IVB Metrology Workshop | MINUTES

REVISION DATE: 8/18/2017 3:15:00 PM

Relevant Test:	Sequence IVB
Note Taker:	Chris Mileti
Meeting Date:	08-15-2017
Comments:	Sequence IVB Metrology Workshop hosted by Lubrizol. The main purpose of this workshop was to review the Generation-2 Keyence software.

1. DISCUSSION:

a) Chamfered Intake Camshafts:

i) The intake camshafts for the upcoming prove-out tests will have lobes with chamfered edges.

ii) OHT's vendor is refinishing the surface of each lobe after the chamfers are applied.
   (1) The purpose of this refinishing is to remove any debris from the chamfering process.

iii) This process has the following unanticipated consequences:
   (1) It is slightly reducing the length/diameter of the lobe.
   (2) It is increasing the R_a of the lobe surface.
   (3) It may be altering the surface hardness of the lobe.

iv) Surface R_a:
   (1) Lubrizol and Intertek agree that the change in R_a will probably not be significant.
   (2) OHT will work with their vendor to establish a R_a specification for future camshaft batches.
      (a) They will target a R_a of 0.2µm for the Batch-D chamfered camshafts.
   (3) Intertek's R_a data:
      (a) Their historical data for (178) Batch-A and Batch-C intake camshafts had an average R_a of 0.18µm.
      (b) The average R_a for their (3) recent chamfered camshafts was 0.65µm.

v) Surface Hardness of Lobe:
   (1) Earlier work performed by Lubrizol indicated that the hardened outer layer of the intake lobes does not extend very far below the surface.
   (2) As a result, Lubrizol is moderately concerned that removing additional material from the lobe (as is being done during the chamfering process) may be reducing the camshaft's surface hardness.
   (3) OHT's vendor will be collecting surface hardness data on the chamfered lobes today.

vi) Impact on Lifter Grades:
   (1) The chamfered camshaft will definitely shift the bell curve distribution of the intake lifter grades used by the labs.
      (a) The bell curve will shift toward lifter grades that are numerically higher.
   (2) The smaller camshaft lobes will reduce the valve lift by 0.1mm.
      (a) This is a change of approximately 0.5% (which is obviously very small).
   (3) The 2NR-FE engine has available lifter grades that range between (approximately) 20 and 50.

(a) The labs agreed that 36 is probably one of the more common grades.
(b) Exhaust grades are typically higher than intake grades.

(4) The smaller diameter of the chamfered intake lobes will require an increase of about 2-3 grades.
(a) As a result, the labs may need to shift the range of lifter grades that they typically inventory.

vii) Edge-Detect with PDI Scans:

(1) It is possible that the PDI software can mistakenly place the "edge" of the lobe on the chamfer instead of the end of the flat surface.
(2) Even with this being the case, Lubrizol still recommends leaving the edge-detect feature activated.
(a) Releveling can be performed manually if the "edge" is placed on the chamfer.
(3) The Sequence IVB exhaust camshafts already have a chamfered edge, and they are being measured on the PDI without any significant problems.

b) Intake Lifter Crown:

i) Lubrizol would like to relax the acceptability criteria for the crown/profile of intake lifters.
(1) The current criteria result in an excessive number of rejected intake lifters.
(2) For example, Intertek currently has an inventory of (150) rejected intake lifters.

ii) It is difficult to use rejected intake lifters on the exhaust-side of the engine because the grade requirements are very different.

iii) Toyota's current production specification for lifter crown is 0µm-15µm.

iv) Section H of the procedure, which deals with the PDI measurements, contains qualitative acceptability criteria for a lifter's profile.
(1) It is common to have lifters with an asymmetric profile.

v) Exxon does not have the OHT lifter fixture that was designed for use with the PDI.

vi) The profile of the lifter crown is critical for the PDI measurements.
(1) However, the lifter crown is probably less critical for the 3-D Keyence measurements.

vii) Proposal by the Workshop Attendees:

(1) All intake and exhaust lifters for the Sequence IVB must have a W_t between 0µm-15µm.
(2) Section H of the Sequence IVB procedure will no longer contain subjective specifications for acceptable and unacceptable lifter profiles.
(a) It will be up to the discretion of the Keyence operator to determine if the lifter should or should not be used.

c) General Discussion about PDI Measurements:

i) There are no rejection criteria for camshafts in the Sequence IVB procedure.
(1) Do we need to add rejection criteria to the procedure?
(2) Intertek stated that (at a minimum) camshafts with convex or concave lobes should be rejected.

ii) The Sequence IVB procedure requires that camshaft lobes are measured for W_t, R_a and R_{sk}.
(1) However, the Sequence IVB report only contains W_t and R_a.

iii) Section H needs to be added to the most recent draft of the Sequence IVB procedure that is posted on the TMC website.

iv) The attendees agreed to continue taking PDI traces of both camshafts.

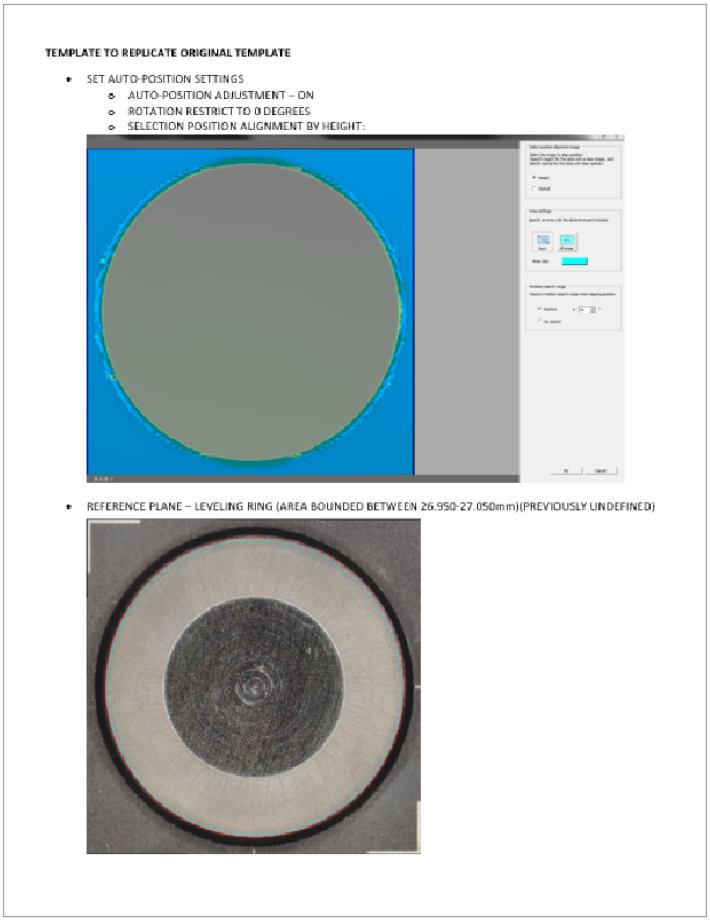
v) The attendees agreed to continue measuring the camshaft oil feed holes, journal diameters and overall bend.
(1) Intertek noted that these measurements frequently lead to the identification of unexpected hardware problems.

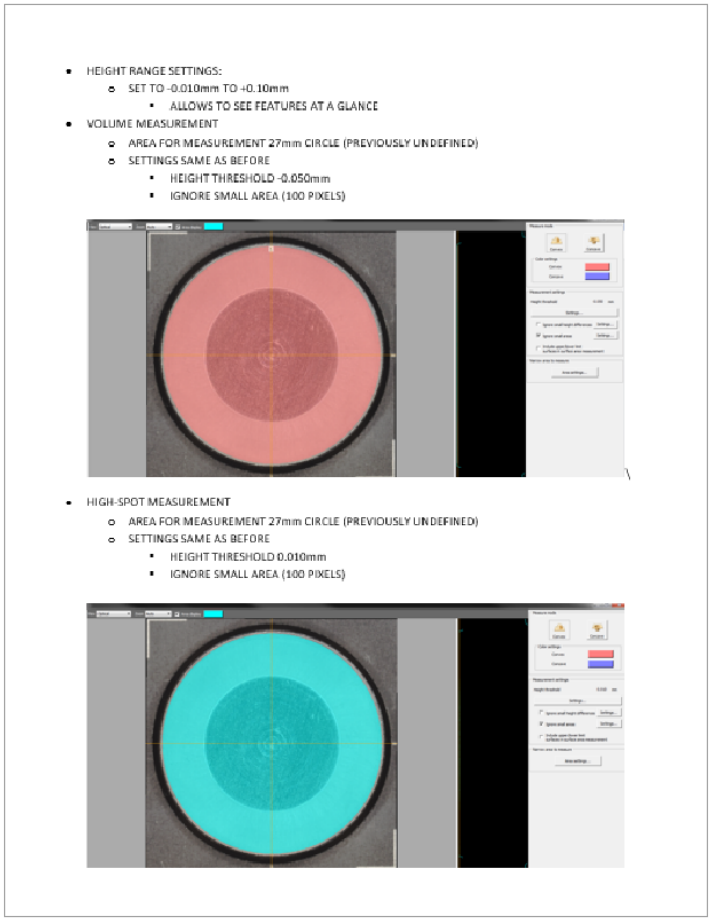
d) General Discussion about IVB Data Dictionary:

i) R_{sk} will need to be added to the upcoming version of the IVB Data Dictionary.
ii) The TMC needs to update the LTMS database for the Sequence IVB.
   (1) This will require the Surveillance Panel to decide on the data that should be included in LTMS.
   (2) Once the dataset is populated, the statisticians can start data-mining the information to establish acceptability criteria for parts (such as the camshafts).

e) Review of Keyence Measurements:

i) Exxon and Afton were both able to use the settings provided by Lubrizol prior to the workshop.
ii) Selecting "auto" save or "manual" save will be up to the preference of each lab.
iii) During the meeting, Lubrizol provided a document that summarized the settings that were used.





iv) Lubrizol's Initial Recommendations:

(1) Lubrizol recommends selecting the appropriate Keyence settings to prevent the image from rotating.
   (a) It is almost impossible for the lifter to rotate if the OHT fixture is being used.
(2) The data capture process that is currently being used is very robust.
   (a) Most of the measurement variability is probably occurring during post-processing.

v) Talc:

(1) Afton and Intertek have both experimented with the same talc spray.
   (a) The spray creates "waves" of talc on the surface of the part that can interfere with the measurements.

(2) There was a unanimous agreement among the workshop participants that talc should be used on all post-test lifters (and that non-talc measurements on post-test lifters can be eliminated).

vi) Premeasuring Lifters:

(1) Some of the workshop participants discussed the possibility of premeasuring lifters from popular grades to create a readily available inventory of test parts.

(2) Lubrizol and Intertek have not tried to establish an inventory of premeasured lifters.
(a) Both labs feel that there is enough lead time to measure lifters for a specific test kit.

f) Keyence VIEWER Settings:

i) There was a consensus among the workshop participants that the following Viewer settings should be used:
(1) 40X – High Magnification
(2) Standard Mode
(3) Auto Brightness

ii) These settings should not significantly increase measurement time over current levels.

iii) The group discussed a previous trial that was performed by Intertek, Southwest and Lubrizol to determine the impact of ambient lighting on lifter measurements.
(1) The results indicated that ambient lighting had no impact on the performance of the Keyence.

g) Establishing Lifter Grades for an Engine:

i) The labs have requested engineering prints for the trays that are used by Lubrizol to store and transport test kits.

ii) The feeler gauge must slide under the camshaft lobe easily when measuring valve clearance.

iii) The Sequence IVB procedure needs to provide guidance regarding how lifter grades are selected based on valve clearance.

iv) Guidance Provided by Intertek:

(1) *Intake valve clearance specification (cold):* 0.00571-0.00925 inches

(2) *Exhaust valve clearance specification (cold):* 0.0108-0.0144 inches

Intake Valve Clearance (in)	Direction of Grade Change	Number of Grades to Change
0.005	Down	2
0.006	Down	1
0.007	No Change	No Change
0.008	No Change	No Change
0.009	Up	1
0.010	Up	2
0.011	Up	3
0.012	Up	4

Exhaust Valve Clearance (in)	Direction of Grade Change	Number of Grades to Change
0.010	Down	2
0.011	Down	1
0.012	No Change	No Change
0.013	No Change	No Change
0.014	Up	1
0.015	Up	2
0.016	Up	3
0.017	Up	4

h) Statistical Analysis by Kevin O'Malley:

i) Kevin O'Malley performed a statistical review of the small set of Keyence data collected by Intertek and Lubrizol during the past week.

(1) He sent an email that summarized his findings to both labs on 08-11-2017.

ii) Excerpts from the 08-11-2017 Email:

(1) As you know 4 of the 8 lifters measured by LZ were chosen to also be measured by IAR.

(2) They were chosen to span the range of the observed measurements (of all 8 lifters) and represent both new and EOT lifters.

(3) Based on the measurements from these 4 lifters, the ideal situation is not present; this would be a combination of low measurement variability coupled with no difference between Lab's measurements.

(a) It seems the 25X mode is the least viable solution. The measurement variability is generally higher and the difference between the labs may depend on whether a new or EOT lifter is used. Keep in mind that this could also mean that the difference between the labs changes across the measurement range since the EOT lifters measured are on the lower end of the measurement range compared to the new filters.

(b) While the 40X Superfine Mode generally has the least measurement variability, it also shows a difference in the labs which appears to vary across the measurement range.

(c) This leaves the 40X Standard Mode. While this is not the ideal situation, it may be the best we have so far. The measurement variability is the lowest when the leveling donut it used, but the lab difference appears more consistent when the ring is utilized.

(d) More data from additional filters and labs should be gathered prior to a final determination. The group could consider dropping the 25X mode from future work.

(4) More Detail:

(a) There is obviously a difference in the measurement depending on the leveling type used; the ring almost always yields higher measurements.

(b) In general, IAR measurements are higher than LZ's:

(i) When the 25X Mode is utilized:

1. LZ's average measurements on the new filters (32-00307A and 44-00169A) are higher by about 0.04 on average.

2. In the EOT lifters (32-00287A & 36-00008A), there is a difference in the magnitude of the lab difference between the leveling types with the ring showing a larger difference between the lab's measurements.

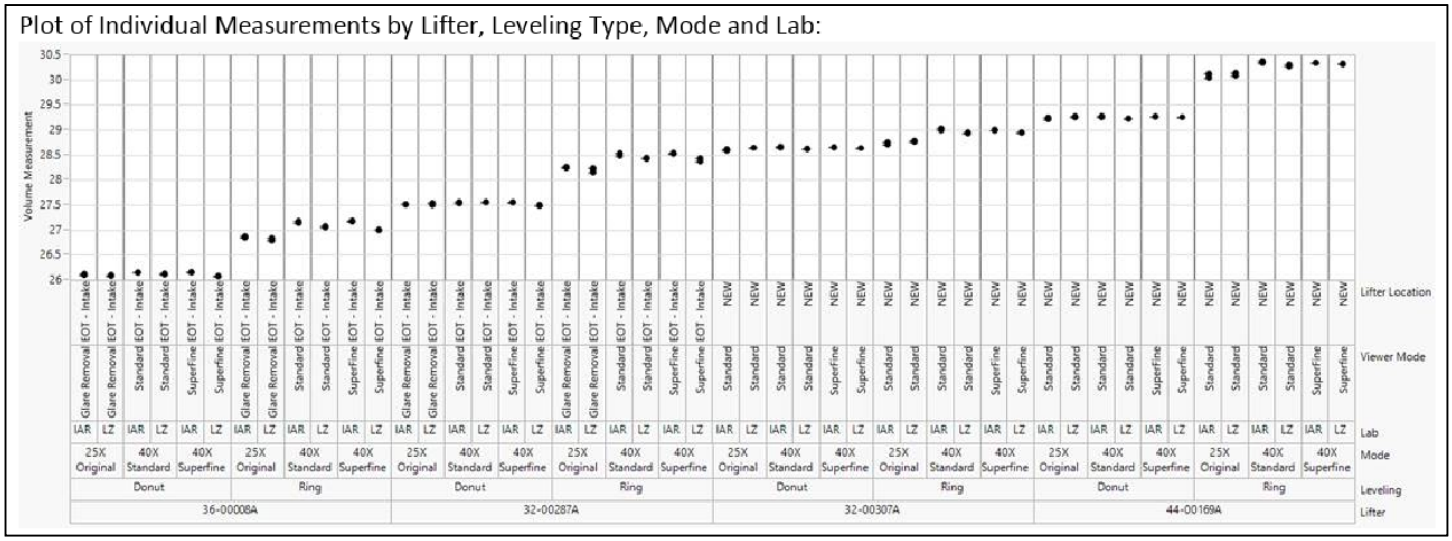
(ii) When the 40X Standard Mode is utilized:

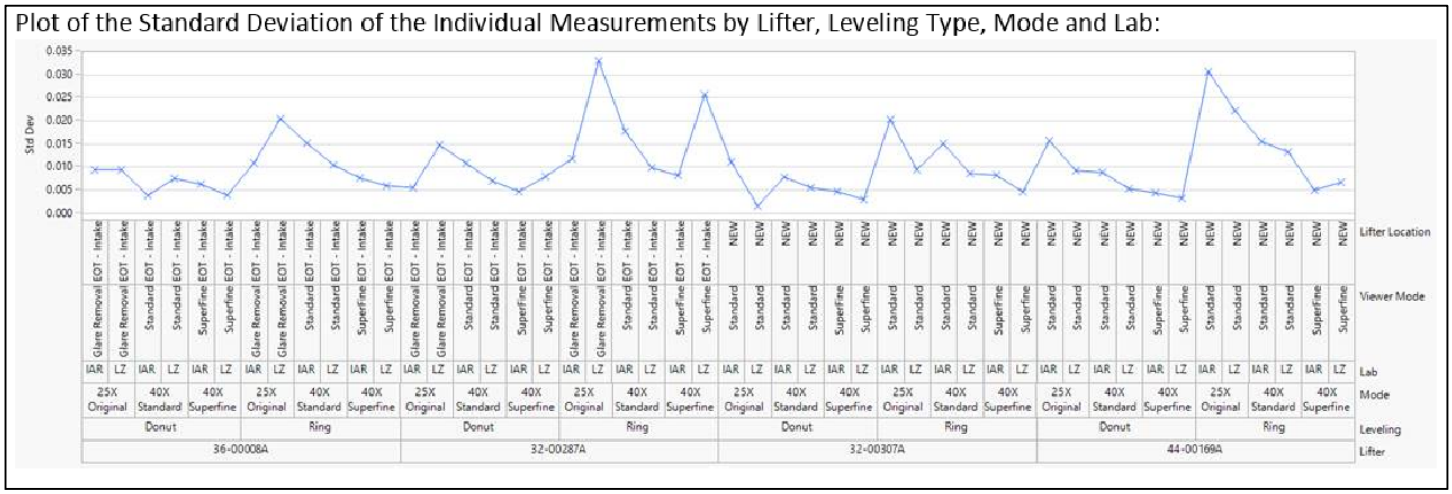
1. IAR's average measurements are almost always higher than LZ's and the difference between the labs is greater when the ring is used.

(iii) When the 40X Superfine mode is utilized:

1. IAR's average measurements are always higher than LZ's
2. The difference between the labs is greater when the ring is used and is more pronounced in the new filters

(c) Generally speaking, the measurement variability (i.e., the standard deviation in the 6 measurements taken on a lifter under a specific set up) is larger when the ring is used with either the 25X or 40X Standard mode. The measurement variability is generally the least when the 40X Superfine Mode is used with either of the leveling types.

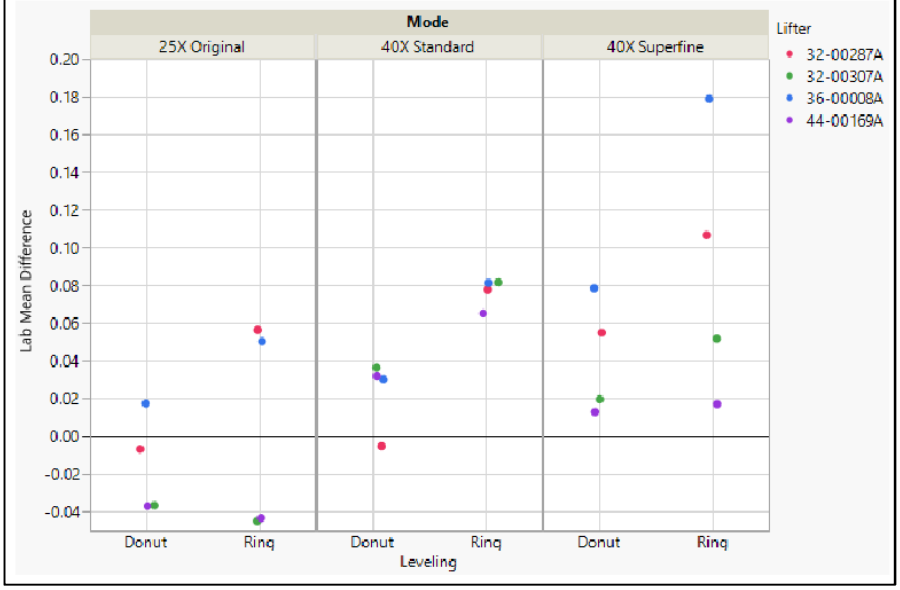




Plot of the Difference in the Average Measurement between the Labs:

A negative value implies that LZ's average measurement was more than that of IAR

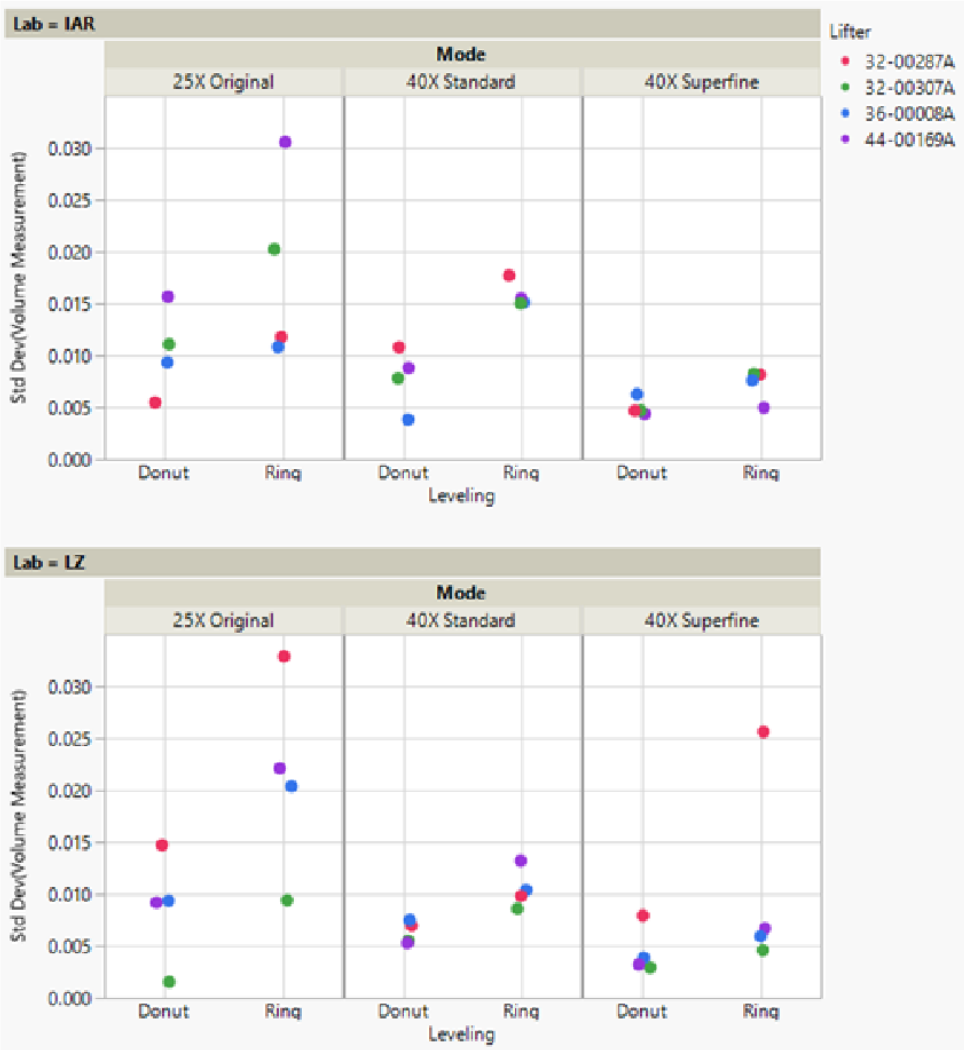
A positive value implies that IAR's average measurement was more than that of LZ



Standard Deviation of Measurements by Lifter:

Lab's plotted separately

Data plotted by Mode and Leveling Type



iii) O'Malley's Comments During Meeting:

(1) This group needs to determine if there is "a difference in how the labs differ" in regard to the Keyence measurements.

(2) His email from 08-11-2017 summarized how the Keyence units at Intertek and Lubrizol responded to various changes in software settings.

(a) He warned that the Keyence units at the remaining (3) laboratories may respond differently than those at the first (2) laboratories.

i) New Proposals for Keyence Methodology:

i) Proposal by Southwest:

(1) It may be possible to use the capabilities of the G-2 software to directly compare the pre-test and post-test lifter scans.

(2) The "CAD Compare" feature can be used to accomplish this.

(3) This will require the use of .STL files along with some extra calculations.

ii) Proposal by Lubrizol:

(1) It may be possible to use the top surface of the OHT fixture as the reference plane.

(2) The hole used to hold the lifter could be cut deeper.

(a) This will allow the lifter and the top surface of the OHT fixture to remain in the Keyence unit's field of view.

2. FORWARD ACTION PLAN:

a) Upcoming Prove-Out Testing:

i) New Keyence Settings:

(1) The group agreed to the following Keyence settings for the upcoming prove-out tests:

(a) G-2 software

(b) 40X, high magnification

(c) Standard mode

(d) The reference plane will be applied using a ring template (provided by Lubrizol).

(e) Auto-positioning will be used.

(f) Auto-brightness will be used.

(g) Rotation-restriction will be used.

(h) Talc will be used on end-of-test hardware.

(2) All of the labs already have the necessary templates.

ii) Repeat Measurements:

(1) O'Malley recommended collecting repeat measurements during the prove-out testing.

(2) Intertek suggested repeating the pre-test and post-test scans for the 2nd row of prove-out testing.

(a) Intertek already started the 1st row of prove-out testing with the older Keyence settings and templates (so they will obviously not be able to provide repeated pre-test measurements).

(b) These repeated measurements would only be necessary for the intake camshafts.

(c) SWRI would not be required to provide repeated measurements for their 2nd high-event lobe failure candidate oil in Row 2.

(3) Ideally, O'Malley would like to see (6) repeated measurements per lifter.

(a) However, at a minimum he would need at least (3) repeated measurements per lifter.

(b) O'Malley does not need to see the lifter removed and replaced during these repeated measurements.
(i) Previous round-robin measurements suggested that there was no systematic bias with removing and replacing the lifters.

iii) Keyence Software:

(1) Intertek, SWRI and Lubrizol will need to submit measurements using both the G-1 and G-2 Keyence software.

b) Round-Robin:

i) Each of the labs can collect their lifter images before the variables of the round robin are established.
(1) Different templates and post-processing settings can be applied to these images at a later time.

ii) Each laboratory will provide a list of the lifter grades that they used for their first prove-out test.
(1) This list will be used to select the lifter grades to use for the round-robin.

iii) Only intake lifters will be used.

c) Summary of Prove-Out Testing Expectations (B. Buscher Email, 08/15/2017 at 3:34PM EST):

	Intertek	Southwest	Lubrizol	Exxon
Mass Loss	Yes	Yes	Optional	Optional
PDI Measurements	Yes	Yes	Optional	Optional
G-1 Software with Original Settings	Yes	Yes	Yes	No
G-2 Software with New Settings	Yes (Excluding Row 1)	Yes	Yes	Yes
(3) Repeats using G-2 Software	Yes	Yes	Yes	Yes

Action Items	**Person responsible**	**Completion Date**

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

Attendees	Organization	Contact Information
Bill Buscher	Intertek	
Ray Cleven	Intertek	
Steven Avis	Exxon	
Victor Veiga	Exxon	
Matthew Hayden	Afton	
Taylor Bartholomew	Southwest	
Jason Bowden	OHT	
Chris Mileti	Lubrizol	
Mike Kinzel	Lubrizol	
Brian Smargiasso	Lubrizol	
Phil Austin	Lubrizol	
Jerry Brys	Lubrizol	
Kevin O'Malley	Lubrizol	