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Committee D02 on PETROLEUM PRODUCTS AND LUBRICANTS

Issued: August 19, 2015

Reply to: Dan Worcester
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These are the unapproved minutes of the 08.18.2015 Sequence VI Surveillance Panel call.

The meeting was called to order at 8:30 AM Central Time by Chairman Nathan Moles.

Agenda

The Agenda is the included as Attachment 1.

1.0 Roll Call

The Attendance list is Attachment 2. Mike McMillan was voting for Infineum, Adrian Alfonso for Intertek, Brian Marks for BP, Dan Lanctot for TEI and Amol Savant for Ashland.

2.0 Approval of minutes

2.1 Approval of the minutes of the 08.10.2015 meeting.

MOTION: Approve the minutes from the 08.10.2015 conference call.
[Dan Worcester, Nathan Moles, second] Approved unanimous.

3.0 Action Item Review

3.1 OHT to provide update on current VIE inventory and service engine order. –OHT There are 59 of the current engines remaining. An order has been placed for 260 engines.

3.2 Labs reported VID engine inventory and expected depletion date of VID engines.
-Expected life of engines range from 2016 Q1 to 2018
Lab1: 1 engines
Lab2: 2 engines
Lab3: 3 engines
Lab4: 2 engines This will be an on-going effort.

3.3 SP chair and test sponsor to investigate what is needed to establish VID equivalent limits for VIE. This will be an on-going effort.

4.0 Old Business

4.1 List of items to be reviewed after the Precision Matrix
Do we really need to run three RO tests to establish the new engine for LTMS?
Discussion of reducing the new reference requirement to two oils, then a third oil run after a defined number of candidates.
Discussion of using FEI 2 and FEI Sum for references to match candidate pass/fail criteria.
Discussion of evaluating 80/20 ratio of BL before to after for FEI 1 and 10/90 for FEI 2.
Should the acceptance bands value of 1.96 be rounded up? Due to the rounding on FEI 1 and 2 the actual pass limit is 1.91 and 1.92. This will be an on-going effort.

4.2 Update on progress of 5W-30 Tech1 in VIE testing. –Labs
-FEI1/2 = 1.09/1.05 @ 349 hours This test exceeded the procedure limit of -0.2 to 0.4 BLB Delta.
- FEI1/2 = 0.29/0.37 @ 2059 hours This test was later declared invalid.
Lubrizol will run this oil and SwRI will repeat a run on a new engine with the same hours.

4.5 Engine hours needs to be addressed in the precision matrix and there is concern in the industry that the current design does not adequately address this. Alternate matrix designs have been requested.
Statisticians will come up with the list of potential designs once all variables (engines, oils, etc.) have been decided. Jo Martinez did two presentations. See Attachments 3 and 4. These covered prove out [see New Business 5.2] and precision matrix design options. The current VIE data shows more FEI 2 statistical variation [s = 0.2] and a majority of the data

is on early engine hours. For the Precision Matrix, the Surveillance Panel will determine the format that moves forward. The existing version has 542-2, 1010-1 and 0W-16 Tech 1 oils, but that final oil will be replaced with a new one. There are 8 stands, 6 labs and 53 runs. There was discussion on the number on runs approve in the MOA, so this will be verified.

There was discussion on whether new engines or some with hours for approaches 1 through 6. Approach 3 would include BOI/VGRA when that group has oils selected. Approach 5 would allow labs to switch to new engine for stand calibration runs. Approaches 2 and 3 would both start with new engines but approach 2 would run more hours on some engines.

There was a request for each voting member to give their preference for which matrix design versions will move forward.
OHT waive; Ashland 5, 4, 3; Afton 5, 3; TMC waive; Shell 3, 5; IAR 2, 3; GM 3, 2; BP 3, 4; Lubrizol 3, 2; EM 3, 5; Infineum 4, 2; Ford 5, 4, 3; Oronite 3, 2; TEI waive; SwRI waive. The majority was 5 votes for 2, 3 and 11 votes for #3. The Stats group will work on the options.

4.6 Update from task force, to investigate alternative Sequence VIE procedures that would improve 0W-16 response in the Sequence VIE test. - Charlie Leverett/Bill Buscher/Satoshi Hirano Dan Worcester will take over Chair of the GF-6B Task Force to develop the VIF test version. Volunteers will be requested from the original Task Force. The Toyota 6 stage recommendation will be used for stage conditions and oils supplied.

New Business

5.1 Discussion on third reference oil for precision matrix (replacement for 1011).

5.2 Review updated prove out data statistical analysis (presentation attached). –Jo Martinez
See Old Business, 4.5

6 **Next Meeting will be at the Chair notification.**

The meeting adjourned at 10:12 AM.

Sequence VI Surveillance Panel Conference Call Agenda
August 18 @ 9:30-11:00AM EST

Call-in information is included below:

Call-in Number: 866-528-2256
Conference Code: 3744024

1.0) Roll Call

Do we have any membership changes or additions?

2.0) Approval of minutes

2.1 Approve the minutes from the August 10, 2015 Sequence VI Surveillance Panel.
ftp://ftp.astmtmc.cmu.edu/docs/gas/sequencevi/minutes/VIMinutes20150810%20Conference%20call.pdf

3.0) Action Item Review

3.1 OHT to provide update on current VIE inventory and service engine order. –OHT

3.2 Update of VID engine inventory and expected depletion date of VID engines.

-Expected life of engines range from 2016 Q1
Lab1: 2 engines
Lab2: 2 engines
Lab3: 2 engines
Lab4: 1 engines

3.3 SP chair and test sponsor to investigate what is needed to establish VID equivalent limits for VIE

4.) Old Business

4.1 List of items to be reviewed after the Precision Matrix

-Do we really need to run three RO tests to establish the new engine for LTMS?

-Discussion of reducing the new reference requirement to two oils, then a third oil run after a defined number of candidates.
-Discussion of using FEI 2 and FEI Sum for references to match candidate pass/fail criteria.
-Discussion of evaluating 80/20 ratio of BL before to after for FEI 1 and 10/90 for FEI 2.
-Should the acceptance bands value of 1.96 be rounded up? Due to the rounding on FEI 1 and 2 the actual pass limit is 1.91 and 1.92.

4.2 Update on progress of 5W-30 Tech1 in VIE testing. –Labs
-FEI1/2 = 1.09/1.05 @ 349 hours
- FEI1/2 = 0.29/0.37 @ 2059 hours

4.3 Engine hours needs to be addressed in the precision matrix and there is concern in the industry that the current design does not adequately address this. Alternate matrix designs have been requested (presentation attached). –Jo Martinez

4.4 Update from task force, to investigate alternative Sequence VIE procedures that would improve 0W-16 response in the Sequence VIE test.
- Charlie Leverett/Bill Buscher/Satoshi Hirano

5.) New Business

5.1 Discussion on third reference oil for precision matrix (replacement for 1011).

5.2 Review updated prove out data statistical analysis (presentation attached). –Jo Martinez

6.) Next Meeting

Call of the chairman

7.) Meeting Adjourned

ASTM SEQUENCE VI

Name	Address	Phone/Fax/Email	Attendance
Jason Bowden Voting Member	OH Technologies	Phone: (440) 354-7007 jhbowden@ohtech.com	ATTEND
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Tracey King Voting Member	Haltermann	Phone: tking@jhaltermann.com	ATTEND
Charlie Leverett Voting Member	Intertek Automotive Research Adrian Alfonso for Charlie	Phone: (210) 647-9422 charlie.leverett@intertek.com	
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Dan Worcester Voting Member	Southwest Research Institute	Phone: (210) 522-2405 dan.worcester@swri.org	ATTEND

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Tom Smith		Valvoline	
Hap Thompson	Hapjthom@aol.com	VIE Facilitator	

ASTM SEQUENCE VI

Name	Address	Phone/Fax/Email	Attendance

VIE Prove-Out Data Analysis

Statisticians Group

8/14/15

Statisticians Group

- Art Andrews, Exxon Mobil
- Doyle Boese, Infineum
- Eric Liu, SwRI
- Todd Dvorak, Afton
- Rich Grundza, TMC
- Kevin O'Malley, Lubrizol
- Jo Martinez, Oronite

Conclusions

The current VIE data indicates statistical discrimination among the oils tested for FEI1 and FEI2.

Based on the analysis presented the estimated standard deviation for both FEI1 and FEI2 is 0.20. VID LTMS standard deviation is 0.12 and 0.14 for FEI1 and FEI2, respectively. Other estimates have also been calculated based on various subsets of the oils tested.

The standard deviation estimates are based on models including oil, lab, engine within lab and engine hour effects.

Engine Hours should be included in the precision matrix design.

In some of the analyses, lab and engine within lab effects are statistically significant.

VIE Data

Oil	Sample Size	Engine Hours
542	10	347-1606
542-1	26	347-2827
542-2	13	363-3130
1010	29	346-2411
1010-1	3	564-844
541-1	10	346-746
5w30T1*	1	349
Total	92	346-3130

Oil	# of VIE Tests with Engine Hours ≤ 800	# of VIE Tests with Engine Hours > 800
542	8	2
542-1	23	3
542-2	10	3
1010	24	5
1010-1	2	1
541-1	10	0
5w30T1	1	0
Total	78	14

*Validity Code RN, not run per procedure

Data Concerns

- Data used in the analysis is not designed but observational and therefore have a lot of correlation among the variables
  - Engines did not run the same mix of oils
  - Many engines have limited tests
- High percentage of the tests were run in early engine hours
  - In most cases there's a lack of randomization of oil order in new engines
- Most of the data in higher hours are with 542
- FM carry-over effects could not be accounted for in this data

VIE FEI1_OR

Combined Oils 542, 542-1, 542-2 and 1010, 1010-1

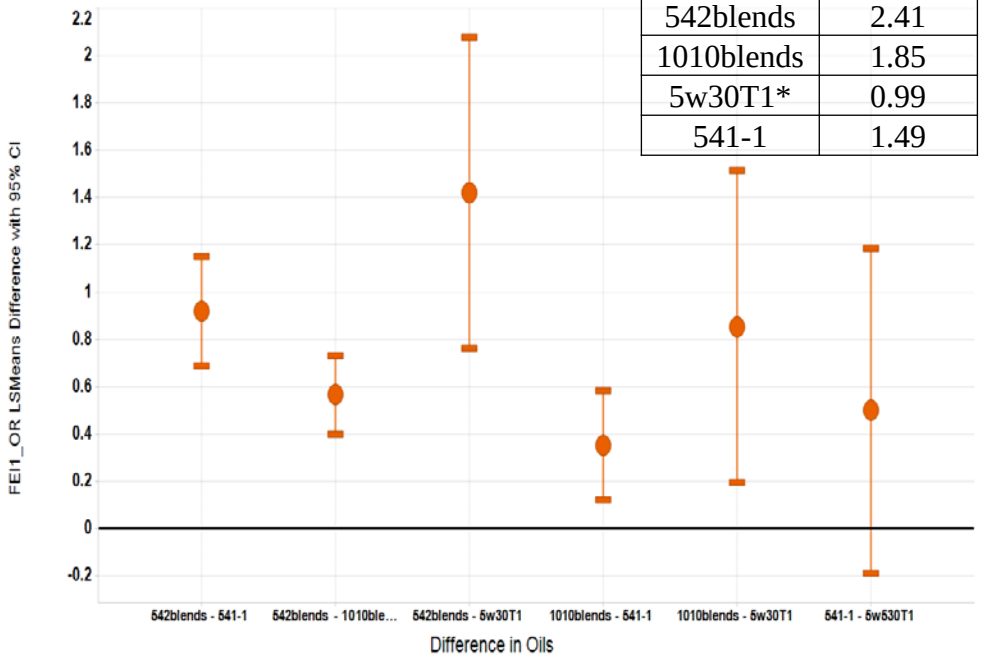
Model: s = 0.20

- Engine Hours [linear]
- Oils [542, 1010, 541-1, 5w30T1]
- Labs [A, B, C, D, F, G]
- Engine(Lab)

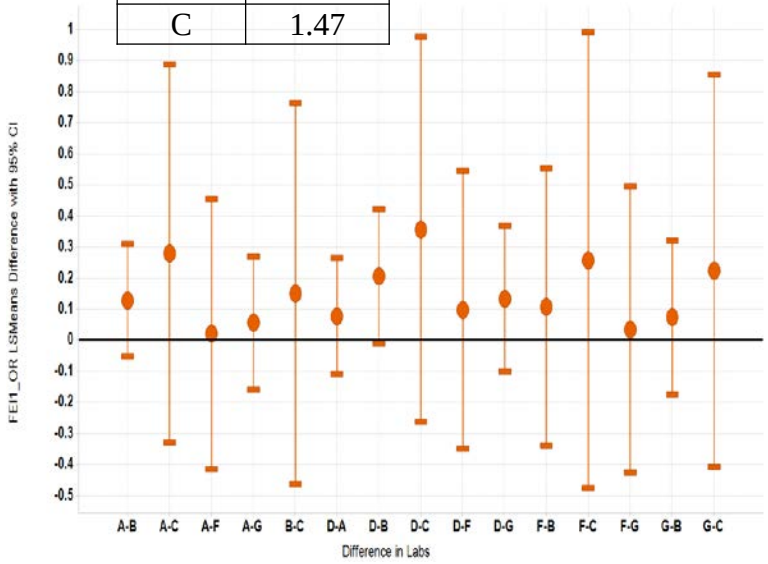
Conclusions (5% level of significance):

1. Oil: 542 > 1010 > 541-1, 5w30T1
2. Lab: No significant lab differences

Oil	LS Mean
542blends	2.41
1010blends	1.85
5w30T1*	0.99
541-1	1.49



Lab	LS Mean
D	1.83
A	1.75
F	1.73
G	1.70
B	1.62
C	1.47



Oil/Lab Comparisons with intervals that do not include 0 are significantly different

* Validity Code RN – not run per procedure

VIE FEI2_OR

Combined Oils 542, 542-1, 542-2 and 1010, 1010-1

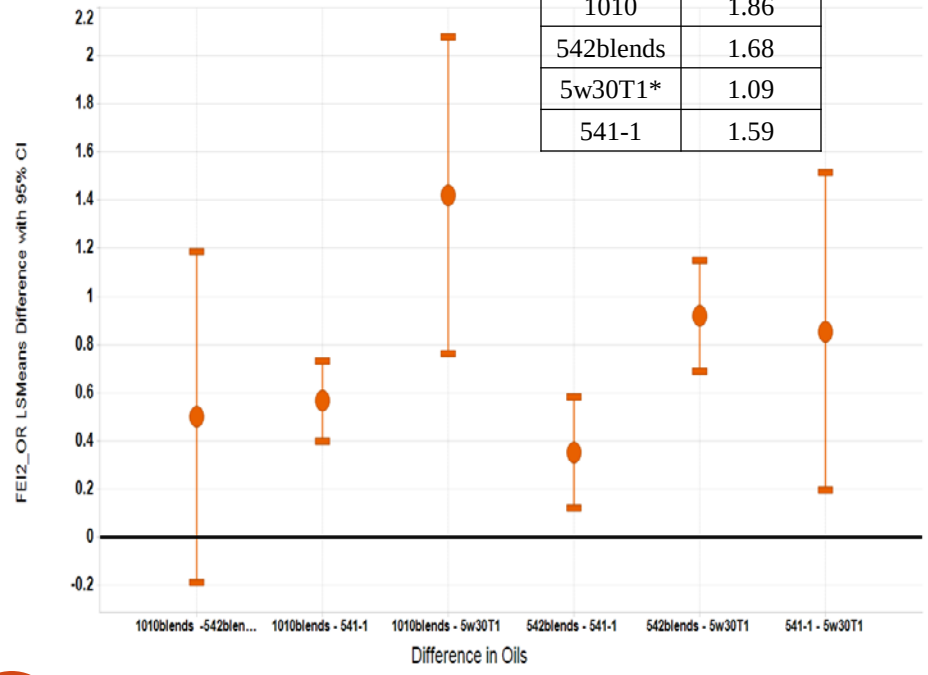
Model: s = 0.20

- Engine Hours [linear]
- Oils [542, 1010, 541-1, 5w30T1]
- Labs [A, B, C, D, F, G]
- Engine(Lab)

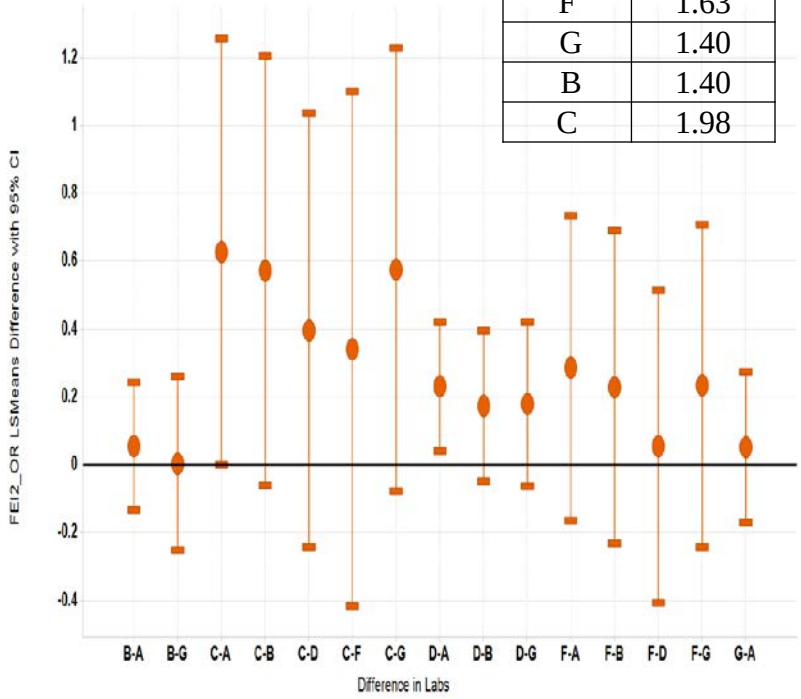
Conclusions (5% level of significance):

1. Oil: 1010 > 542, 541-1, 5w30T1
2. Lab: D > A

Oil	LS Mean
1010	1.86
542blends	1.68
5w30T1*	1.09
541-1	1.59



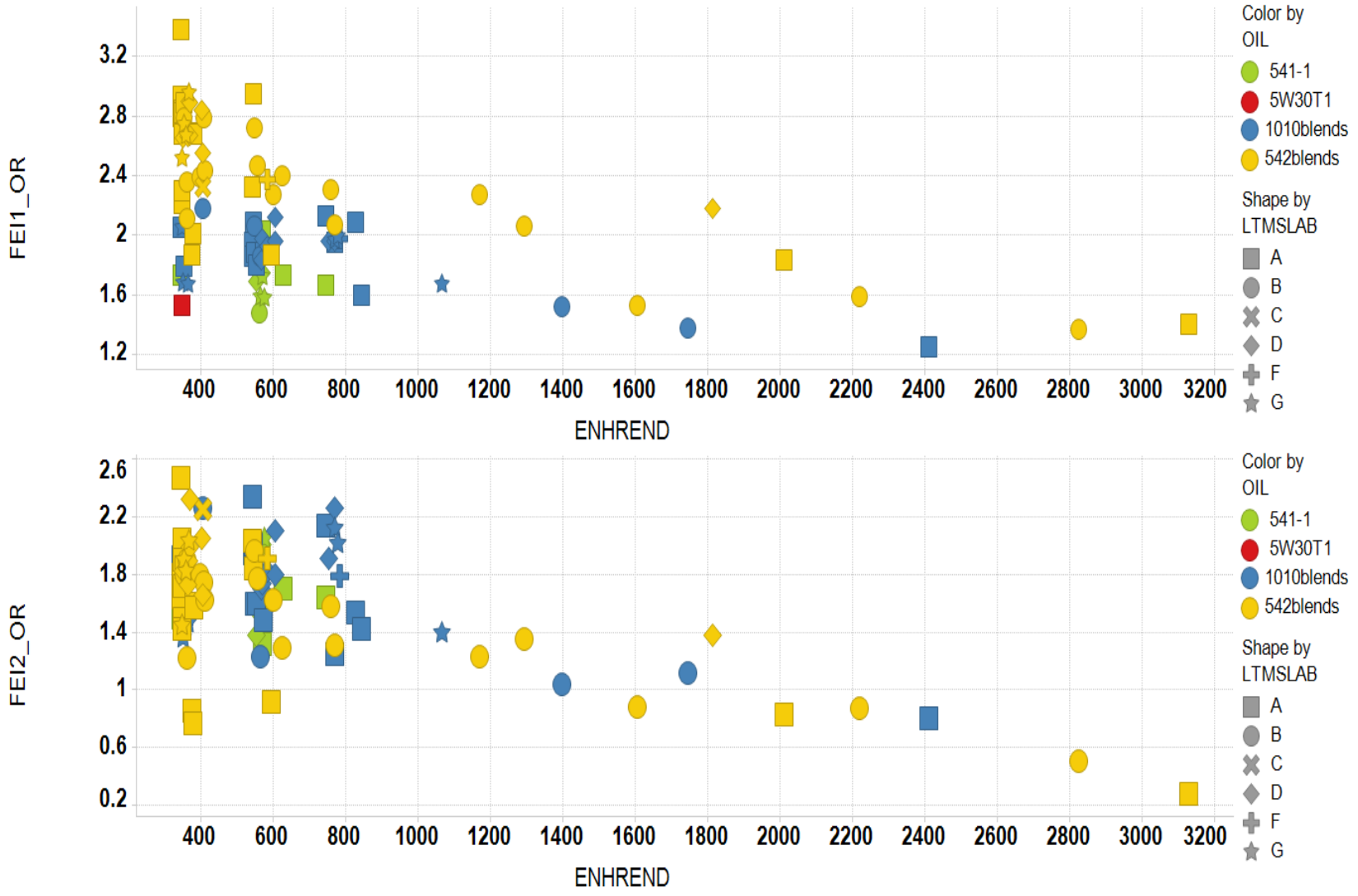
Lab	LS Mean
D	1.58
A	1.35
F	1.63
G	1.40
B	1.40
C	1.98



Oil/Lab Comparisons with intervals that do not include 0 are significantly different

* Validity Code RN – not run per procedure

VIE FEI by Engine Hour



* *Note:* 5w30T1 Validity Code RN – not run per procedure

VID Precision Matrix and VIE Comparison

FEI1				FEI2			
VID Precision Matrix		VIE Prove-Out		VID Precision Matrix		VIE Prove-Out	
Oil	LS Mean	Oil	LSMean	Oil	LS Mean	Oil	LSMean
X (542)	1.49	542blends	2.41	X (542)	0.8	542blends	1.68
		1010blends	1.85			1010blends	1.86
A (540)	1.32			A (540)	1.04		
		5w30T1*	0.99			5w30T1*	1.09
D (541)	0.87	541-1	1.49	D (541)	0.71	541-1	1.59
s	0.14	s	0.20	s	0.16	s	0.20

VID Precision Matrix Oil Discrimination

FEI1: X(542), A(540) > D(541)

FEI2: A(540) > D(541), X(542)

VIE Prove-Out Oil Discrimination

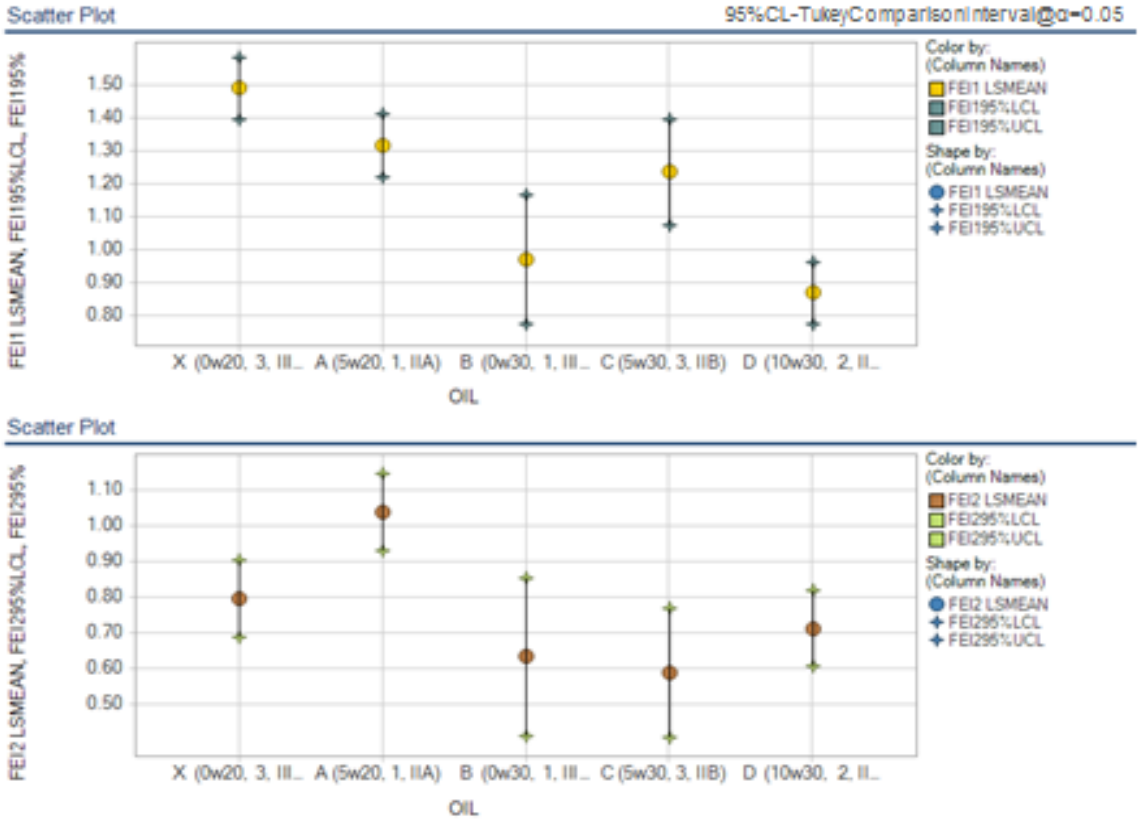
FEI1: 542blends > 1010 > 541-1, 5w30T1

FEI2: 1010 > 541-1, 542blends, 5w30T1

*Validity Code RN – not run per procedure

VID Precision Matrix

FEI LSMean by Oil



OIL	FEI1 LSMEAN	FEI2 LSMEAN
A	1.32	1.04
B	0.97	0.63
C	1.24	0.59
D	0.87	0.71
X	1.49	0.80
OIL Difference	**P-value**	**P-value**
A-B	0.0172	0.0133
A-C	0.8792	0.0008
A-D	<.0001	0.0007
A-X	0.0706	0.0173
B-C	0.1651	0.9963
B-D	0.8579	0.9612
B-X	0.0002	0.6228
C-D	0.0018	0.7044
C-X	0.0468	0.2286
D-X	<.0001	0.7457

FEI1: A, X > B, D

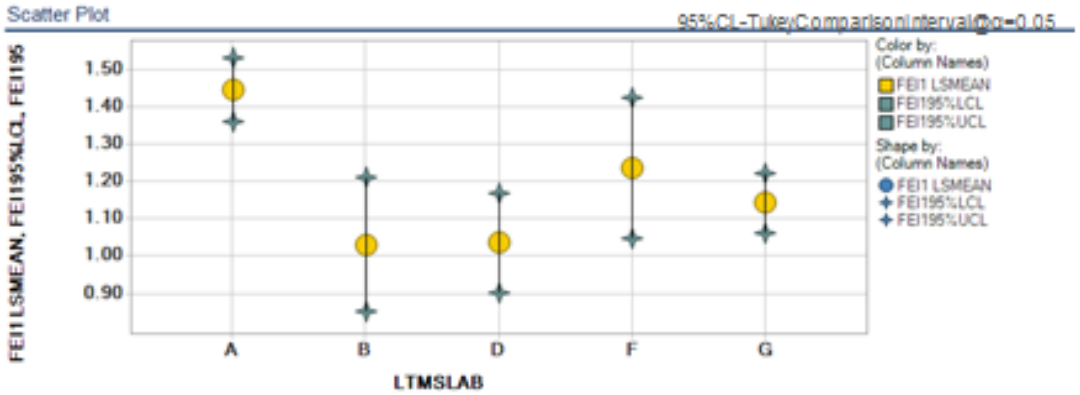
X > C > D

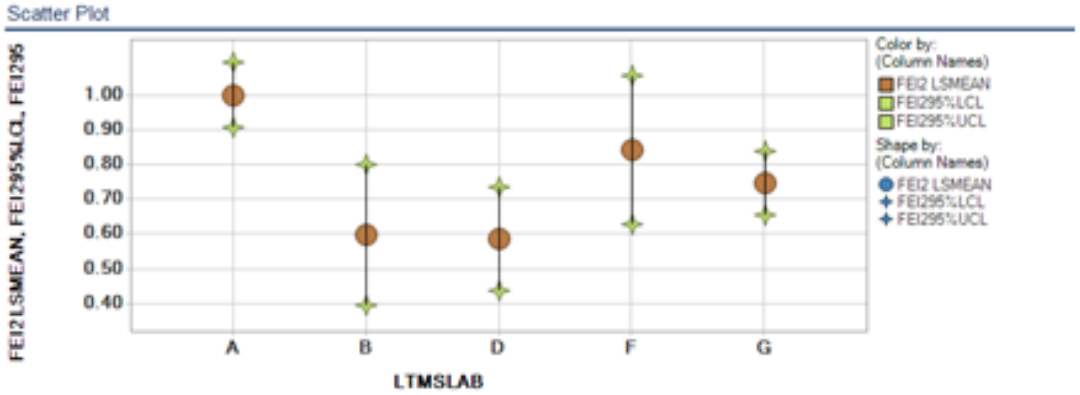
FEI2: A > B, C, D, X

Based on repeated oils data.

VID Precision Matrix

FEI LSMean by Lab



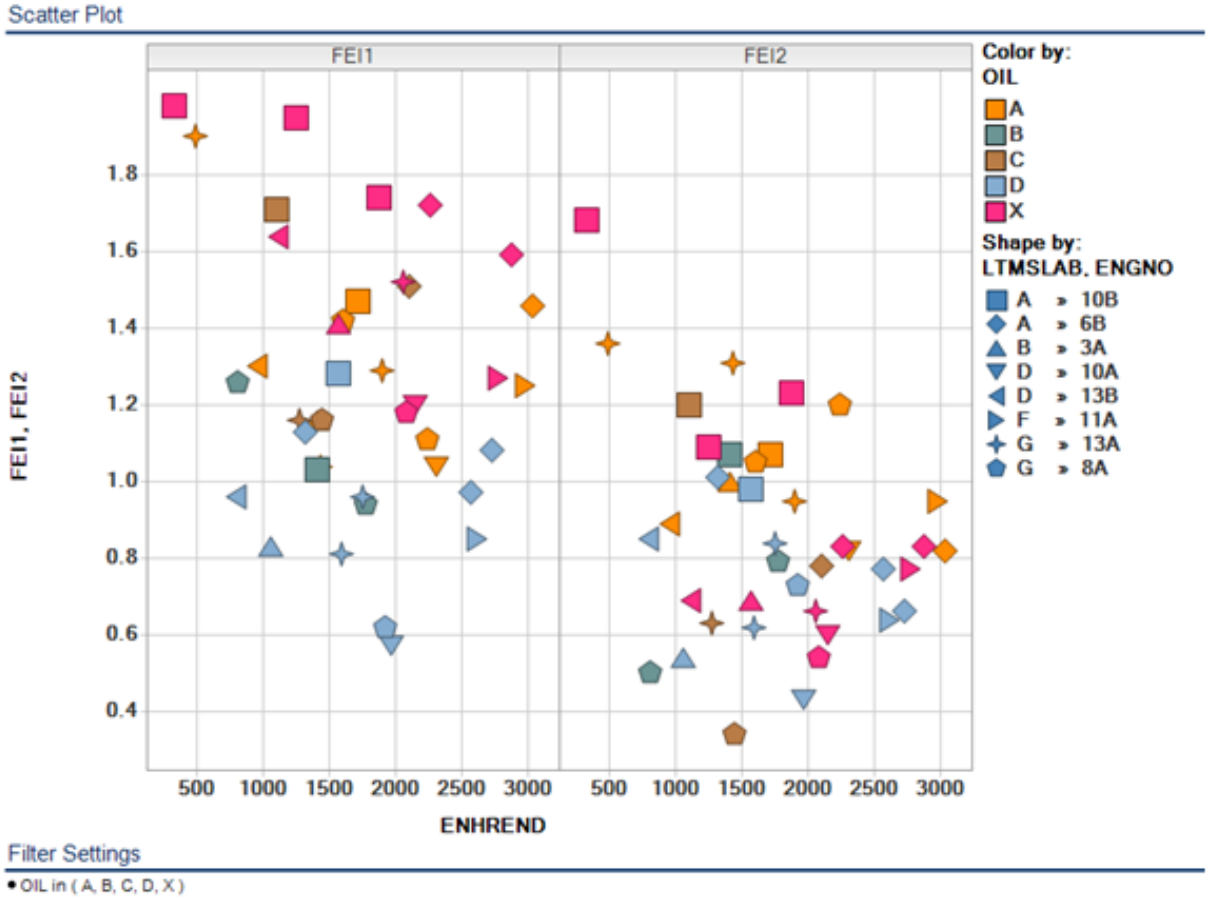


Lab A is significantly higher than labs B, D and G while lab F is not significantly different than the other labs.

Based on repeated oils data.

VID Precision Matrix

FEI by Engine Hours



VID Data and VIE Comparison

FEI1				FEI2			
VID Data		VIE Prove-Out		VID Data		VIE Prove-Out	
Oil	LS Mean	Oil	LSMean	Oil	LS Mean	Oil	LSMean
542blends	1.52	542blends	2.41	542blends	0.83	542blends	1.68
1010	1.34	1010blends	1.85	1010	1.07	1010blends	1.86
540	1.32			540	1.01		
		5w30T1*	0.99			5w30T1*	1.09
541blends	0.91	541-1	1.49	541blends	0.67	541-1	1.59
s	0.12	s	0.20	s	0.13	s	0.20

VIE Prove-Out Oil Discrimination
FEI1: 542blends > 1010 > 541-1, 5w30T1
FEI2: 1010 > 541-1, 542blends, 5w30T1

VID Data Oil Discrimination

FEI1: 542blends > 1010, 540 > 541blends

FEI2: 1010 > 540 > 542blends > 541blends

Oil	# of VIE Tests with Engine Hours ≤ 800	# of VIE Tests with Engine Hours > 800
542	8	2
542-1	23	3
542-2	10	3
1010	24	5
1010-1	2	1
541-1	10	0
5w30T1	1	0
Total	78	14

* VID Data as of 2/19/15
* 5w30T1 Validity Code RN – not run per procedure

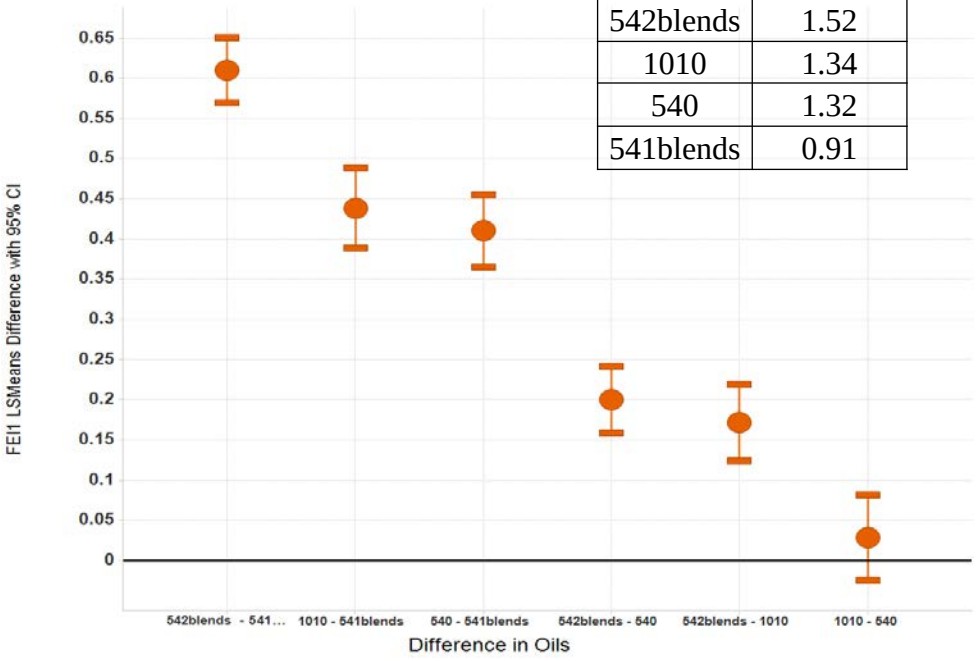
VID FEI1

Combined Oils 542, 542-1, 542-2 and Oils 541, 541-1

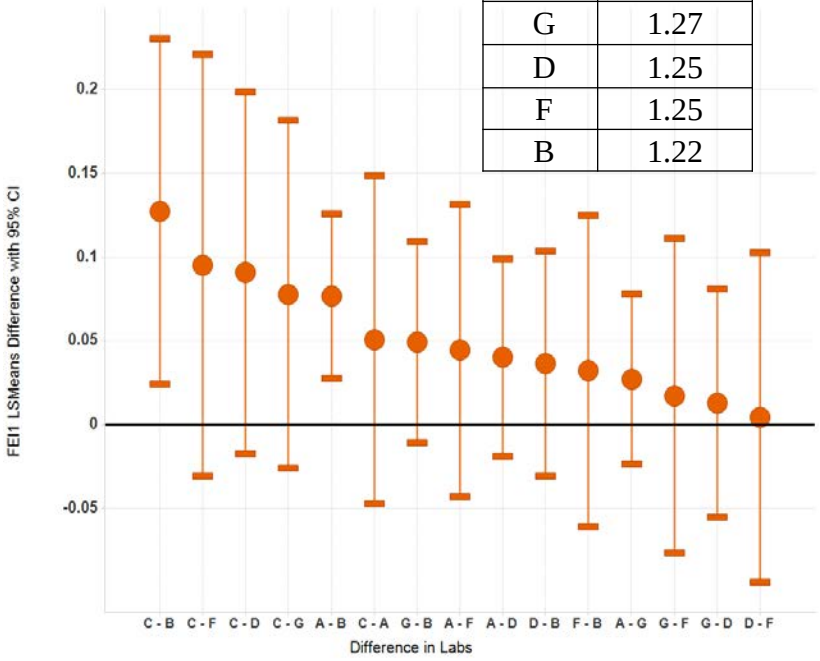
Model: s = 0.12
- Oils [542, 1010, 541, 540]
- Labs [A, B, C, D, F, G]
- Engine(Lab)

Conclusions (5% level of significance):
1. Oil: 542 > 1010, 540 > 541
2. Lab: C, A > B

Oil	LS Mean
542blends	1.52
1010	1.34
540	1.32
541blends	0.91



Lab	LS Mean
C	1.34
A	1.29
G	1.27
D	1.25
F	1.25
B	1.22



Oil/Lab Comparisons with intervals that do not include 0 are significantly different

* VID data as of 2/19/15

VID FEI2

Combined Oils 542, 542-1, 542-2 and Oils 541, 541-1

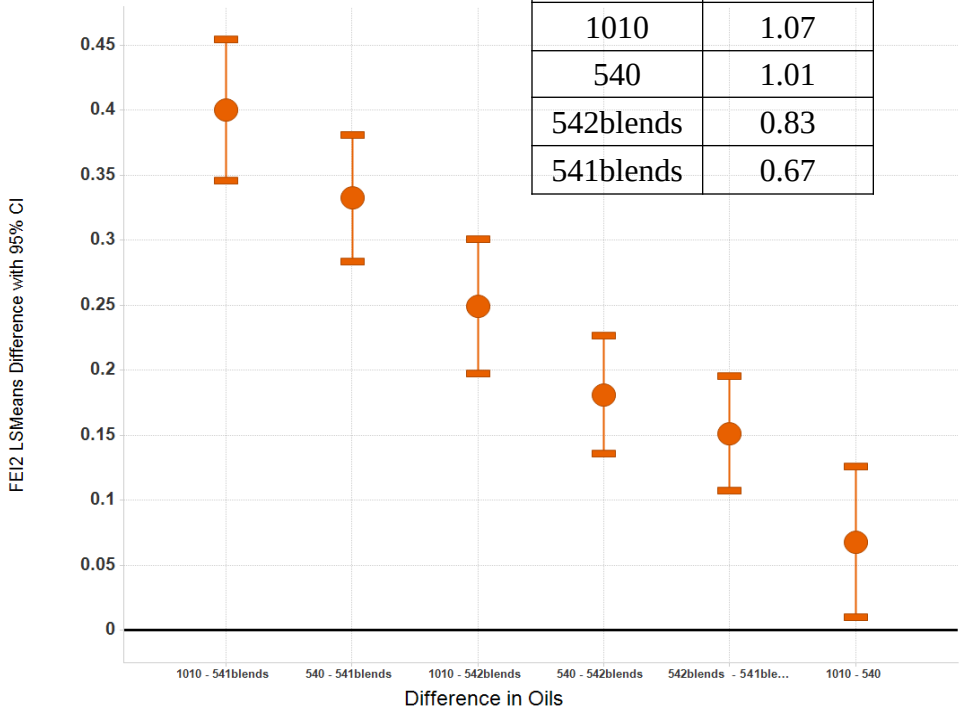
Model: s = 0.13

- Oils [542, 1010, 541, 540]
- Labs [A, B, C, D, F, G]
- Engine(Lab)

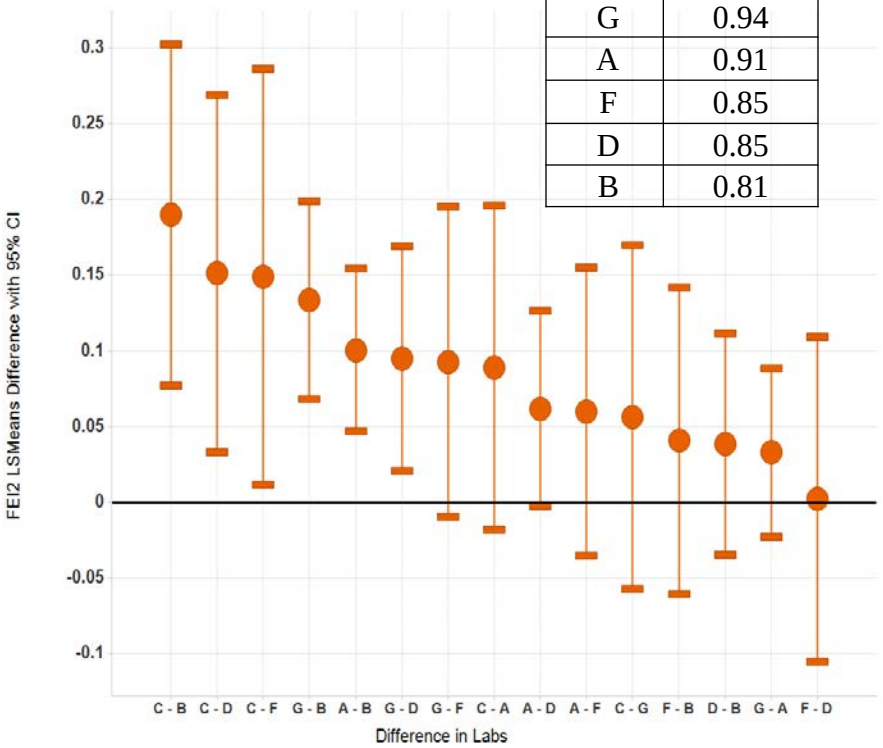
Conclusions (5% level of significance):

1. Oil: 1010 > 540 > 542 > 541
2. Lab: C > B, D, F; G, A > B; G > D

Oil	LS Mean
1010	1.07
540	1.01
542blends	0.83
541blends	0.67



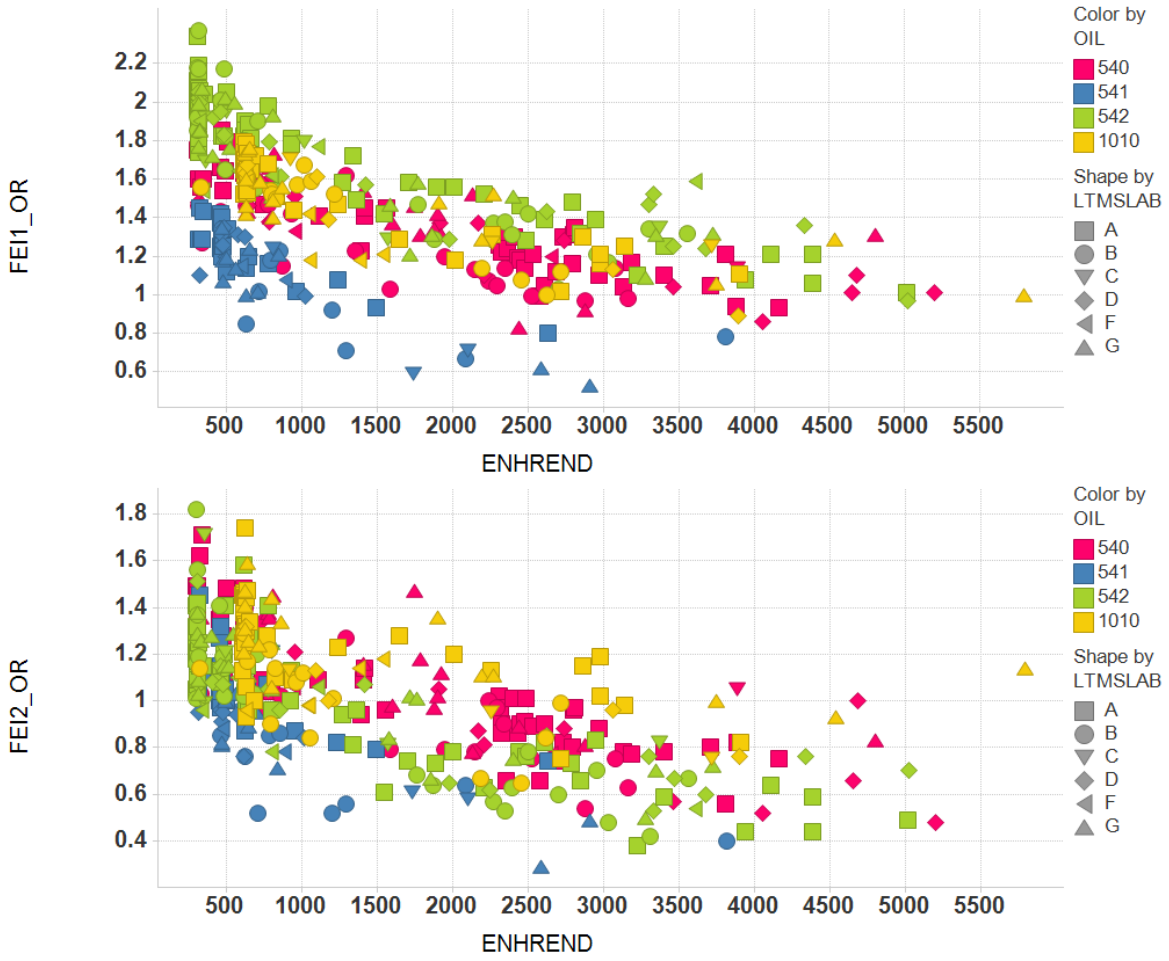
Lab	LS Mean
C	1.00
G	0.94
A	0.91
F	0.85
D	0.85
B	0.81



Oil/Lab Comparisons with intervals that do not include 0 are significantly different

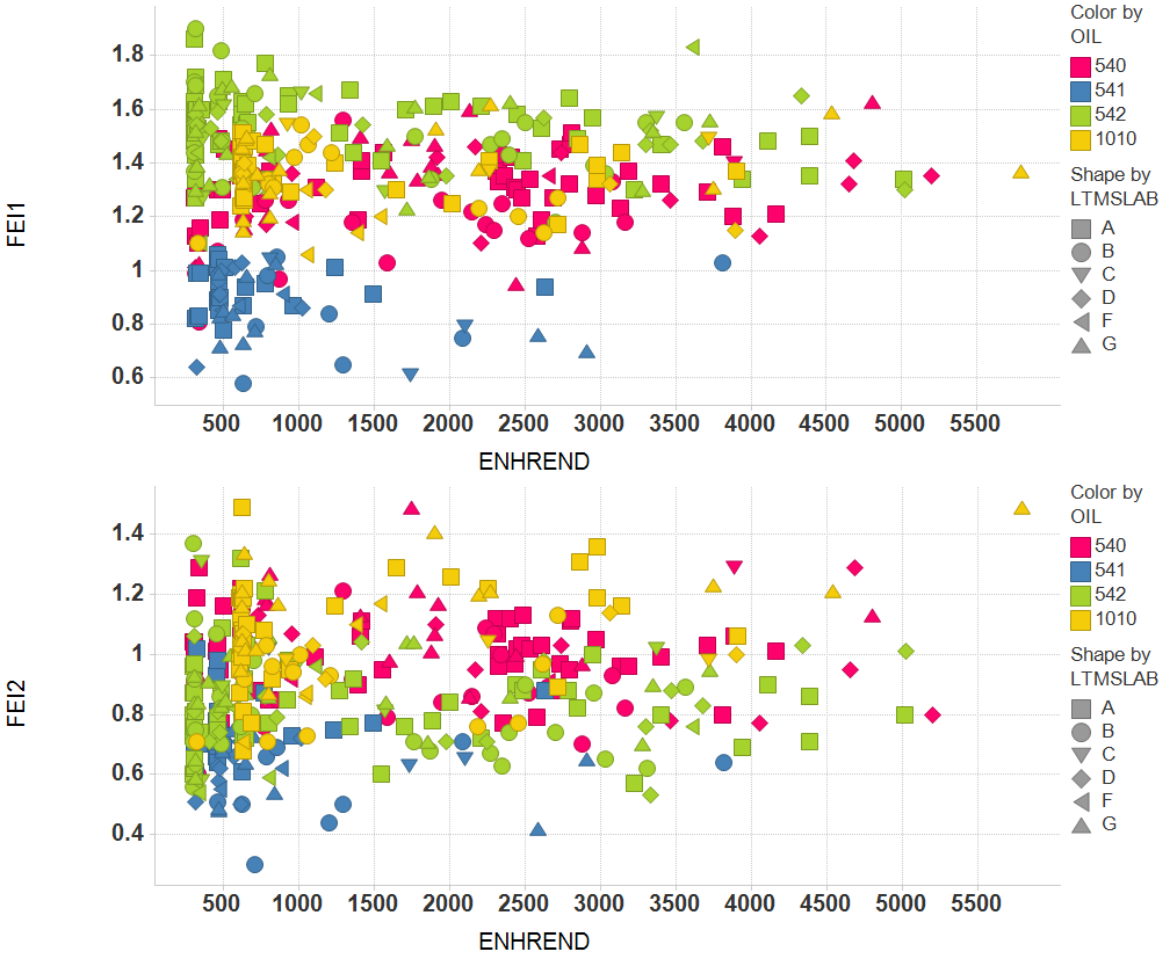
* VID data as of 2/19/15

VID FEI (Unadjusted) by Engine Hour



* VID data as of 2/19/15

VID FEI (Adjusted) by Engine Hour



* VID data as of 2/19/15

VID Data and VIE Comparison (542 and 541 only)

FEI1				FEI2			
VID Data		VIE Prove-Out		VID Data		VIE Prove-Out	
Oil	LS Mean	Oil	LSMean	Oil	LS Mean	Oil	LSMean
542blends	1.52	542blends	2.43	542blends	0.83	542blends	1.74
541blends	0.91	541-1	1.47	541blends	0.68	541-1	1.67
s	0.13	s	0.17	s	0.12	s	0.14

VIE Prove-Out Oil Discrimination

FEI1: 542blends > 541-1

FEI2: not significant

VID Data Oil Discrimination

FEI1: 542blends > 541blends

FEI2: 542blends > 541blends

Oil	# of VIE Tests with Engine Hours ≤ 800	# of VIE Tests with Engine Hours > 800
542	8	2
542-1	23	3
542-2	10	3
541-1	10	0
Total	51	8

* VID data as of 2/19/15

VID Data and VIE Comparison (542 and 1010 only)

FEI1				FEI2			
VID Data		VIE Prove-Out		VID Data		VIE Prove-Out	
Oil	LS Mean	Oil	LSMean	Oil	LS Mean	Oil	LSMean
542blends	1.52	542blends	2.40	542blends	0.82	542blends	1.68
1010	1.35	1010blends	1.86	1010	1.07	1010blends	1.86
s	0.12	s	0.21	s	0.15	s	0.21

VIE Prove-Out Oil Discrimination

FEI1: 542blends > 1010

FEI2: 1010 > 542blends

VID Data Oil Discrimination

FEI1: 542blends > 1010

FEI2: 1010 > 542blends

Oil	# of VIE Tests with Engine Hours ≤ 800	# of VIE Tests with Engine Hours > 800
542	8	2
542-1	23	3
542-2	10	3
1010	24	5
1010-1	2	1
Total	67	14

* VID data as of 2/19/15

Standard Deviation Estimates

RMSE, estimate of s	FEI1		FEI2	
	VID	VIE	VID	VIE
All Oils, VID Prove-Out Matrix	0.22	0.20	0.26	0.20
All Oils, VID Precision Matrix	0.14	0.20	0.16	0.20
All Oils, Current VID Data	0.12	0.20	0.13	0.20
542 & 541 blends only	0.13	0.17	0.12	0.14
542 & 1010 blends only	0.12	0.21	0.15	0.21

* VID data as of 2/19/15

GF-6 VIE PRECISION MATRIX

Statisticians Task Force

August 18, 2015

GF-6 PM Design Statisticians Task Force

- Art Andrews, Exxon Mobil
- Doyle Boese, Infineum
- Kevin O'Malley, Lubrizol
- Todd Dvorak, Afton Chemical
- Jo Martinez, Chevron Oronite
- Ricardo Affinito, Chevron Oronite
- Eric Liu, SwRI
- Luc Girard, API

Objectives:

- Surveillance panel needs to decide precision matrix design approach
  - Options/approaches have been discussed within SP
  - Decision needed so design can be finalized

- Oils need to be finalized
  - 542-2; 0w20
  - 1010-1; 5w20
  - 0w16 Tech 1: No longer a viable VIE matrix oil

Design Assumptions:

- 8 stands; 6 labs
- Funding for 53 matrix tests

Actual Cost

	Planned Test Stands								GF-6 Precision Matrix ONLY			
	Afton	LZ	XOM	Ashland	IAR	SwRI	Stands	TEST Cost	Total Runs	Cal Runs	Cal $'s	Total $'s
Chrysler Oxid. (Seq. IIIH Rep)	1	1	None	1	2	2	7	**$57,250**	28	14	**$801,500**	**$1,603,000**
Sequence IVB (Toyota)	None	1	None	None	2	2	5	**$49,250**	20	10	**$492,500**	**$985,000**
Sequence V-V8	1	1	None	1	2	2	7	**$63,000**	28	14	**$882,000**	**$1,764,000**
LSPI (Ford)	None	1	None	None	2	2	5	**$14,250**	20	10	**$142,500**	**$285,000**
Chain Wear Test (Ford)	1	None	None	1	2	2	6	**$45,750**	24	12	**$549,000**	**$1,098,000**
Sequence VIE	1	1	1	1	2	2	8	**$32,750**	53	24	**$786,000**	**$1,735,750**
											$3,653,500	**$7,470,750**

IAR and SwRI have 2 Stands for Each Test

Seq, IIIH, Seq. IVB, Seq. V, LSPI, Chain Wear are 4 Tests per Stand

Seq. VIE, 7 tests per stand for the first stand + 4 test per stand for the second.

Seq, IIIH, Seq. IVB, Seq. V, LSPI, Chain Wear have 2 Calibration Tests/Stand

Seq. VIE has 3 Calibration Tests/Stand

Test Funding - Total	$7,470,750
Donated Tests - Total	$3,653,500
Industry Funding MOA - Total	$3,817,500
Actual Matrix Cost	$3,817,250
Extra Funding	$250

VIE Matrix: Summary of Considerations

Considerations previously discussed within the surveillance panel:

1. Can engines that currently have hours on them be set aside, now, for matrix testing? These could be engines currently on stands or sitting in inventory. In either case, no more tests would be run on these engines prior to the matrix. Can we know why engines are sitting in inventory?
   a) If not, can the engine availability spreadsheet be updated on a routine basis and sent to the statisticians' task force, with comments on why engines are sitting in inventory.

   - Engines currently in use **can't** be set aside for matrix testing. List of available engines will be updated regularly with comments on why engines are sitting in inventory. List will also be updated based on the labs' willingness to offer engines with a lot of hours on it.

2. If needed, can labs install new engines for matrix testing? YES

3. If the precision matrix requires more than one engine on a stand and the second engine is sitting in inventory with hours on it, will that second engine need some sort of "re-break in"? YES If so, what will this entail? Run "16-32 hours" aging.

4. If an engine has >3100 hours after the last matrix test finishes and no other engine was used on the same stand, will the calibration/donated tests still count?
   - Based on MOA, 3 calibration tests can be counted for all engines. Labs will decide whether they're willing to offer an older engine in the matrix (SW is willing, LZ might, IAR is not willing). Will know for sure before the start of the matrix.

5. The statisticians' task force is currently trying to put a precision matrix together to assess stand/engine, oil, and engine hour effects. Are there other potential effects/factors we should be aware of when designing the matrix? NO

6. Do the matrix oils (RO542-2, RO1010-1, Tech1) contain friction modifier? Ask TMC

VIE Precision Matrix Approach 1

- All stands start with new engines
- Consecutive matrix tests

For illustrative purposes only:

Engine Hours	XOM	Afton	Ashland	LZ	IAR Engine 1	IAR Engine 2	SwRI Engine 1	SwRI Engine 2
350	1010-2	1010-2	Oil3	Oil3	Oil3	542-2	542-2	1010-2
550	Oil3	542-2	542-2	1010-2	1010-2	Oil3	Oil3	542-2
750	542-2	Oil3	1010-2	542-2	542-2	1010-2	1010-2	Oil3
950	542-2	Oil3	1010-2	542-2	542-2	Oil3	1010-2	Oil3
1150	Oil3	542-2	542-2	1010-2	1010-2	542-2	Oil3	542-2
1350	1010-2	1010-2	Oil3	Oil3	Oil3	1010-2	542-2	1010-2
1550		Oil3			542-2	1010-2	1010-2	Oil3

VIE Precision Matrix Approach 2

- All stands start with new engines
- Consecutive matrix tests
- 2 engines run longer; 6 end earlier

For illustrative purposes only:

Run Order	SW1	SW2	IAR1	IAR2	LZ	Afton	Ashland	XOM	
SOT Engine Hours	150	150	150	150	150	150	150	150	Eng Hrs
1	542-2	1010-2	Tech 1 0W-16	542-2	Tech 1 0W-16	1010-2	Tech 1 0W-16	1010-2	350
2	Tech 1 0W-16	542-2	1010-2	Tech 1 0W-16	1010-2	542-2	542-2	Tech 1 0W-16	550
3	1010-2	Tech 1 0W-16	542-2	1010-2	542-2	Tech 1 0W-16	1010-2	542-2	750
4	1010-2	Tech 1 0W-16	542-2	Tech 1 0W-16	542-2	Tech 1 0W-16	1010-2	542-2	950
5	Tech 1 0W-16	1010-2	1010-2	1010-2	1010-2	542-2	542-2	Tech 1 0W-16	1150
6	542-2		Tech 1 0W-16						1350
7	1010-2		542-2						1550
8	542-2		542-2						1750
9	Tech 1 0W-16		1010-2						1950
10	1010-2		Tech 1 0W-16						2150
11	Tech 1 0W-16		542-2						2350
EOT Engine Hours	2150	1150	2150	1150	1150	1150	1150	1150	Total Runs
Runs/Engine	11	5	11	5	5	5	5	5	52

VIE Precision Matrix Approach 3

- All stands start with new engines
- BOI/VGRA (or other candidates) interspersed within matrix
- If pursued, BOI/VGRA plan needed (timing and # of tests)

For illustrative purposes only:

Engine Hours	XOM	Afton	Ashland	LZ	IAR Engine 1	IAR Engine 2	SwRI Engine 1	SwRI Engine 2
350	1010-2	1010-2	Oil3	Oil3	Oil3	542-2	542-2	1010-2
550	Oil3	542-2	542-2	1010-2	1010-2	Oil3	Oil3	542-2
750	542-2	Oil3	1010-2	542-2	542-2	1010-2	1010-2	Oil3
950	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA
1350	542-2	Oil3	1010-2	542-2	542-2	Oil3	1010-2	Oil3
1750	Oil3	542-2	542-2	1010-2	1010-2	542-2	Oil3	542-2
1950	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA	BOI/VGRA
2150	1010-2	1010-2	Oil3	Oil3	Oil3	1010-2	542-2	1010-2
2550		Oil3			542-2	1010-2	1010-2	Oil3

VIE Precision Matrix Approach 4

- Not all engines are new; SOT engine hours depend on available engines
- Consecutive matrix tests
- If pursued, updated inventory list needed from labs

For illustrative purposes only:

Run Order	XOM	Afton	Ashland	LZ	IAR Engine 1	IAR Engine 2	SwRI Engine 1	SwRI Engine 2
Engine	New	New	New	OHT#15	New	New	OHT#42	OHT#63
SOT EngHr	150	150	150	1700	150	150	1700	1200
1	1010-2	1010-2	Oil3	Oil3	Oil3	542-2	542-2	1010-2
2	Oil3	542-2	542-2	1010-2	1010-2	Oil3	Oil3	542-2
3	542-2	Oil3	1010-2	542-2	542-2	1010-2	1010-2	Oil3
4	542-2	Oil3	1010-2	542-2	542-2	Oil3	1010-2	Oil3
5	Oil3	542-2	542-2	1010-2	1010-2		Oil3	542-2
6	1010-2	1010-2	Oil3	Oil3	Oil3		542-2	1010-2
7	542-2	Oil3	1010-2	542-2	542-2		1010-2	Oil3
EOT EngHr	1550	1550	1550	3100	1550	950	3100	2600

VIE Precision Matrix Approach 5

- Not all engines are new; SOT engine hours depend on available engines
- Some stands switch engines
- Consecutive matrix tests

For illustrative purposes only:

Run Order	SW1	SW2	IAR1	IAR2	LZ	Afton	Ashland	XOM
SOT Engine Hours	1700	1200	1200	150	1700	2400	150	150
1	542-2	T15w30	T15w30	1010-2	1010-2	T15w30	542-2	542-2
2	542-2	1010-2	542-2	542-2	1010-2	T15w30	T15w30	1010-2
3	1010-2	1010-2	542-2	T15w30	542-2	1010-2	T15w30	T15w30
4	T15w30	542-2	1010-2	1010-2	T15w30	3000	542-2	T15w30
EOT Engine Hours			2000			150		
SOT Engine Hours			150			1010-2		
5	1010-2	542-2	T15w30		T15w30	542-2	1010-2	542-2
6	T15w30	T15w30	1010-2		542-2	542-2	1010-2	1010-2
7	542-2	T15w30	542-2		542-2	T15w30	T15w30	1010-2
EOT Engine Hours	3100	2600	750	950	3100	950	1550	1550

VIE Precision Matrix Approach 6

- SOT engine hours mandated:
  - Some engines new
  - Some engine with mid range hours
  - Some engine with higher hours
- Consecutive matrix tests

For illustrative purposes only:

Run Order	XOM	Afton	Ashland	LZ	IAR Engine 1	IAR Engine 2	SwRI Engine 1	SwRI Engine 2
SOT EngHr	Mid	High	Low	High	Low	Mid	Low	High
1	1010-2	1010-2	Oil3	Oil3	Oil3	542-2	542-2	1010-2
2	Oil3	542-2	542-2	1010-2	1010-2	Oil3	Oil3	542-2
3	542-2	Oil3	1010-2	542-2	542-2	1010-2	1010-2	Oil3
4	542-2	Oil3	1010-2	542-2	542-2	Oil3	1010-2	Oil3
5	Oil3	542-2	542-2	1010-2	1010-2	542-2	Oil3	542-2
6	1010-2	1010-2	Oil3	Oil3	Oil3	1010-2	542-2	1010-2
7		Oil3			542-2	1010-2	1010-2	Oil3

Comparison of Approaches

	Approach 1	Approach 2	Approach 3	Approach 4	Approach 5	Approach 6
	All stands new	All stands start new; 2 engines run longer	All stands new	Use available engines	Use available engines PLUS switching engines	Mandate SOT engine hours
	Consecutive Mx Tests	Consecutive Mx Tests	Intersperse with BOI/VGRA tests	Consecutive Mx Tests	Consecutive Mx Tests	Consecutive Mx Tests
Max EOT Hours	~1750	2 engines have higher hours	Higher hours can be achieved	Depends on availability	Depends on availability	Higher hours can be achieved
Matrix Duration	Shorter	Longer	Longer	Shorter	Shorter	Shorter
Impact of 0w16 tests on VIE Mx testing	None	None	None	Possible for engines if 0w16 oils were run	Possible for engines if 0w16 oils were run	Possible for engines if 0w16 oils were run
Testing at early hours to estimate hours effect	Better	Better	Better	Good	Good	Good
Evaluation of oil discrimination at higher hours	Good	2 engines have higher hours	Better	Possibly Better	Possibly Better	Better
Risk engine use ends before Mx tests are completed	Lower	Higher for 2 engines	Higher	Depends on availability	Mitigates higher risk	Higher
Engine potentially calibrated post matrix with remaining engine life	Likely	Less likely for 2 engines	Likely	Depends on availability	Likely	Depends on availability
Carry over effect	Depends on oils selected, but can be designed for	Depends on oils selected, but can be designed for	Depends on oils selected, but can be designed for; harder to design for	Depends on oils selected, but can be designed for	Depends on oils selected, but can be designed for	Depends on oils selected, but can be designed for
FM effect may change over engine life	Good	2 engines have higher hours	Better	Better; Depends on availability	Better; Depends on availability	Better