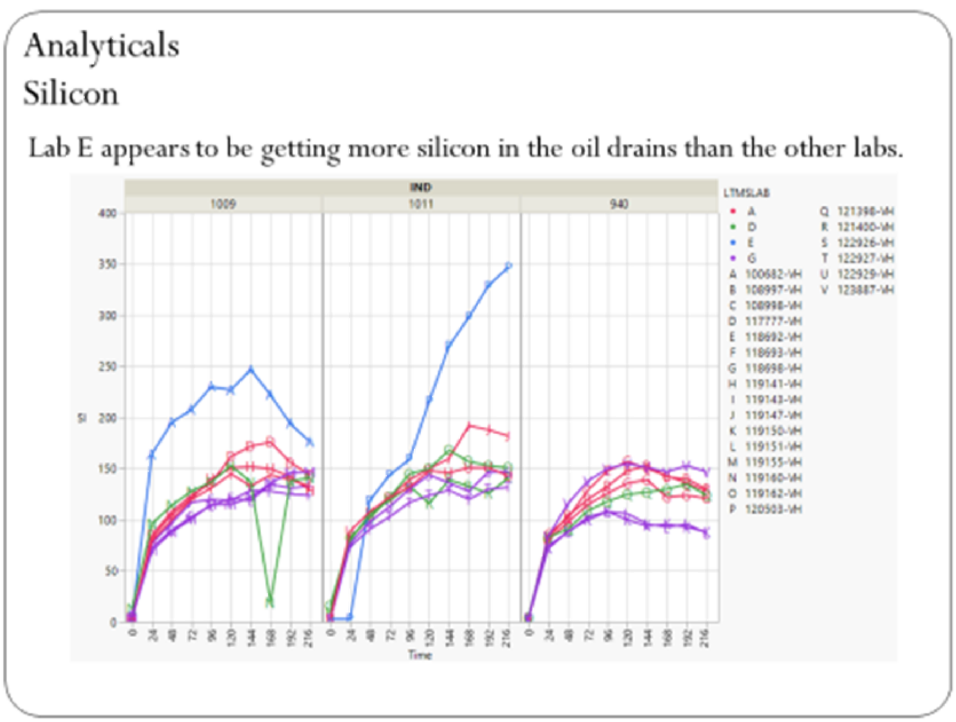
ii) The correlation between backpressure and sludge is not overwhelming, but the statisticians decided to still bring it to the attention of the Surveillance Panel.

iii) There was some discussion about adding an actual Stage/Phase 3 exhaust backpressure set-point.

(1) A set-point would probably increase sludge severity.

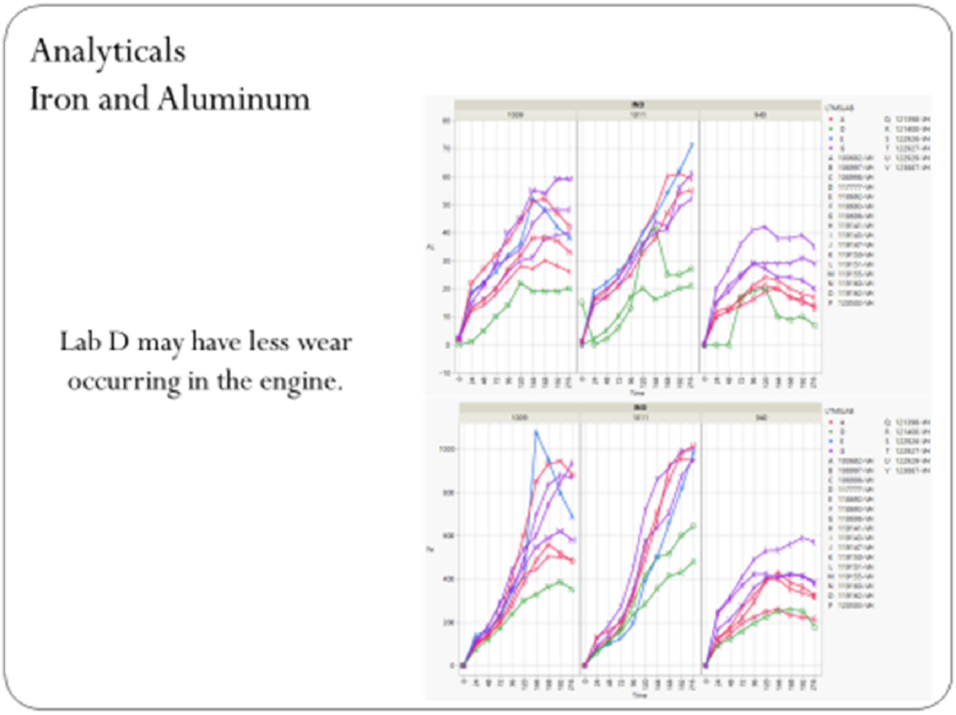
(2) It will also be very difficult to control to a backpressure set-point while the engine is at idle.

i) Slide #19:



i) Lab E has significantly more silicone in its oil drains than the other labs.
ii) Afton and SWRI are not applying silicone to their camshaft tie-downs.
iii) Ashland is using silicone on their camshaft tie-downs and in certain other locations throughout the engine (such as the front cover).
iv) Intertek will talk to its engine builder to determine where RTV is being used on its engines.

j) Slide #20:



i) Lab D has less iron and aluminum in its oil drains.

k) Engine Build Workshop:

i) The five Sequence VH test labs have agreed to hold an engine build workshop in the near future.
ii) The oil pressure differences previously discussed will be at the top of the agenda.

2. SETTING TARGETS:

a) Background:

i) This portion of the conference call focused on the ***VH LTMS Summary.docx*** document and the ***VH LTMS work 20170621.xlsx*** spreadsheet.
ii) Both files were emailed to the Sequence V Surveillance Panel by A. Ritchie on 06-22-2017 at 8:58AM EST.

b) Setting Targets:

i) Ford asked whether a motion is needed to set the VH targets.
   (1) Infineum replied that the Precision Matrix is used to set the targets.
   (2) The Surveillance Panel has already agreed that the submitted Precision Matrix tests were operationally valid.

c) Review of LTMS Summary Document:

i) Bullet #1:

(1) The RACS parameter shows better performance if a transformation is used.
(2) The group will need to approve this transform.

ii) Bullet #3:

(1) The two submitted tests from Lab E were included in the calculation of targets.

iii) Bullet #6:

(1) The statisticians are recommending a lab-based LTMS system that is similar to that used for the Sequence VG test.
(2) The Sequence VH LTMS system will use Z_i and e_i limits.
    (a) This is a departure from the current VG system.
(3) The Z_i Lambda is different than what was used for the VG system.
    (a) This change should reduce the "masking" of problems.
(4) At least (3) tests will be needed to calibrate a test stand.
(5) At least (4) tests will be needed to calibrate two test stands.
(6) Ashland will need to run one more test in order to calibrate their stand.
(7) Labs will almost always have a severity adjustment unless Z_i=0.
    (a) However, this severity adjustment may be extremely small.
(8) If a lab gets too far away from a target, it will need to return closer to that target in order to calibrate.
(9) Bullet 6e is a new concept for the Sequence V.
(10) Bullet 6f allows the Surveillance Panel to implement tighter limits if needed, such as when there is a known change that can impact overall severity.
(11) The concept discussed in Bullet 6h has been successfully used in other tests.

iv) Bullet #7:

(1) Reference requirements remain unchanged from the Sequence VG test.

d) Review of LTMS Work Spreadsheet:

i) Severity adjustments will not be changed until a lab can produce a passing result.
ii) There are no longer separate LTMS charts for each stand.

iii) SvM Charts:

(1) The lines on the *AES SvM* tab are straight and parallel – which is ideal.
(2) The lines on the *RAC SvM* tab are curved because of the transform.
(3) The lines on the *AEV50 SvM* tab are not parallel.
    (a) This is not ideal.
    (b) The oil limits may need to be changed as more data becomes available.
(4) The lines on the *APV50 SvM* tab are also not parallel.
    (a) However, the lack of parallel lines is not as much of a concern as it is for the AEV50 parameter.

e) Motion for Surveillance Panel Approval of the Sequence VH Test:

i) **Official motion:** *The Sequence V Surveillance Panel agrees that the Sequence VH is ready to be moved forward as an ASTM standard to be considered as a long-term replacement for the Sequence VG test to measure low temperature sludge and varnish performance. The Sequence V Surveillance Panel further recommends that the Chairman of the Sequence V Surveillance Panel makes a recommendation to the PCEOCP and AOAP groups that the Sequence VH test be brought forward for inclusion as a test for the evaluation of low temperature sludge and varnish in the ILSAC GF-6 and other API S-categories. The "VH LTMS summary" document be adopted as written for the Sequence VH LTMS.*

ii) Ford submitted this motion to the Surveillance Panel, and Intertek seconded the motion.

iii) The TMC noted that LTMS changes require a waiting period of at least two-weeks.
iv) The TMC also requested an additional meeting to discuss how LTMS will be implemented for this test.
v) Results of vote:
(1) *Affirmative votes:* Afton, Lubrizol, Oronite, OHT, Haltermann, VP, TMC, Ford, Intertek, SWRI, Valvoline, Infineum
(2) *Did not cast votes:* TEI, General Motors, Shell

Action Items	**Person responsible**	**Completion Date**
Schedule an engine build workshop.	All Labs	

Follow-up Notes/Updates:	**Initials**	**Date Added**