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Good afternoon everyone,

Sorry this took a while to get out. Please find the minutes below of the August 26th meeting held by the Mack Surveillance Panel. Please feel free to let me know if there are any changes or revisions needed. Thanks.

Mack Surveillance Panel Meeting

Southwest Research Institute, San Antonio, TX
August 26, 2013

Attendees:

Bob Campbell	Afton
Christian Porter	Afton
Mark Cooper	Chevron Oronite
Jim Rutherford	Chevron Oronite
Riccardo Conti	ExxonMobil
Jim Carter	Haltermann
Pat Fetterman	Infineum
Bob Salgueiro	Infineum
Jim Gutzwiller	Infineum
Elisa Santos	Infineum
Jim Moritz	Intertek
Andy Broff	Intertek
Michael Conrad	Lubrizol
Jim Matasic	Lubrizol
Nick Secue	Lubrizol
Kurt Johnson	SwRI
Jim McCord	SwRI
Bob Warden	SwRI
Zack Bishop	TEI
Mark Sutherland	TEI
Jeff Clark	TMC
Sean Moyer	TMC
Greg Shank	Volvo/Mack
Allison Athey*	Volvo/Mack

Chris Cauley* Volvo/Mack

Jason Bieneman* MAHLE

*only participated via telecom during the discussion on piston rings

The meeting was called to order at 1:07 pm CDT by chair Mark Cooper.

UPDATE ON RING SUPPLIER CHANGE

Zack Bishop gave an update on the ring supplier change that had happened in the past. It was noted that "R" batch piston rings had issues with oil consumption in the Mack T-11. When it came time to order the next batch "S" rings, TEI added specific instructions to the purchase order forms to "pay special attention to the plasma coating" in an effort to get a more dense ring coating which ultimately seemed to fix the T-11 oil consumption issue. The "R" and "S" ring batches were manufactured by ring supplier Perfect Circle. Perfect Circle was then acquired by MAHLE Group sometime in the '08-'09 timeframe and the next order of rings, the "T" batch was filled by MAHLE. Zack commented the "S" and "T" rings were manufactured to the same specification and request for a more dense ring coating but were made by two different suppliers. Zack noted that the piston rings did differ in color, with the "S" ring plasma coatings appearing black while the "T" ring plasma coatings appeared to be a dark gray.

Mark Cooper displayed Jim Rutherford's presentation on the Mack T-12 reference test data. On slide 3, looking at oil consumption vs reference test date, it was clear the oil consumption from the period of 1/2006 through mid-2010 had notably lower oil consumption, in the range of 50-70 g/hr. It was believed that these rings used during this period, batches "P", "R", and "S" were manufactured by Perfect Circle. Starting in mid-2010 through late 2012, the "T" batch of rings supplied by MAHLE were used in reference oil testing that had a step change in oil consumption in the range of 60-85 g/hr. From late 2012 through till now, the "U" batch of rings also supplied by MAHLE were used in reference oil testing that had highly variable oil consumption results ranging from 74-110 g/hr. The objective of what the panel was trying to achieve with MAHLE was stated as: work with ring and piston suppliers to determine what to change in order to get back to historical oil consumption levels.

Mark Cooper then shared slides on piston ring surface analysis completed using an optical interferometer. Batch "T" top rings and 2nd rings were analyzed 180 deg from the ring gap. The 2nd rings had a taper as expected while the top ring was barrel faced and did have some small variations in barrel shape. Next, used rings were analyzed from Intertek's UUXO completed reference tests where they had recorded the highest and lowest oil consumption in recent history. Again, there was no difference noted in the 2nd rings and only slight variations in barrel shape in the top ring face profiles. While the analysis hoped to turn up an obvious geometry difference that could explain oil consumption difference, nothing stood out in the results.

DISCUSSION WITH MACK T-12 PISTON RING SUPPLIER MAHLE

At 1:34 pm CDT, Allison Athey and Chris Cauley, both of Volvo/Mack dialed into the meeting. Not long after we were also joined by Jason Bieneman of MAHLE by telephone. Greg Shank (Volvo/Mack) gave Jason an overview of how the piston rings are used in industry oil testing. Jason confirmed that while Perfect Circle was purchased by MAHLE most things related to material and designs did not change.

Zack Bishop described the plasma coating porosity/density issue to Jason. That purchase orders in

2010 for 3,000 batch "T" rings and in 2012 for batch "U" rings had the same special instructions requesting a more dense coating that had been previously requested of Perfect Circle. Jason said that the ring coating process had little room for modification as the ring coatings had to meet several different areas of performance. If they tried to make a change to the ring coating process it could adversely affect other properties of ring wear performance and in extreme cases lead to scuffing. Also, if the ring coating was changed significantly the test would have to be redesigned. Jason asked if the Surveillance Panel had considered that oil consumption could be due to factors other than the rings? The Labs believed the issue was in the power assembly.

Jim Moritz provided a copy of a July 2008 report by MAHLE about batch "P" and "R" rings that were analyzed by MAHLE for porosity. Porosity was measured under 500X magnification. The "P" batch rings had a % porosity of 6.1% while the "R" batch rings had a 7.5% porosity. Coating porosity had a requirement to be within 5% and 15%.

It was noted by Jim Matasic (Lubrizol) that while rings could have the same number of pores (% porosity) the size of the pores could be different (porosity density).

ACTION: Jason Bieneman to check internally if MAHLE has a rating assessment for porosity.

ACTION: Jason Bieneman to check if MAHLE still has the "R", "S", "T" and "U" rings provided in late 2012 for analysis of ring geometry to see if they can be assessed for porosity.

ACTION: Jason Bieneman to determine if MAHLE can supply rings with similar porosity to batch "P" rings.

Jason confirmed that if this had been a ring used in engine production and a customer had come back complaining of high oil consumption, MAHLE would have looked at the same parameters that have already been analyzed, namely ring tension and gap to make sure they have not changed.

It was noted that the "special batch S" rings with the revised plasma coating was only used in the Mack T-11 test to address the oil consumption issue that had been experienced with the "R" rings. The data collected in the Mack T-11 indicated that lower porosity resulted in better oil consumption. Bob Campbell suggested that the panel needs to quantify the porosity of the new rings to compare back to the older "P" and "R" batch rings.

Soot was noted as a contributor to ring wear but all the average soot levels of the reference oils were within 0.5% of each other. It was also noted that the ring weight loss in the Mack T-12 comes from corrosive wear along the ring bottom flank. Greg noted that ring wear had not changed. Jim Matasic agreed to go back and look in his office and see if any piston rings remained.

MACK T-12 REVISED PISTONS

A question was raised on where we stood with the order for more piston forgings? Chris Cauley (Volvo/Mack) confirmed the availability of the tooling to machine the microalloy pistons. Chris updated everyone that the piston manufacturer was traveling and Chris still needed to confirm how to order the new forgings. Because of the two month lead time on the forgings, the panel's desire was to order the forgings now to get the process started and then while they were being manufactured, figure out what process and changes we wanted to make to the final machining of

the forgings to improve oil consumption.

CPD UPDATE

Upon their return, Mark Sutherland (TEI) gave an update on recent TEI activity.

TEI is supplying serialized **fuel injectors** for Mack engine tests.

Mack T-8 – TEI is trying to isolate down to 1 re-manufacturer, 1 injector body, and 1 injector tip.

Mack T-11 – TEI has identified that there are 2 different injector bodies, with 90% being of 1 type.

There is a 120 day lead time for ordering T-11 fuel injectors.

Mack T-12 – TEI has inspected the injectors and found only 1 body and 1 tip.

Change in oil filter centrifuge housing of Mack T-8

Mack stopped manufacturing the housing part number 25GB525M. Mack confirmed that 27GB332-M2 was the only part available but it does not have pre-drilled bosses. The concern is around vibration leading to failure of the housing and where to place the oil gallery thermocouple.

ACTION: Jim Moritz to work with TEI to see if the oil filter housing 27GB332-M2 can be made to work and they will also look at oil filter housings with built in relief valves to see if they can be made to work as well.

New Mack T-11/T-12 Connecting Rods are being purchased and closely screened by TEI.

Mack T-11/T-12 Piston Crowns - TEI has noted lots of diversity in casting numbers, valve cut out chamfer and bowl entry. TEI is only sending those pistons with casting numbers on them (production pistons) and a smooth bowl entry.

Mack T-8 Piston crowns coatings have changed from the old flat finish to a shiny finish. The expectation is that the change in finish appearance will not change their performance.

Mack T-11 Small Turbo is in short supply. TEI is out of supply and have placed orders with Volvo. Volvo does manufacture the turbos but postpones TEI's orders and ships the produced turbos elsewhere.

Mack T-11/T-12 are out of batch "S" liners. TEI have 2814 batch "T" liners which are not only approved for use in the Mack T-8. Jim Moritz asked if maybe they could be used for the Mack T-11 as well. It was suggested that the combination of "S" rings and "T" liners lead to a shorter life in the T-11 but it was also acknowledged that there was little experience with the batch "T" liners in the T-11 test.

MOTION: Jim Matasic (Lubrizol) made a motion to allow the use of batch "T" liners starting with the next reference in the Mack T-11 test. Jim Rutherford (Chevron Oronite) seconded the motion. The motion carried with 9 approvals, 1 waive (TMC), and no objections.

The Mack E7 block, used for the T-11 and T-12 is no longer in production. TEI currently have 200 available. TEI cannot obtain bare blocks from Volvo/Mack Remanufacturer (VMR), who will only

supply a complete engine. The suggestion to alternatively use junkyard blocks was considered but dismissed due to uncertainty around the history of the junkyard engines. TEI needed an estimate on how many engines to buy for their blocks. They estimated they sell around 4-5 per year, assume a 10 year test life and there needs to be about 50 blocks available. Bob Campbell asked if VMR could screen used blocks?

ACTOIN: TEI to check if they can order 20 engines from VMR.

ACTION: Can Mack put pressure on VMR to keep parts available for these tests. Greg will ask.

TMC Round Robin Data

The Round Robin data on metrology and used oil analysis collected by TMC was reviewed.

The raw data was reviewed by eye only. Lab #3 consistently was higher than the other labs on liner wear measurement. Liner "B" appeared to throw off the standard deviation. Excluding Lab # 3, the data was believed to look like historic performance on these parameters.

The Round Robin used oil data was reviewed. Kinematic Viscosity @ 40C and 100C across all labs looked good. Soot was noted to have a 0.3% spread between the labs. TMC will go back and work with the labs to identify if there is an instrument/equipment bias that may have affected the Soot results. MRV at Lab #3 had problems so no data was reported. There was a large variation in TBN measurement. Greg Shank asked for Nitration data, which was believed to have been measured, but remained to be added.

ACTION: Labs to report their nitration results to TMC for inclusion in the Round Robin analysis.

ACTION: TMC will verify with the labs which method of PDSC was run as there was some confusion.

ACTION: TMC to verify with the labs which method of TBN was run as the data spread was very wide.

It was noted that if the T-13 was to incorporate any of the parameters from the Round Robin as Pass/Fail criteria, then those methods for measurement should be incorporated into the T-13 test procedure.

Reference Oils Discussion

Greg Shank shared that at the last NCDT meeting, it was discussed that wear tests should have data with the new proposed PC-11B (low HTHS viscosity) oils to ensure that the test precision is maintained with those oils. The question keeps coming up at NCDT that the Surveillance Panels of wear tests should determine if they can roll new reference oils in, to bring in new low viscosity oils.

Jim Matasic asked how do we come up with enough data to measure for precision? The minutes from the Cummins Surveillance panel meeting where this same topic was covered was reviewed.

Was the purpose for running low HTHS oils to 1) determine if the test will be OK and check the precision or 2) find a new reference oil that's sensitive to test changes. Mack engine tests are referenced so infrequently, that two reference oils could not be supported. Pat Fetterman (Infineum) saw two different scenarios: 1) Take the current Reference oil and blend it to a low HTHS or 2) EMA goes through a selection process and picks PC-11 demonstration oils then selects one or two oils to try in the Mack T-12. The Mack Surveillance panel agreed that they needed more clarity from NCDT as to what they were asking for from the panel.

ACTOIN: Greg Shank will ask NCDT to clarify what they are asking for from the surveillance panels.

Proposal to Reduce Limits for PC-11B Oils in Mack T-11 test

Greg explained that for PC-11A oils, the Mack T-11 limits should remain as they are today. However, for PC-11B might not be backward compatible, and modern engines are low soot producers anyway, Volvo/Mack was willing to have a discussion on possibly reducing the Soot limits for PC-11B oils. One possible scenario was to use API CI-4 PLUS T-11 limits for PC-11B oils. This topic will remain open for discussion.

Possible Change From Merit based T-12 to Individual P/F Parameters

Volvo agreed that assuming the Mack T-13 does have Pb limits, Volvo wouldn't want to repeat them in the T-12. So the Surveillance Panel will have to decide if the T-12 for PC-11 only has ring wear, liner wear, and oil consumption, do we need a merit system or can we just use individual pass/fail parameters? Again this topic will remain open for discussion by the panel.

The Mack Surveillance Panel Meeting adjourned at 4:37PM CDT.

Respectfully submitted,

Bob Salgueiro

Industry Liaison Advisor

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