

Daimler Surveillance Panel Meeting Minutes

July 27, 2023

9:00 AM – 11:00 AM CST

Call Participants:

Lubrizol – Robert Slocum (Chairman)

Southwest Research Institute – Jose Starling (Secretary), Robert Warden

Intertek – Josh Ward

Daimler - Suzanne Neal

Afton – Bob Campbell

Infineum - David Brass, Elisa Santos, James Gutzwiller

TEI – Derek Grosch

Chevron Oronite – Josephine Martinez

TMC – Sean Moyer

Haltermann Solutions – N/A

ExxonMobil – N/A

Ford – N/A

Agenda Items

DD13 Hardware Availability Update – Derek Grosch presented an updated hardware availability table as shown in the attached slides. At current usage rate there is approximately 5 to 7 years' worth of kits remaining on most batched components. Main issue is getting the exhaust rocker arms and Jake Brake rockers. Some small orders of these were coming in periodically but not sufficient to include in every kit. There is already a motion in place that allows the lab to reuse these components as necessary.

DD13 Updated Precision Statement – It was asked if the panel wanted to update the procedure with an updated precision statement using the latest data? The current precision statement in the procedure has been in place since the procedure became an ASTM method in 2016 and includes only the 12 matrix tests. There are currently 36 tests worth of data in the LTMS system. Sean stated that in general its expected to update the precision statement in the procedure as more data becomes available. David suggested that if we are updating the data then we should include the latest referencing data.

Sean Moyer made the motion to update the precision statement in the test procedure with the latest reference data. Bob Warden seconded the motion. No negatives on the motion. The motion passed.

It was asked how this precision statement would impact referencing criteria. It was stated that this motion would not change or impact the LTMS or referencing criteria in any way since the test does not have any severity adjustments. It was stated that the group could revisit the LTMS referencing criteria as well but that would need to be looked at separately. Suzanne stated that since we updated the precision statement if it makes sense to update the LTMS as well. David Brass stated that if we update the LTMS to use these numbers then it may be difficult to not pass a reference due to the increased numbers.

Suzanne is ok to update the procedure but would like the group to revisit the idea of updating the LTMS criteria as well to match the precision statement in the near future.

DD13 Low Viscosity Reference Oil – The group was presented with the various options for a low viscosity reference oil (see attached presentation). There are two proposed suppliers see slide 5 and 6 with provided test results. The first supplier has three oils which are low viscosity. David provided the statement that *Oils B and C are both variations of oil A. Oil B has a level 1 ZDP minor mod to Oil A. Oil C is a straight dntreat of Oil A to target borderline DD-13 performance and the PC-12 chemical targets.*

The second supplier has one oil which has a lead time of approximately 12 weeks. It is also a group III & IV base stock mix which was mentioned as not being ideal. David stated that a decision on which oil to select would need to be made as soon as possible since there could be up to a 4-month delay to acquire the oils depending on supplier. It is expected that each lab would need to run two tests on the oil.

It was asked if this low viscosity reference oil would replace the oil or would be added to the list of oils used as reference oils. Some stated that they may not support this low viscosity testing if it is not going to be a reference oil moving forward. It was asked that the group think about what they are looking for in this reference oil. Bob C. stated that he would recommend that the agreement be that the new oil would take place of the current oil. It was stated that this can be the agreement but once the new data is available the group can make that motion.

Robert stated that they would feel uncomfortable replacing this oil without observing the test data first and how it reacts. Bob C. mentioned that in the HD world we are data poor, so the more reference fluids we have the less data we get. It was also asked if it was worth it to use this money and time to switch from the current 5W-30 2.9 HTHS FA-4 oil to a very close 5W-20 2.7 HTHS oil. Is this small change significant enough to deem this switch and use of funds? This is the only test that runs a 5W-30 oil other than the T13, all others utilize a 15W-40 oil. This may point towards the DD13 needing this the least.

In general, it seems to be that the group may be in consensus that this test may not need this new low HTHS reference oil. Testing will still be needed for BOI/VGRA which may involve the oils presented or may involve different oils.

Robert Slocum made the motion to continue using the current DD13 reference oil (864-1) and not pursue a new lower HTHS low viscosity reference oil. Bob Campbell seconded the motion.

Approval of the Motion: Lubrizol, Afton, Daimler, SwRI, Intertek, Chevron Oronite, Infineum. TEI and TMC waived. The motion passed.

Action Item: Suzanne to work with TMC to ask Oil X supplier if it could be formulated as a 2.6 HTHS oil or if there is data for it already available as a 2.6 HTHS formulation.

DD13 Proposal for liner screening limits (David Brass, see attached Infineum Presentation) – Screening limits are in place, but a new suggested limit was proposed based on analysis and data set presented by Infineum. It was presented that there have been several early scuffs (before or at 30 hours) in reference oil testing with no correlation to date, lab, or batch. An internal candidate and reference oil study showed that surface roughness, Ra in particular, seems to correlate with early scuffing. It is not always

consistent which shows that there is some other mechanism that is impacting early scuffs, however it is a start to improve the test variability.

If this limit would be included, it would eliminate an additional 22% of the available liners. It was asked if we need to dig deeper on liners that scuffed with an Ra greater than 0.28 and see if there is anything else there that we missed. It was stated that instead of moving forward with this proposal now, we can take a few weeks to take a deeper look at the data and see if the proposed limits make sense.

Action Item: Robert Slocum to send Derek at TEI the kit numbers which correlate with the additional data that is desired. Derek to send out the individual roughness traces to the group for each kit/liner. Once the data is available, the panel members are to analyze the data to observe if any other correlations exists and reconvene in approximately two weeks to discuss further.

Walk-in Topics: None

Meeting was adjourned at 10:58 AM CST.

Next Meeting: Two weeks from now.

DD13 S.P. Meeting 7/27/2023

Prepared By: Robert Slocum and Suzanne Neal

DD13 S.P. Agenda

- DD13 Hardware Availability Update – 15 Minutes
- DD13 Updated Precision Statement – 15 Minutes
- DD13 Low Viscosity Reference Oil – 30 Minutes
- DD13 Proposal for Liner Screening Limits – 45 Minutes
- Next Steps / Discussion – 15 Minutes

DD13 Hardware Availability Update

- No complete kits currently @ TEI
 - A4720503634 (Jake Brake Rocker) and A4710500834 (exhaust rocker) arms currently unavailable
 - 37 - 3634 and possible additional total 120 by next week
- Possible proposal to re-use these two parts in short term?
 - Vote? Motioned on previously.

Part	Batch	Quantity	Kits Remaining	Years Remaining*
Top Ring	C	2070	345	7.8
Second Ring	B	1807	301	6.8
Oil Ring	B	1247	208	4.7
Piston	B	1818	303	6.9
Liner	D	2254	376	8.5

*Based on Last 12 months of sales

DD13 Updated Precision Statement

DD 13 Precision Update Updated Calculations

Test Precision for DD13 Scuffing Test

Post-Precision Matrix (5/5/16)					
	Intermediate Precision		Reproducibility		No. of Tests
Test Result	S	i.p.	S	R	
Hours to Scuff	26	72	26	72	12

4/7/22 Update					
	Intermediate Precision		Reproducibility		No. of Tests
Test Result	S	i.p.	S	R	
Hours to Scuff	42	118	42	118	36

- Does Panel want to update procedure with latest precision statement
- Vote?
- Will update using latest data.
- LTMS followup

DD13 Low Viscosity Reference Oil

First Proposed Oil:

Data provided on 3 related oils of similar technology with detail provided on what variations were made for context along with DD-13 data on each. Oil C is the oil proposed for use in the low viscosity reference oil matrix. For the supply, it would take us 4-6 weeks at the most to blend and deliver 950 gallons from the time the decision is made to use the oil. Possible sooner if we need to expedite it.

	P (ppm)	S (ppm)	%SASH	HTHS	Base Stock Group	Scuff Result (hours)	Test Date
Oil A	761	2580	.99	2.58	III	41	2/2018
Oil B	1100	3222	.98	2.64	III	31	6/2018
Oil C (RO proposal)	685	2322	.89	2.74	III	86	6/2023

DD13 Low Viscosity Reference Oil

Second Proposed Oil:

Actual test result (not a modeled result or on a 'similar' oil); a five-year supply is possible with a lead time of 12 weeks, possibly less.

Supplier	Test	%P	%S	%SASH	Viscosity Grade	HTHS	Base Stock Group	Performance
4	DD13	0.073	0.297	0.9	5W-20	2.67	III-IV mix	30 <u>hrs</u> to Scuff

DD13 Low Viscosity Reference Oil

- **Which reference oil does panel recommend?**
- **Panel currently not interested in pursuing low visc**
- **Any questions need to be answered or addressed?**
- **Ask for Oil X (864) down to 2.6 or a data point??**
- **Decision needed by? September 2023 by latest.**
- **Sooner the better. Testing needed before BOI/VGRA...**
- **Motion and voted to stay with current ref oil**
- **Formal feedback to David and Karin**

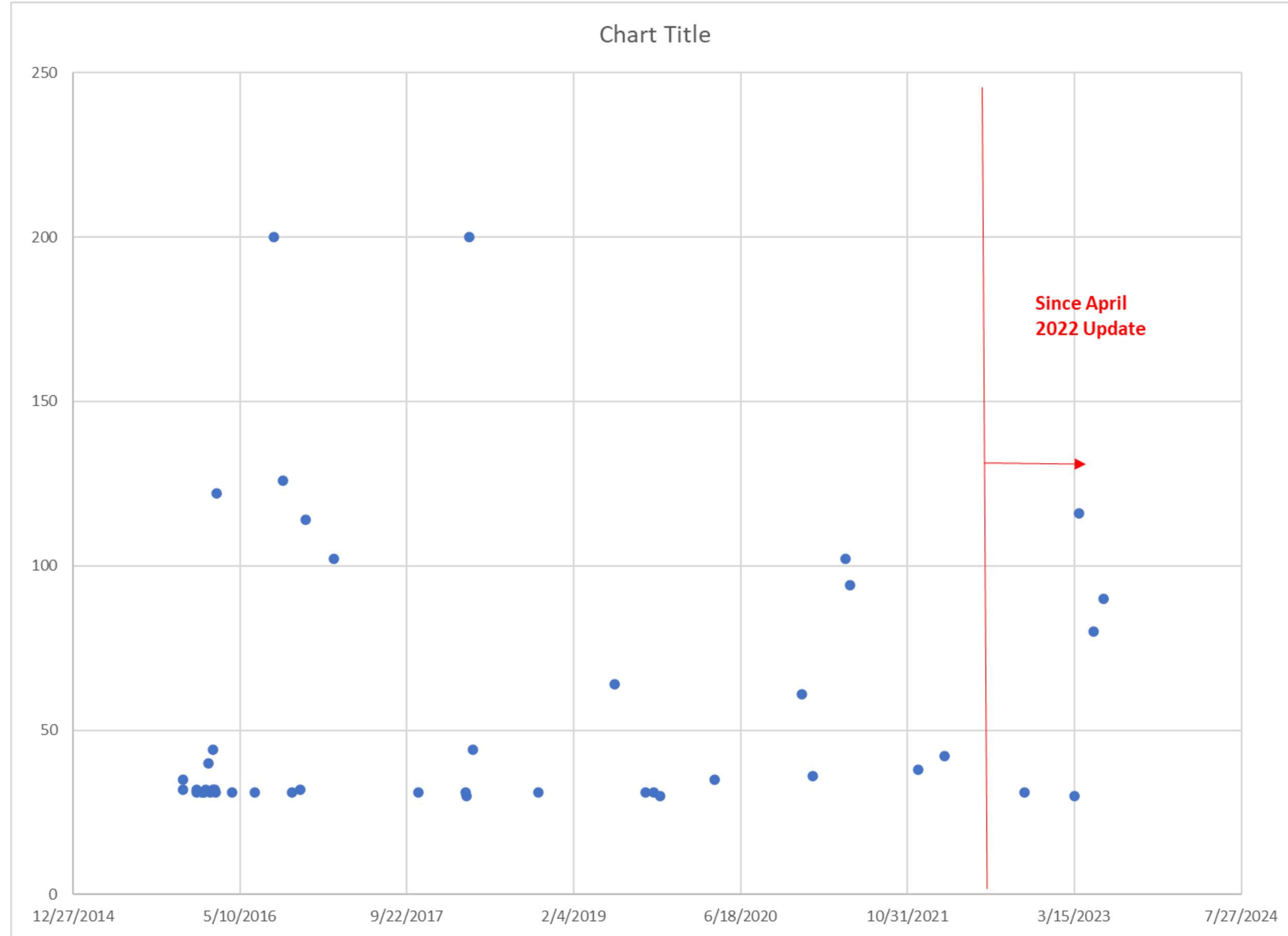
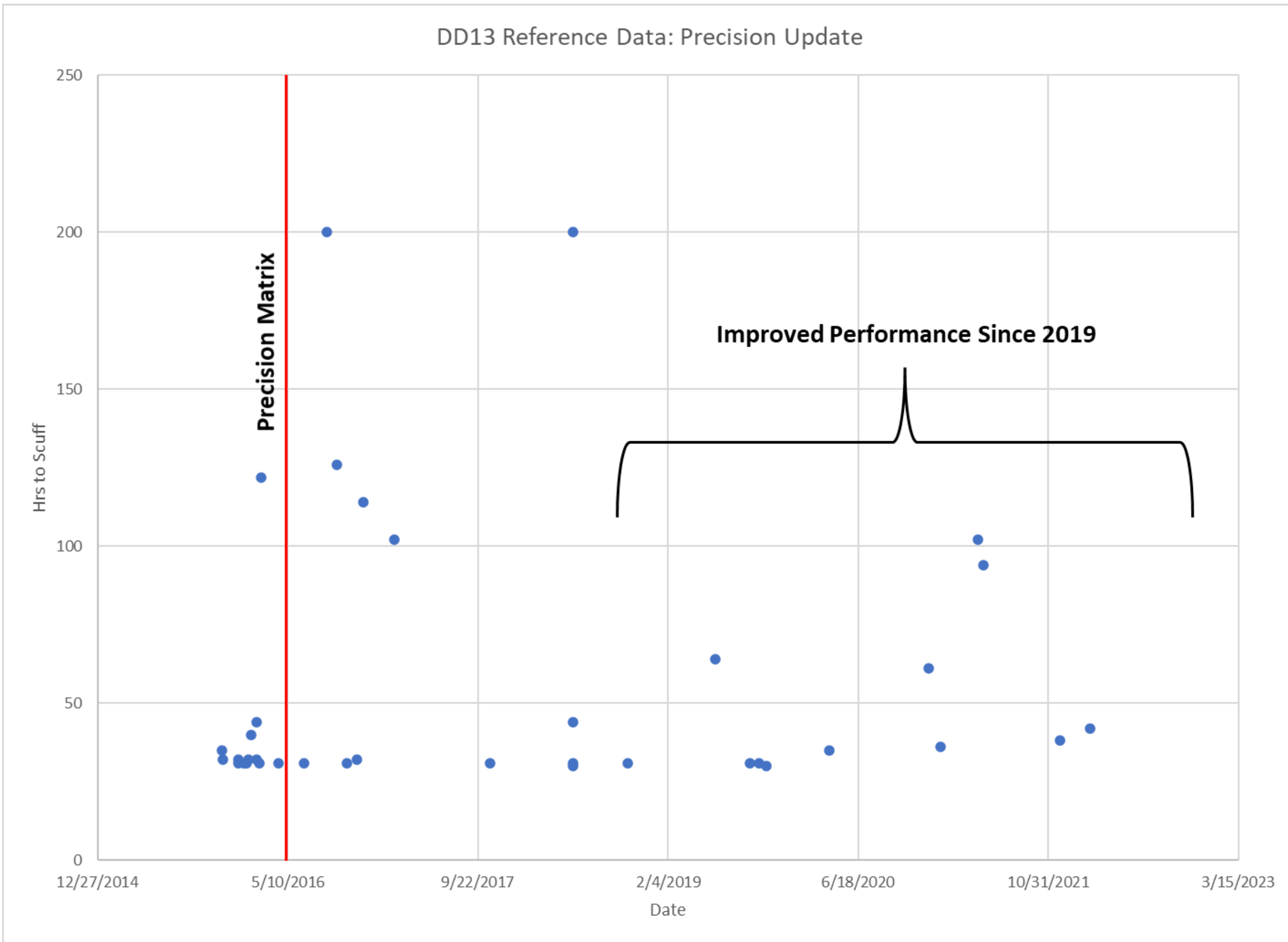
DD13 Proposal for Liner Screening Limits

- Liner Screening Limits

Next Steps / Discussion

- Next SP Meeting before Chicago?
- 2 weeks from now after 10th – 2 hour
- Any prep needed for NCDT in Chicago?
 - SP update on reference oil selection
 - Whether selected or not
 - Aug 10th matrix design

DD13 Updated Precision Statement



DD13 Proposal for Liner Screening Limits

Alec Labb, David Brass

July 2023

Performance you can rely on.



Background



- Since the introduction of the Batch C liners there has been an increased probability that oils will scuff in the DD13 scuffing test prior to 31 hrs.
- A number of calibration tests on TMC 864-1 have been deemed invalid since they did not reach 30 hours on test. There were also a few calibration tests that did not reach 31 hours. This did not occur before the liner supplier was changed. These events are not restrictive to one lab, liner batch or range of time.

Oil	Hours to Scuff	Lab	Liner Batch	Top Ring Batch	Date Completed
TMC 864-1	4	G	C	B	10/11/18
	4	A	C	B	11/10/20
	4	G	D	B	4/13/21
	4	A	D	B	2/1/22
	24	A	C	B	12/10/20
	30	G	C	B	3/19/18
	30	G	D	B	9/15/19
	30	A	C	B	10/20/19
	30	A	D	C	3/16/23

- Infineum has conducted a study looking at both the reference oil TMC 864-1 and our own candidate database to better understand what might be causing this increased probability of early timed scuffing events.
- Infineum performed contact modelling of the DD13 power cylinder and found that the liner roughness played the largest role in the fluid film thickness and the propensity for the scuffing event.

Hardware Variability



- An analysis of Infineum's testing database was performed, and for a given test the liner with lowest R_a roughness value in the kit showed the highest propensity to scuff

Liner Roughness Ranking	Scuffing Rate %
1 (Lowest Ra)	80.8%
2	7.8%
3	0%
4	3.8%
5	3.8%
6 (Highest Ra)	3.8%

In 89% of tests, the liners with the lowest two R_a values scuffed

Infineum Candidate Testing, Oils Repeated



Oil	Oil	Result	Liner Kit
			Lowest Ra (um)
Oil Formulation 1	Test #1	Fail	< 0.28
	Test #2	Fail	< 0.28
	Test #3	Pass	< 0.28
	Test #4	Pass	≥ 0.28
Oil Formulation 2	Test #1	Fail	< 0.2
	Test #2	Fail	< 0.2
	Test #3	Fail	< 0.2
	Test #4	Pass	≥ 0.28
Oil Formulation 3	Test #1	Fail	< 0.28
	Test #2	Pass	≥ 0.28

- Infineum looked at our candidate database for repeated testing on the same oil formulations.
- Infineum found that oils that pass with a liner roughness $R_a \geq 0.28$ um could fail if run with liner roughness $R_a < 0.28$ um

Liner Roughness Comparison PNB vs. Batch C



	DDC-Honed (0.0002" R Stylus)	DDC-Honed (0.0001" R Stylus)	Batch C (0.0002" R Stylus)	Batch C (0.0001" R Stylus)	Batch C Specification
Ra (μm)	0.35±0.12	0.40±0.12	0.22±0.05	0.26±0.06	n.a.
Rk (μm)	0.65±0.19	0.79±0.21	0.43±0.06	0.50±0.08	0.2-0.8
Rvk (μm)	1.24±0.28	1.32±0.26	0.98±0.31	1.13±0.36	0.7-2.0
Rpk (μm)	0.19±0.03	0.21±0.02	0.21±0.06	0.23±0.08	<=0.27

	DDC-Honed Specification (0.0002" R Stylus)	Batch C Specification (0.0001" R Stylus)
Rk (μm)	0.2-0.8	0.2-0.8
Rvk (μm)	0.5-1.8	0.7-2.0
Rpk (μm)	<=0.20	<=0.27

- The minimum roughness from the original DDC-honed liners used when this test was developed was $R_a = 0.28 \mu\text{m}$. For this reason, premature scuffing events were likely not seen during this time frame.
- The Batch C and Batch D liners had many parts with $R_a < 0.28 \mu\text{m}$ as the average liner from Batch C had $R_a = 0.26 \mu\text{m}$.
- Currently we do not have a screening parameter for R_a

Oil X

Effect of Liner Roughness



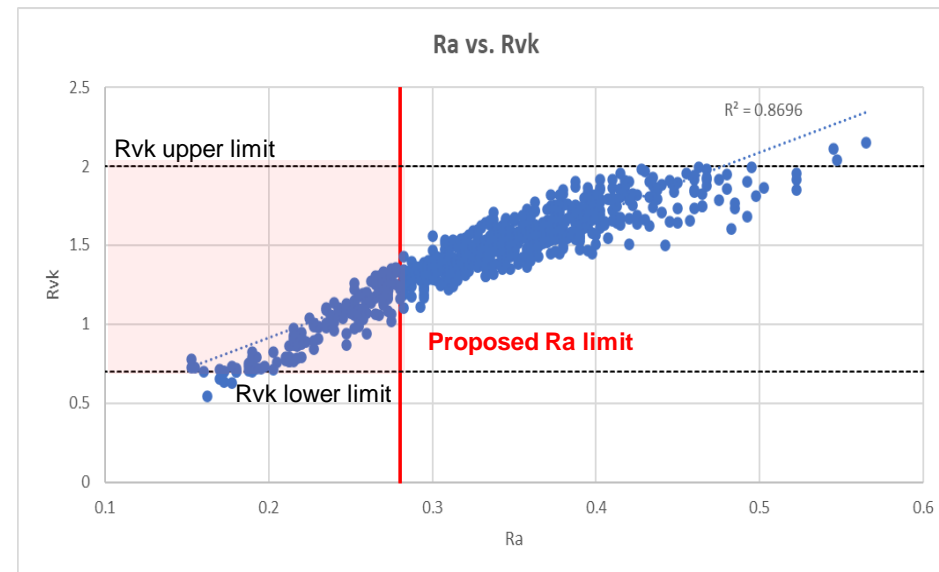
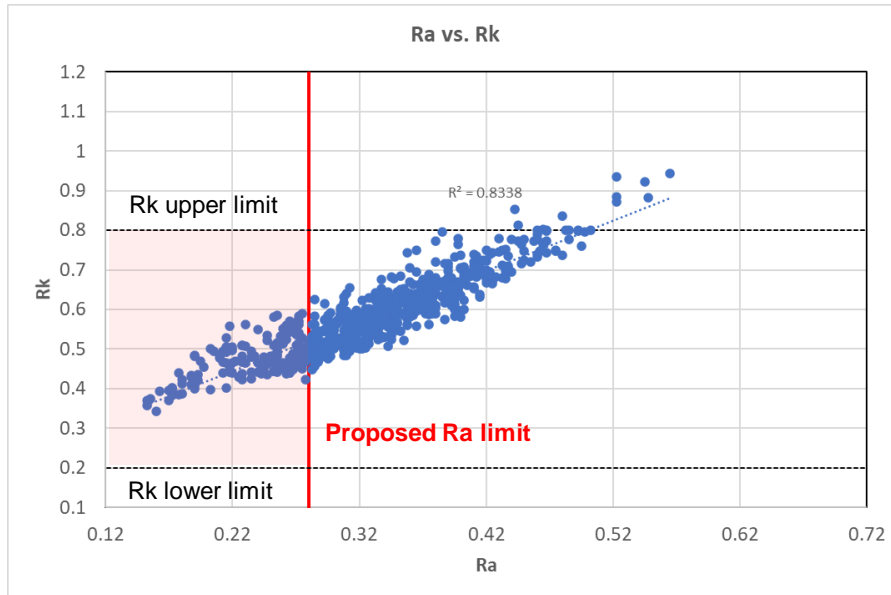
Oil	Hours to Scuff	Liner Batch	Top Ring Batch	Liner Kit Lowest Ra (um)	Liner Roughness					
					RAAVLR1	RAAVLR2	RAAVLR3	RAAVLR4	RAAVLR5	RAAVLR6
TMC 864-1	4	C	B	0.2	0.22	0.26	0.2	0.26	0.26	0.25
	4	C	B	0.23	0.23	0.24	0.29	0.27	0.3	0.26
	4	D	B	0.32	0.32	0.42	0.34	0.37	0.33	0.34
	4	D	B	0.32	0.34	0.34	0.39	0.32	0.36	0.34
	24	C	B	0.24	0.24	0.28	0.27	0.3	0.31	0.35
	30	C	B	0.21	0.24	0.22	0.21	0.22	0.31	0.25
	30	D	B	0.25	0.34	0.3	0.3	0.37	0.25	0.31
	30	C	B	0.30	0.35	0.32	0.3	0.32	0.33	0.32
	30	D	C	0.25	0.46	0.27	0.34	0.39	0.25	0.29

Bolded font signifies scuffed cylinders

- Applying the learning on the liner to the TMC 864-1 results showed that many of these failures also occurred with smoother liners ($R_a < 0.28$ um), on the order of 60%.
- There were some further tests that still scuffed at low hours which suggests that corrective action on the liners is only one of the steps that this surveillance panel will need to consider.

Liner Properties – Batch D

- R_a shows good correlation with R_k and R_{vk}
- R_a does not show good correlation with R_{pk} ($R^2 = 0.5$)

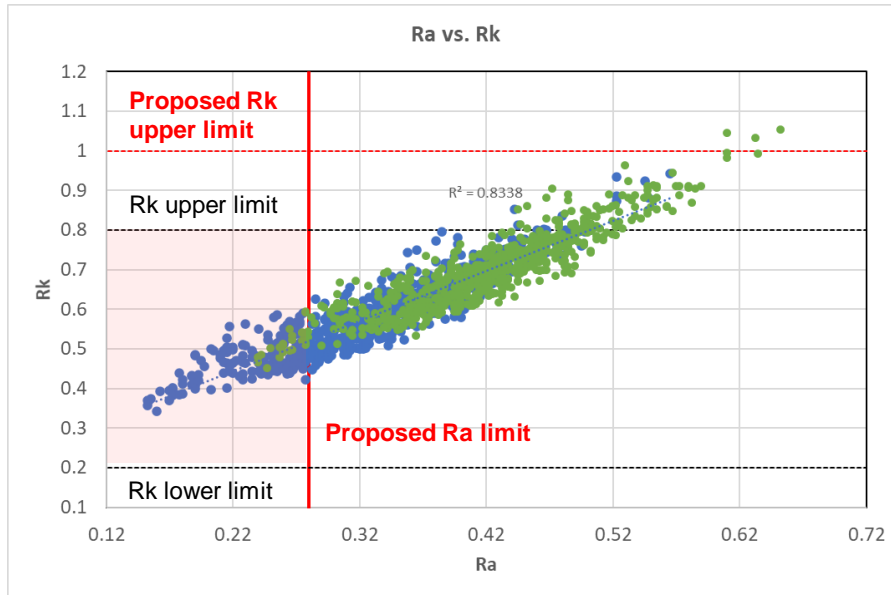


- Average R_k value for Batch C liners = 0.5 microns
- Average R_k value for the Batch D liners = 0.59 microns
- The liners improved from Batch C but still are much smoother than previous DDC honed liners
- It is recommended that future Batches of liners target higher R_k values and liners are rejected based on R_a values

Liner Properties – Future Batch Recommendation



- R_a shows good correlation with R_k and R_{vk}
- R_a does not show good correlation with R_{pk} ($R^2 = 0.5$)



- Recommendation is to increase the target value in production of the next batch to $R_k = 0.7 \text{ um}$. (Green data suggests similar distribution of parts around this target)
- To allow a lower rejection rate on the top end, R_k limits should be expanded to higher values
- For Batch D it is recommended that we add an R_a limit to reject smoother liners

- In order to prevent premature and unexpected test failures, Infineum suggests an additional parameter of **minimum liner surface roughness R_a of 0.28 μm** for hardware to be qualified to run in the DD13 Scuffing test
- To allow for higher target R_k for liners, the R_k limit should be increased from 0.8 to 1.0 μm

Proposed liner roughness values

Property	Current Limit	Proposed New Limit
R_a (μm)	None	≥ 0.28
R_{vk} (μm)	0.7 – 2.0	0.7 – 2.0
R_k (μm)	0.2 – 0.8	0.2 – 1.0
R_{pk} (μm)	0 – 0.27	0 – 0.27

Acceptable Liners by Chosen Limit



- Based on 680 liner measurements obtained from TEI for Batch D, 22% of liners would be screened out by R_a

	$R_a < 0.28 \text{ um}$	$R_a \geq 0.28 \text{ um}$	% Acceptable
TEI Measured Liners	149	531	78%

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