

LSPI SURVEILLANCE PANEL MINUTES

Date: 15 Nov 19

| ATTENDEES | |
|------------|--|
| SWRI | Khaled Rais, Christine Eickstead, Pat Lang |
| INTERTEK | Al Lopez, Jason Soto |
| AFTON | Scott Smith |
| LUBRIZOL | George Szappanos |
| INFINEUM | Andy Ritchie, Charlie Leverett, Doyle Brunson, |
| FORD | Ron Romano |
| APL | Tim Hadaway, Christian Mueller |
| TMC | Rich Grundza |
| OHT | Jason Bowden |
| TEI | Dan Lanctot |
| SHELL | Jeff Hsu |
| GM | Tim Cushing |
| HALTERMANN | Prasad Tumati |
| ORONITE | Robert Stockwell |

- Al Lopez from IAR explained the presentation on the dealer piston situation, see attachment. Summary as follows:
 - Al Lopez advised that IAR is running low on BB pistons and advised that they would like to use dealer pistons moving forward.
 - In the 06/14/2016 and 07/30/2017 timeframe, a total of 43 reference oil runs were conducted on dealer pistons with AA1 designation. Yi summary on those results look reasonable see table in attachment.
 - Intertek advised that there are two letter designations for the dealer pistons that they would like to use, AA1 and AB1. Their plan is to use AA1s first and then move to AB1s using standard new engine reference protocol when running on either designation.
 - Robert Stockwell wanted everyone to be aware that we will be approving these pistons designation AB1) on only two references.
 - Ron Romano advised the group that these dealer pistons are very similar to the BB pistons and he has no issue with using them. In fact, the AB1 pistons are closer to the BBs than the AA1s because the AB1s and BBS have a 2.5 mm oil drain holes while the AA1s have 3 mm holes.
 - Andy Ritchie stressed that he would like it to be clear that the pistons used in any test be noted so it can be deciphered when needed.

Motion:

To allow the use of dealer pistons AG9Z-6108-D for Sequence IX registered testing following a successful calibration (two reference runs). AA1 pistons will be consumed before switching to AB1 pistons. At least one of the calibration runs must use oil TMC 224. Effective 11/15/2019.

Jason Soto - IAR / Ron Romano - Ford.
Motion Passed 13-0-1

- **Processing Issues:** Two changes were suggested by SwRI based on data from references. The first change was to section 12.2.2.1 in order to include very early ignition events that were previously being deemed invalid cycles. The second was to change the wording in 12.2.2.3 to exclude data where PMINV deviates from the mean by more than 0.5 V because it previously only excluded data with PMINV less than the mean minus 0.5. Deviations in either the positive or negative direction have been seen when a sensor is impacted.

Motion: To change section 12.2.2.1 to “Remove all cycles with a MFB2 > 30°” instead of the current “Remove all cycles with a MFB2 < -30°.”

Khaled Rais – SwRI / Jason Soto – IAR
Motion Passes 13-0-1

Motion: To change 12.2.2.3 to ...“remove all cycles with a pressure minimum voltage (PMINV) different than the mean of remaining PMINV by more than 0.5 V. For example, if the mean PMINV of the remaining engine cycles on cylinder 1 is -8.02 V, remove all cycles with PMINV < -8.52 V or PMINV > -7.52.”

Khaled Rais – SwRI / Jason Soto – IAR
Motion Passes 13-0-1

- Other discussion:
 - Once introduced for testing, a name change for 2019-BB pistons was suggested by Andy Ritchie to make them easier for clients to identify and more accurate because the pistons are actually made based on the AC2 print not the BB print.
 - SwRI identified that the compression ratio was found to be higher with the 2019-BB pistons than the BB pistons. The group discussed the possibility of using a thicker 1.33 mm head gasket instead of the current 0.895 mm thick gasket was put forward to help reduce the compression ratio when using the 2019-BB pistons. SwRI will look into how much of an impact the switch is estimated to make. LZ and APL said that they would also be willing to check the compression ratio to confirm SwRI’s findings.

- **New business:**

Rich Grundza requested that the group please ensure that we use consistent designations on the Sequence IX Report Form 16 for pistons. The current possibilities are now 2016 BB, Dealer AA1, or Dealer AB1.

Seq IX Dealer Piston Batch Introduction

Jason Soto

11/05/2019

Background

- AC2 pistons were used during test development and for the precision matrix.
- BB pistons were introduced through references right after the PM and are currently being used for registered testing.
- IAR used AA1 (AG9Z-6108-D) pistons that were purchased from the dealership for non-registered work. These pistons were used in between the AC2 and BB piston batches from 06/14/2016 to 07/30/2017.
- One dependent lab has run out of BB pistons and IAR is on the verge of running out as well. IAR is proposing the approval to use dealership pistons (AG9Z-6108-D) for registered testing.

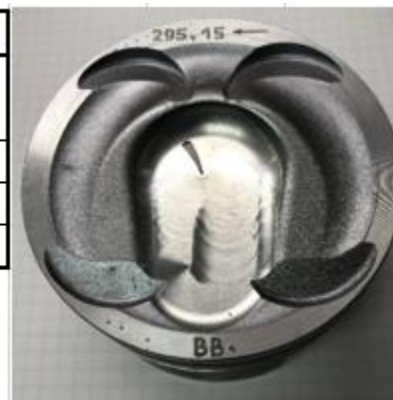
BB and Dealership piston equivalency

- 17 different engines were run with dealership pistons between 06/14/2016 and 07/30/2017 for a total of 43 reference oil runs.

| RO | N | Avg Yi | Avg Events | Target |
|-------|----|--------|------------|--------|
| 220 | 5 | 0.816 | 0.86 | 0.44 |
| 221 | 3 | -0.115 | 10.66 | 10.94 |
| 222 | 35 | -0.422 | 16.73 | 17.69 |
| Total | 43 | -0.256 | | |

Piston Measurements

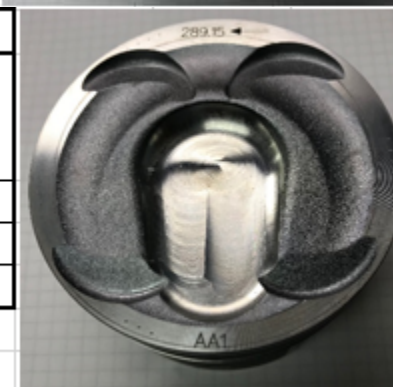
| | Piston Type | Ring Land | Longitudinal | Transversal |
|-------------------------|------------------------|-------------------|--------------|-------------|
| Manufacture Date | Industry Batch 2016 | First | 86.647 | 86.764 |
| Grade ID | BB | Second | 86.378 | 86.391 |
| PT Number | N/A | Third | 86.773 | 86.772 |
| Ring Design | 1st design | Skirt w/o coating | N/A | 87.452 |



| | Piston Type | Ring Land | Longitudinal | Transversal |
|-------------------------|--------------|-------------------|--------------|-------------|
| Manufacture Date | (5/22/2017) | First | 86.682 | 86.777 |
| Grade ID | AB1 | Second | 86.381 | 86.386 |
| PT Number | AG9Z-6108-D* | Third | 86.723 | 86.726 |
| Ring Design | 1st design | Skirt w/o coating | N/A | 87.461 |



| | Piston Type | Ring Land | Longitudinal | Transversal |
|-------------------------|-------------------------------|-------------------|--------------|-------------|
| Manufacture Date | (12/14/2015 to 11/17/2016) | First | 86.67 | 86.778 |
| Grade ID | AA1 | Second | 86.323 | 86.322 |
| PT Number | AG9Z-6108-D* | Third | 86.749 | 86.763 |
| Ring Design | 1st design | Skirt w/o coating | N/A | 87.461 |



**Dealership purchased components*

Dealer Piston Referencing

- Sequence IX severity is adjusted for every engine. Each new engine requires a minimum of two references to calibrate. They must have very good repeatability to calibrate on only two references ($e_i \leq 1.000$).
- At least one reference test will use oil TMC 224. This will give us evidence that TMC 224 is performing adequately before any candidates are run.
- The normal referencing with the dealer pistons combined with 43 other reference oil runs is far more candidate protection than we normally see on hardware changes.

Motion

- To allow the use of dealer pistons AG9Z-6108-D for Sequence IX registered testing following successful calibration. At least one of the calibration runs must use oil TMC 224.

Sequence IX SP Call

SOUTHWEST RESEARCH INSTITUTE®

Khaled Rais

11/15/2019



FUELS & LUBRICANTS RESEARCH

Processing Issues

12.2.1 *General*—To determine combustion cycle validity, each cylinder is evaluated separately. Invalid combustion cycles are removed from each cylinder's data set prior to performing the LSPI calculations for peak pressure (denoted by *PP* or *P_{MAX}* – see Note 5) and mass fraction burn at 2 % (*MFP2*).

NOTE 5—The symbols *PP* and *P_{MAX}* are used interchangeably throughout this method to denote the peak pressure. *P_{MAX}* is used by AVL (see A11.2) and *PP* is used in section 12 and Forms 11 to 15 of the Report Forms (see Annex A12).

Note 6—*MFB2* is the engine crankshaft angle, in °, measured when 2 % of the mass fraction of fuel has been burned during a combustion cycle.

12.2.2 Use the following criteria to identify invalid cycles:

12.2.2.1. Remove all cycles with a *MFB2* < -30°. #1

12.2.2.2 Remove all cycles with a *PP* < 2 MPa.

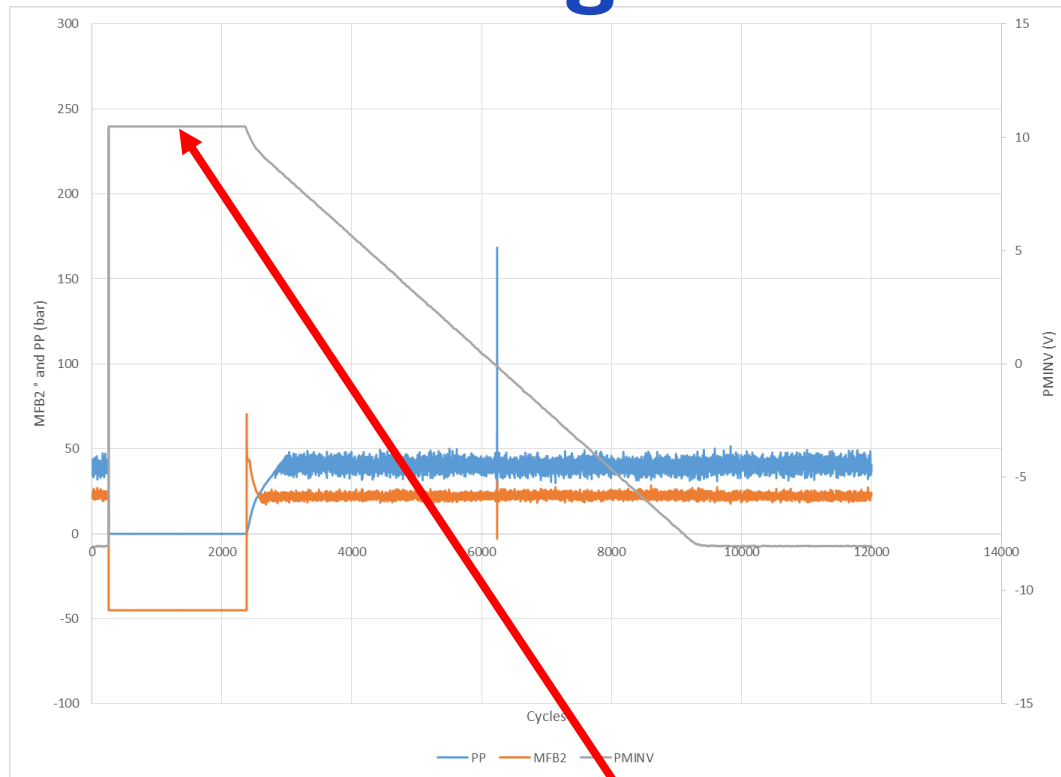
12.2.2.3 After all invalid *MFB2* and *PP* cycles have been removed (see 12.2.2.1 and 12.2.2.2), remove all cycles with a pressure minimum voltage (*PMINV*) less than the mean of remaining *PMINV* - 0.5 V. For example, if the mean *PMINV* of the remaining engine cycles on cylinder 1 is -8.02 V, remove all cycles with *PMINV* < -8.52 V. #2

Processing Issue #1



Not counted because $MFB2 < -30$
Recommendation: Should the limit be > 30 ?

Processing Issue #2



Valid because $PMINV > -8.5$

Recommendation: Should the limit be $abs(PMINV - PMINV \text{ mean}) > 0.5$ is invalid?

Processing Issue Motions

- Motion 1: To change section I2.2.2. to “Remove all cycles with a $MFB2 > 30^\circ$ ” instead of the current “Remove all cycles with a $MFB2 < -30^\circ$.”
- Motion 2: To change I2.2.2.3 to ...“remove all cycles with a pressure minimum voltage (PMINV) different than the mean of remaining PMINV by more than 0.5V. For example, if the mean PMINV of the remaining engine cycles on cylinder I is -8.02 V, remove all cycles with $PMINV < -8.52\text{ V}$ or $PMINV > -7.52$.”

New 2019-BB Pistons Matrix

| Run | A1 | A2 | G1 | G2 |
|-----|-----|-----|-----|-----|
| 1 | 224 | 221 | 220 | 221 |
| 2 | 220 | 224 | 221 | 224 |
| 3 | 221 | 220 | 224 | 221 |
| 4 | 221 | 224 | 224 | 220 |
| 5 | 224 | 221 | 221 | 224 |