Address 100 Barr Harbor Drive
PO Box C700
W. Conshohocken, PA
19428-2959 | USA

Phone 610.832.9500
Fax 610.832.9666
Web www.astm.org

COMMITTEE D02 ON PETROLEUM PRODUCTS, LIQUID FUELS, AND LUBRICANTS

Issued: August 01, 2016

Reply to: Dan Worcester
Southwest Research Institute
6220 Culebra Rd.
San Antonio, TX 78238
Phone: 210.522.2405
Email: dworcester@swri.org

These are the unapproved minutes of the 07.26-27.2016 Sequence VI Face to Face Meetings.

The meeting was called to order at 8:35 AM Central Time by Nathan Moles.

Agenda

The Agenda is the included as Attachment 1.

1.0 Roll Call

The Attendance list is Attachment 2 for 07.26 and Attachment 3 for 07.27.
See Attachment 4 for Motions and Actions.

2.0 Approval of minutes

2.1 Approval of the minutes of the 07.19.2016 conference call.

ftp://ftp.astmtmc.cmu.edu/docs/gas/sequencevi/minutes/VIMinutes201600719ConferenceCall.pdf

MOTION: Approve the minutes from the 07.19.2016 conference call.

Nathan Moles, Robert Stockwell second. The minutes were approved with the action below.

1. Action Item – Correct the short block kit quantities w/ and w/o right heads included in the previous surveillance panel meeting minutes.

The 07.19 minutes will be changed to show the correct quantities for engines with right heads. There were also going to be corrections to the wording of two motions, but those were changed during this meeting and will be included in these minutes as new motions.

3.0 Action Item Review

3.1 OHT to provide update on current VIE inventory –OHT

133 -002 version engines remain.

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

-Expected depletion of VID engines 2016 Q3

~70 test starts at independent labs remain

IAR has about 23 tests remaining, SwRI has about 14 tests left. IAR had two abandoned engines that were not on target and may install and run those again.

3.3 Review LTMS spread sheet ahead of meetings –All

There were no comments.

3.4 Corrected Motions from meeting minutes on 5/25/2016:

1. *Move forward with the VIE test allowing up to 4 full length test with the 4^{th} test starting no later than 900 hours.*
2. *After the completion of the 4^{th} run on the 4^{th} VIE engine installed in each stand, test lab will run a donated 5^{th} test on a reference oil to be determined.*

There were sufficient changes to these motions that they will move forward a new motions for this meeting.

Motion – Move forward with the Sequence VIE test allowing up to 4 full length tests with the last test starting no later than 900 hours.

Tim Cushing / Nathan Moles / Passed Unanimously 14 – 0 – 0

Motion – After the completion of the last run on each of the first three calibrated engines installed in each lab, the test lab will run a donated 5^{th} test on the same reference oil used in the first acceptable calibration test on that engine.

Bill Buscher / Jeff Hsu / Passed Unanimously 14 – 0 – 0

3 Old Business

4.1 Update from task force, to investigate alternative test procedure Sequence "VIF" that would improve 0W-16. – Dan Worcester/Satoshi Hirano The matrix is complete. The Stat Group has begun review. There will be further discussion on 07.27.

4.2 Update from task force to investigate option to use short blocks to supplement engine inventory. –Adrian Alfonso/Bill Buscher
934 engine kits have been requested. IAR will continue work on a flow comparison of the VIE and VID flow nozzles. Cliff Salvesen asked if there were more of the VID rings in stock. Jason Bowden will check on this and report back.

4.3 Update from task force, to investigate engine cleaning procedure. –Dan Worcester
SwRI third test on a cleaned engine will be reported this week. There were questions on whether the head cleaning procedure could be used for the engine kits that do not have the right side head.

4.4 List of items to be reviewed after the Precision Matrix -All

4.4.1 Updated analysis of VIE precision matrix N=29
See Attachment 5. Kevin O'Malley gave the presentation. The matrix used 29 tests, 4 runs per engine, 6 labs, 3 oils and engine 128 data was removed. Amol Savant asked why 4 tests per engine were selected and whether this analysis would change if 5 tests per engine is approved later. The review would change at that time. Engine hour corrections were selected for FEI 1 and FEI 2 based on the selected runs, and it was determined a linear equation gave the best response:

FEI1 = FEI1_OR + 0.000518*(ENHREND – 675)

FEI2 = FEI2_OR + 0.000381*(ENHREND – 675)

675 hours was the average for the data reviewed. BLB 1 to 2, and 2 to 3 and BLB 2 to BLA shifts are included on Slide 14. Dave Glaenzer asked why weighted BLB 1 to 2 is not used. This was from early in VID development, and there will be an action to review this.

Action Item – Review use of weighted fuel consumption for BL shift calculations.

FEI 1 showed separation of the oils. Lab G did show a difference between two engines in the lab, and one engine in Lab C only used one test. Repeatability and reproducibility are shown in Slide 26.

FEI 2 separation is not as good on separation. FEI 2 repeatability and reproducibility are shown in Slide 36.

Attachment 6 is the LTMS comparison. This provides targets and standard deviations for each of the three reference oils. It gives two options to determine how engine severity adjustments are set. Option 1 does not cap and Option 2 does. Excess influence is considered as are weight factors [WF]. See Attachment 7. Separate weighting factors for FEI 1 and 2 were discussed. There was a motion to use WF = 1.0. It failed to pass.

Motion – Adopt a weighting factor of 1.0 for calculating SAs for both FEI1 and FEI2 for the Sequence VIE test.
Andy Ritchie / Dave Glaenzer / Failed 5 – 8 – 1

There was then further discussion on the WF value that would provide acceptable test response. Another motion was made:

Motion – Adopt a weighting factor of 0.6 for calculating SAs for both FEI1 and FEI2 for the Sequence VIE test.
Robert Stockwell / Jeff Hsu / Passed 11 – 3 – 0

Setting the cap eliminated the need for Option 1. However there was still a need to set the Acceptance Limit [AL_1] in Option 2.

Motion – Set AL_1 acceptance limits for Sequence VIE calibration tests at 2.0 standard deviations.
Dave Glaenzer / Amol Savant / Passed 8 – 5 – 1

Here are the oil targets and standard deviations:

Targets	FEI1	FEI2
RO1010-1	1.90	1.82
RO542-2	2.56	1.73
RO544	1.30	1.41

	FEI1	**FEI2**
1010-1	0.27	0.25
542-2	0.31	0.30
544	0.26	0.20

Acceptance Limit [AL_2] and [AL_3] were considered next. Discussion noted that an ASTM repeatability limit was 2.8, and that unless a very close fail, 3 references would likely be required if the first test failed. Cliff Salvesen commented that the group should not set AL_3 lower than 2.8. These choices would eliminate excessive influence consideration.

Motion – Set AL_2 acceptance limits for Sequence VIE calibration tests at 2.8 standard deviations, set R (standard deviation ratio) at 1.0 for FEI1 and at 0.48 for FEI2 and use engine hour adjusted Yi data instead of an EIC (excessive influence cap).
Dave Glaenzer / Dan Worcester / Passed 10 – 1 – 3

Motion – Set AL_3 acceptance limits for Sequence VIE calibration tests at 2.0 standard deviations.
Kevin OMalley / Jo Martinez / Passed 13 – 0 – 1

Action Item – Statisticians Group to update the Sequence VIE LTMS flow chart diagram with the results of the motions from this meeting, and provide it to be included in the minutes for this meeting.

Reference oil targets are on slide 6 and the standard deviations for each oil on Slide 7 of the presentation dated 07.26.2016. Based on that information the following motions were made.

Action Item – Statisticians Group to update the Sequence VIE LTMS draft as per the motions from this meeting, and provide it to be included in the minutes for this meeting.

Motion – Accept the FEI1 and FEI2 LS Means, the Standard Deviations for calculating Yi and the Pooled Standard Deviations for calculating SAs, included in slides 6 and 7 of the 7-26-16 VIE LTMS presentation.
Todd Dvorak / Doyle Boese / Passed Unanimously 14 – 0 – 0

Motion – Last non-reference test shall start no later than 100 days from the date of acceptable calibration.
Amol Savant / Dave Glaenzer / Passed 11 – 0 – 2

Reference oils had been set to be randomly assigned as a previous meeting. Andy Ritchie noted that labs will no longer be running RO 542-2 as the first oil on a new engine. There was concern that engine response might change. It is the oil common to the VID, VIE and VIF.

Motion – Set the Sequence VIE reference oil assignment protocol at equal proportion with random assignment for all three reference oils (1010-1, 542-2, 544).
Rich Grundza / Jason Bowden / Passed Unanimously 14 – 0 – 0

There was discussion on whether a new lab could become calibrated after running one reference oil.

Motion – For a new lab (defined as a lab that did not participate in the precision matrix) to be calibrated, the lab must run four operationally valid tests on multiple reference oils, to be assigned by the TMC, in a single stand and engine combination, with at least one replicated reference oil.
Nathan Moles / Robert Stockwell / Passed Unanimously 14 – 0 – 0

The meetings adjourned at 5:04 PM on Tuesday.

The meeting was called to order at 8:30 AM Central Time 07.27.2016 by Nathan Moles.

4.4.2 Review and Finalize VIE LTMS Requirements

Tim Cushing presented a letter from the EPA on how to handle GF-5 oils for the VID and VIE. There is a separate letter in progress that will cover the 0W-16 VIS grade. Andy Ritchie noted that when tests for the VID are no longer available, oil acceptance for fuel economy would go provisional. Jim Linden stated that the EPA needed to be notified when the VID was not available and that a provisional license for fuel economy might not work except on oils that passed before the provisional license was implemented. See Attachments 8 and 9.

Lisa Dingwell covered a presentation on operational data from the VIE Precision Matrix. See Attachment 10. There were 29 valid tests considered. Oil pressure in FEI 1 and 2 were reviewed. The VIF data was also reviewed, but more data is needed. See Slide 5 for the parameters for FEI 1 and Slide 8 for FEI 2.

Break in was discussed as having an effect on early engine response. There was concern a lab might run a few hours of break in to get an engine that failed a reference to be considered new. As the procedure calls for another trace at an additional 50 hours, a motion was made.

Motion – A lab must run a minimum of an additional 50 hours of break-in, following an unacceptable reference test, in order for an to be considered a new engine for calibration purposes.
Amol Savant / Robert Stockwell / Passed 13 – 0 – 1

The VIE procedure will need review and a final version generated. The TMC web site has a version dated 08.24.2015, before reduced runs on engines was adopted. Labs will be able to run calibration tests based on the existing draft.

Motion – Official Sequence VIE calibration will start on 8/10/2016 for stand/engines that have completed calibration testing following criteria established in the Sequence VIE LTMS document and using the Sequence VIE draft test procedure and associated surveillance panel meeting minutes.
Dan Worcester / Nathan Moles / Passed Unanimously 14 – 0 – 0

Discussion moved to timing for reference runs and how to monitor those results. There are industry control charts and Lambda values and Level 1 alarm values were selected. The TMC would notify the industry when an alarm occurred. TMC will also maintain the Cusum charts.

Motion – Sequence VIE LTMS industry control charts will consist of EWMA of the Yi results, using Lambda of 0.2 and level 1 alarm at ± 0.859 with an action for the TMC to inform the surveillance panel that the limit has been exceeded, and the surveillance panel then investigates and pursues resolution of the alarm
Rich Grundza / Bill Buscher / Passed Unanimously 14 – 0 – 0

As there is some data needed for VIE industry review, Kevin O'Malley requested the Stat Group coordinate initial oil assignments for the 5th run.

Action Item – Statisticians group to provide the TMC guidance, prior to 8/10/2016, on reference oil assignments for the engines that will run a donated 5th test on the same reference oil used in the first acceptable calibration test on that engine.

4.4.3 Other VIE Items NOT listed???
(RO selection donated 5th test, engine calibration date, etc.)

4.4.4 Investigate what is needed to establish VID equivalent limits for VIE
See Attachment 11 for consideration of VIE limits for the VID. Todd Dvorak noted that the industry would want GF-5 oils. Andy Ritchie stated there was not a 10W-30 in the precision matrix, and the VIE showed reverse performance for oils 542 and 1010. Paired sets are needed. Michael Blumenfield stated we would need to use existing data or run more. Toyota ran the VID on a matrix set of oils and that could be used. Jim Linden noted that there is limited VID engine tests remaining in the industry so that existing data must be considered. The CLOG group will need to provide matrix recommendations. The VIE testing would need to be on calibrated stands. Infineum, Afton, and ExxonMobil agreed to each donate 3 tests. Lubrizol will ask but likely also donate 3. William Buscher stated that IAR has VID engines that were abandoned for being mild on VID targets. If those could run and pass reference, they would have about 60 VID tests available. Jim Linden requested a Task Force be created that would include the Stat Group.
Toyota will check with suppliers about more blends being produced from their VID matrix. This effort will be tabled so a Task Force can develop an matrix and funding. The industry reference oil Tech 1 was made in multiple viscosity grades and could be considered. Nathan Moles stated this would need to be completed before the next AOAP meeting so it could be presented at that time.

Action Item – Create a task force, with Robert Stockwell as chair, to define a process, test matrix, timeline and funding to establish Sequence VIE and VIF equivalency to VID.
Volunteers: Jim Linden, Mike Blumenfeld/Cliff Salvesen, Jason Bowden, Afton Rep., Statisticans Group, Andy Ritchie, Greg M, Rich Grundza, Valvoline Rep.

Action Item – Solicit funding for the Sequence VIE and VIF to VID equivalency matrices.

Action Item – Solicit Sequence VID oils, as recommended by the task force, to be used in the Sequence VIE and VIF to VID equivalency matrices.

Action Item – Toyota to follow up with their suppliers of the oils used in their Sequence VID 0W-16 matrix to see if additional quantities of these oils can be blended and provided for the Sequence VIE and VIF to VID equivalency matrices.

4.4.5 Updated analysis of VIF precision matrix N=14
See Attachment 12. 14 tests were reviewed. There were no lab deltas, but some engine differences within a lab. The Stat Group wants 6 runs on each reference oil. Todd Dvorak stated the review indicated the baseline weights might change but will need more data. The VIF test does show discrimination as a stage gate process was used. Nathan Moles said Lubrizol will run 4 oils on a new engine to gather more data. Kevin O'Malley wants 6 tests per reference oil. There was some discussion on not using 542-2, but the matrix will be developed using 542-2, 543 and 1011.

Motion – Lubrizol to conduct 4 donated supplemental Sequence VIF precision matrix tests on a new stand/engine. The oil run order will be 1) 1011, 2) 543, 3) 542-2 and 4) 1011.
Nathan Moles / Rich Grundza / Passed Unanimously 14 – 0 – 0

4.4.6 Review and Finalize VIF LTMS Requirements
This will be on hold for additional data.

4.4.7 Other VIF Items NOT listed???
(donated 5th test, engine calibration date, VID to VIF equivalency, ect.)
This will be on hold for additional data.

4.4.8 Appendix K template review –Todd Dvorak
See Attachment 13. The areas were completed during the meeting.

4.4.9 Update test procedure
The original Task Force will be contacted to update the VIE procedure. Dave Glaenzer will contact that group.

Motion – Use MTAC to handle repeat candidate tests in Sequence VIE.
Jo Martinez / Lisa Dingwell / Passed Unanimously 14 – 0 – 0

Motion – The Sequence VIE surveillance panel, having established severity and precision control charting via an LTMS system, having established test stand/engine calibration and reference periods, having secured sources for test parts, fuel and reference oils, having identified parameters that may be used for pass-fail criteria, having an up-to-date test procedure and having established continuous surveillance as noted in the Scope and Objectives of the Sequence VI surveillance panel, hereby wishes to inform the Passenger Car Engine Oil Classification Panel, the Auto Oil Advisory Panel and the American Chemistry Council PAPTG, that the Sequence VIE test is ready for inclusion in ILSAC oil category GF-6.
Charlie Leverett / Nathan Moles / Passed Unanimously 14 – 0 – 0

Action Item – Update the Sequence VIE draft procedure to include test precision data and statement. To be completed by 8/10/2016.

5.0 New Business

5.1 TBD

6.0 Next Meetings.

6.1 TBD

The meetings adjourned at 2:15 PM.

Sequence VI Surveillance Panel Conference Call Agenda
July 26 & 27 @ 8:30-5:00PM CST
July 28 @ 8:30-11:30AM CST

Call-in information is included below:

Call-in Number: 800.391.9177
Conference Code: 4875645502
WebEx:

https://meetings.webex.com/collabs/#/meetings/detail?uuid=MCZIWKKBLW2PJIGIBBQ2RCCN87-20XT&rnd=5352.4683001

1.0) Roll Call (8:30-8:40AM)

Do we have any membership changes or additions?

2.0) Approval of minutes (8:40:8:45AM)

2.1 Approve the minutes from the July 19, 2016 Sequence VI Surveillance Panel.

3.0) Action Item Review (8:45-9:15AM)

3.1 OHT to provide update on current VIE inventory –OHT

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

-Expected depletion of VID engines 2016 Q3
~70 test starts at independent labs remain

3.3 Review LTMS spread sheet ahead of meetings –All

3.4 Corrected Motions from meeting minutes on 5/25/2016:

1. *Move forward with the VIE test allowing up to 4 full length test with the 4th test starting no later than 900 hours.*

2. *After the completion of the 4th run on the 4th VIE engine installed in each stand, test lab will run a donated 5th test on a reference oil to be determined.*

4.) Old Business

4.1	9:15-9:20	Update from task force, to investigate alternative test procedure Sequence “VIF” that would improve 0W-16. – Dan Worcester/Satoshi Hirano
4.2	9:20-9:30	Update from task force to investigate option to use short blocks to supplement engine inventory. –Adrian Alfonso
4.3	9:30-9:45	Update from task force, to investigate engine cleaning procedure. –Dan Worcester
4.4		List of items to be reviewed after the Precision Matrix -All
4.4.1	9:45-10:30	Updated analysis of VIE precision matrix N=29
BREAK	10:30-10:45	**
4.4.2	10:30-Noon	Review and Finalize VIE LTMS Requirements
LUNCH	Noon-1	**
4.4.2	1-3	Review and Finalize VIE LTMS Requirements
BREAK	3-3:15	**
4.4.3	3:15-5	Other VIE Items NOT listed??? (RO selection donated 5th test, engine calibration date, ect.)
DAY 2		***
4.4.4	8:30-10:30	Investigate what is needed to establish VID equivalent limits for VIE
BREAK	10:30-10:45	**
4.4.5	10:30-Noon	Updated analysis of VIF precision matrix N=14
LUNCH	Noon-1	**
4.4.6	1-3	Review and Finalize VIF LTMS Requirements
BREAK	3-3:15	**
4.4.7	3:15-5	Other VIF Items NOT listed??? (donated 5th test, engine calibration date, VID to VIF equivalency, ect.)
DAY 3		***
4.4.8	8:30-10:30	Appendix K template review –Todd Dvorak
4.4.9	10:30-11:30	Update test procedure

5.) New Business

5.1 TBD

6.) Next Meeting

TBD

7.) Meeting Adjourned

ASTM SEQUENCE VI

Name	Email/Phone	Company	Attend
Adrian Alfonso **Voting Member**	Phone: (210) 838-0431 adrian.alfonso@intertek.com	Intertek	**ATTEND**
Jason Bowden **Voting Member**	Phone: (440) 354-7007 jhbowden@ohtech.com	OHT	**ATTEND**
Timothy Caudill **Voting Member**	Phone: (606) 329-5708 Tlcaudill@ashland.com	Ashland	
Tim Cushing **Voting Member**	Phone: (248) 881-3518 timothy.cushing@gm.com	General Motors	**ATTEND**
David Glaenzer **Voting Member**	Phone: (804) 788-5214 Dave.Glaenzer@aftonchemical.com	Afton	**ATTEND**
Rich Grundza **Voting Member**	Phone: (412) 365-1034 reg@astmtmc.cmu.edu	TMC	**ATTEND**
Jeff Hsu **Voting Member**	Phone: (832) 419-3482 j.hsu@shell.com	Shell	**ATTEND**
Teri Kowalski **Voting Member**	Phone: (734) 995-4032 teri.kowalski@tema.toyota.com	Toyota	
Dan Lanctot **Voting Member**	Phone: (210) 690-1958 dlanctot@tei-net.com	TEI	
Brian Marks **Voting Member**	Phone: (973) 686-3325 Brian.Marks@bp.com	BP Castrol	
Nathan Moles **Voting Member**	Phone: (440) 347-4472 Nathan.Moles@Lubrizol.com	Lubrizol	**ATTEND**
Andy Ritchie **Voting Member**	Phone: (908) 474-2097 Andrew.Ritchie@infineum.com	Infineum	**ATTEND**
Ron Romano **Voting Member**	Phone: (313) 845-4068 rromano@ford.com	Ford	**ATTEND**
Clifford Salvesen **Voting Member**	Phone: (856) 224-2954 clifford.r.salvesen@exxonmobil.com	ExxonMobil	**ATTEND**
Kaustav Sinha **Voting Member**	Phone: (713) 432-6642 LFNQ@chevron.com	Chevron Oronite	**ATTEND**
Haiying Tang **Voting Member**	Phone: (248) 512-0593 HT146@Chrysler.com	Chrysler	
Dan Worcester **Voting Member**	Phone: (210) 522-2405 dan.worcester@swri.org	SwRI	**ATTEND**

ASTM SEQUENCE VI

Name	Email/Phone	Company	Attend
Ed Altman	ed.altman@aftonchemical.com	Afton	
Bob Campbell	Bob.Campbell@aftonchemical.com	Afton	
Lisa Dingwell	Lisa.Dingwell@AftonChemical.com	Afton	ATTEND
Todd Dvorak	todd.dvorak@aftonchemical.com	Afton	ATTEND
Greg Guinther	greg.guinther@aftonchemical.com	Afton	
Terry Hoffman	Terry.Hoffman@aftonchemical.com	Afton	
Christian Porter	Christian.porter@aftonchemical.com	Afton	
Katerina Pecinovsky	Katerina.Pecinovsky@AftonChemical.com	Afton	ATTEND
Jeremy Styer	Jeremy.styer@aftonchemical.com	Afton	
Amol Savant	ACSavant@ashland.com	Ashland	ATTEND
Tisha Joy	Tisha.Joy@bp.com	BP	
Michael Blumenfeld	Michael.l.blumenfeld@exxonmobil.com Phone: (856) 224.2865	EM	ATTEND
Don Smolenski	donald.j.smolenski@gm.com	Evonik	
Doyle Boese	Doyle.boese@infineum.com Phone: (908) 474-3176	Infineum	ATTEND
Gordon Farnsworth	gordon.farnsworth@infineum.com	Infineum	
Mike McMillan	mmcmillan123@comcast.net	Infineum	ATTEND
Jordan Pastor	Jordan.pastor@Infineum.com Phone: (313) 348-3120	Infineum	
Mike Warholic	Michael.warholic@Infineum.com Phone: 908.474.2065	Infineum	
William Buscher	william.buscher@intertek.com	Intertek	ATTEND
Martin Chadwick	Martin.chadwick@intertek.com	Intertek	ATTEND
Charlie Leverett	charlie.leverett@intertek.com Phone: (210) 647-9422	Intertek	ATTEND
Al Lopez	Al.Lopez@intertek.com	Intertek	
Addison Schweitzer	addison.schweitzer@intertek.com	Intertek	
Bob Olree	olree@netzero.net	Intertek	
Andy Buczynsky	andrew.buczynsky@gm.com	GM	
Thomas Hickl	thomas.hickl@de.gm.com	GM	
Jeff Kettman	Jeff.kettman@gm.com	GM	
Jonas Leber	jonas.leber@opel.com	GM	
Mike Raney	Michael.p.raney@gm.com Phone: (248) 408-5384	GM	
Angela Willis	angela.p.willis@gm.com	GM	
Jerry Brys	Jerome.brys@lubrizol.com Phone: (440) 347.2631	Lubrizol	ATTEND
Jessica Buchanan	Jessica.Buchanan@Lubrizol.com	Lubrizol	
Joe Gleason	Jog1@lubrizol.com	Lubrizol	

ASTM SEQUENCE VI

Name	Email/Phone	Company	Attend
James Matasik	James.Matasic@lubrizol.com	Lubrizol	
Greg Miranda	Greg.Miranda@lubrizol.com Phone: (440) 347.8516	Lubrizol	ATTEND
Kevin O'Malley	Kevin.OMalley@lubrizol.com Phone: (440) 347.4141	Lubrizol	ATTEND
Scott Rajala	srajala@ILAcorp.com	Idemitsu	
Dave Passmore	dpassmore@imtsind.com	IMTS	
Chris Castanien	chris.castanien@neste.com Phone: (440) 290-9766	Neste	
Dwight Bowden	dhbowden@ohtech.com	OHT	
Matt Bowden	mjbowden@ohtech.com	OHT	
Ricardo Affinito	affinito@chevron.com Phone: (510) 242-4625	Oronite	
Ian Elliot	IanElliott@chevron.com	Oronite	
Jo Martinez	jogm@chevron.com	Oronite	ATTEND
Robert Stockwell	rsto@chevron.com	Oronite	ATTEND
Christine Eickstead	christine.eickstead@swri.org	SwRI	ATTEND
Travis Kostan	travis.kostan@swri.org	SwRI	ATTEND
Patrick Lang	Patrick.lang@swRI.org Phone: (210) 522-2820	SwRI	ATTEND
Michael Lochte	mlochte@swri.org	SwRI	
Guy Stubbs	Guy.Stubbs@swri.org	SwRI	
Karen Haumann	Karen.Haumann@shell.com	Shell	
Scott Stap	Scott.stap@tgdirect.com	TG Direct	
Clayton Knight	cknight@tei-net.com	TEI	
Zack Bishop	zbishop@tei-net.com Phone: (210) 877-0223	TEI	
Jeff Clark	jac@astmtmc.cmu.edu	TMC	
Hirano Satoshi	satoshi_hirano_aa@mail.toyota.co.jp	Toyota	
Jim Linden	lindenjim@jlindenconsulting.com Phone: (248) 321-5343	Toyota	ATTEND
Mark Adams	mark@tribologytesting.com	Tribology Testing	ATTEND
Tom Smith		Valvoline	
Hap Thompson	Hapjthom@aol.com	VIx Facilitator	ATTEND
Chris Taylor	Chris.taylor@vpracingfuels.com	VP Racing Fuels	

ASTM SEQUENCE VI

Name	Email/Phone	Company	Attend

ASTM SEQUENCE VI

Name	Email/Phone	Company	Attend
Adrian Alfonso **Voting Member**	Phone: (210) 838-0431 adrian.alfonso@intertek.com	Intertek	ATTEND
Jason Bowden **Voting Member**	Phone: (440) 354-7007 jhbowden@ohtech.com	OHT	ATTEND
Timothy Caudill **Voting Member**	Phone: (606) 329-5708 Tlcaudill@ashland.com	Ashland	
Tim Cushing **Voting Member**	Phone: (248) 881-3518 timothy.cushing@gm.com	General Motors	ATTEND
David Glaenzer **Voting Member**	Phone: (804) 788-5214 Dave.Glaenzer@aftonchemical.com	Afton	ATTEND
Rich Grundza **Voting Member**	Phone: (412) 365-1034 reg@astmtmc.cmu.edu	TMC	ATTEND
Jeff Hsu **Voting Member**	Phone: (832) 419-3482 j.hsu@shell.com	Shell	ATTEND
Teri Kowalski **Voting Member**	Phone: (734) 995-4032 teri.kowalski@tema.toyota.com	Toyota	
Dan Lanctot **Voting Member**	Phone: (210) 690-1958 dlanctot@tei-net.com	TEI	
Brian Marks **Voting Member**	Phone: (973) 686-3325 Brian.Marks@bp.com	BP Castrol	
Nathan Moles **Voting Member**	Phone: (440) 347-4472 Nathan.Moles@Lubrizol.com	Lubrizol	ATTEND
Andy Ritchie **Voting Member**	Phone: (908) 474-2097 Andrew.Ritchie@infineum.com	Infineum	ATTEND
Ron Romano **Voting Member**	Phone: (313) 845-4068 rromano@ford.com	Ford	ATTEND
Clifford Salvesen **Voting Member**	Phone: (856) 224-2954 clifford.r.salvesen@exxonmobil.com	ExxonMobil	ATTEND
Kaustav Sinha **Voting Member**	Phone: (713) 432-6642 LFNQ@chevron.com	Chevron Oronite	ATTEND
Haiying Tang **Voting Member**	Phone: (248) 512-0593 HT146@Chrysler.com	Chrysler	
Dan Worcester **Voting Member**	Phone: (210) 522-2405 dan.worcester@swri.org	SwRI	ATTEND

ASTM SEQUENCE VI

Name	Email/Phone	Company	Attend
Ed Altman	ed.altman@aftonchemical.com	Afton	
Bob Campbell	Bob.Campbell@aftonchemical.com	Afton	ATTEND
Lisa Dingwell	Lisa.Dingwell@AftonChemical.com	Afton	ATTEND
Todd Dvorak	todd.dvorak@aftonchemical.com	Afton	ATTEND
Greg Guinther	greg.guinther@aftonchemical.com	Afton	
Terry Hoffman	Terry.Hoffman@aftonchemical.com	Afton	
Christian Porter	Christian.porter@aftonchemical.com	Afton	
Katerina Pecinovsky	Katerina.Pecinovsky@AftonChemical.com	Afton	ATTEND
Jeremy Styer	Jeremy.styer@aftonchemical.com	Afton	
Amol Savant	ACSavant@ashland.com	Ashland	ATTEND
Tisha Joy	Tisha.Joy@bp.com	BP	
Michael Blumenfeld	Michael.l.blumenfeld@exxonmobil.com Phone: (856) 224.2865	EM	ATTEND
Don Smolenski	donald.j.smolenski@gm.com	Evonik	
Doyle Boese	Doyle.boese@infineum.com Phone: (908) 474-3176	Infineum	ATTEND
Gordon Farnsworth	gordon.farnsworth@infineum.com	Infineum	
Mike McMillan	mmcmillan123@comcast.net	Infineum	ATTEND
Jordan Pastor	Jordan.pastor@Infineum.com Phone: (313) 348-3120	Infineum	
Mike Warholic	Michael.warholic@Infineum.com Phone: 908.474.2065	Infineum	
William Buscher	william.buscher@intertek.com	Intertek	ATTEND
Martin Chadwick	Martin.chadwick@intertek.com	Intertek	ATTEND
Charlie Leverett	charlie.leverett@intertek.com Phone: (210) 647-9422	Intertek	ATTEND
Al Lopez	Al.Lopez@intertek.com	Intertek	
Addison Schweitzer	addison.schweitzer@intertek.com	Intertek	
Bob Olree	olree@netzero.net	Intertek	
Andy Buczynsky	andrew.buczynsky@gm.com	GM	
Thomas Hickl	thomas.hickl@de.gm.com	GM	
Jeff Kettman	Jeff.kettman@gm.com	GM	
Jonas Leber	jonas.leber@opel.com	GM	
Mike Raney	Michael.p.raney@gm.com Phone: (248) 408-5384	GM	
Angela Willis	angela.p.willis@gm.com	GM	
Jerry Brys	Jerome.brys@lubrizol.com Phone: (440) 347.2631	Lubrizol	ATTEND
Jessica Buchanan	Jessica.Buchanan@Lubrizol.com	Lubrizol	
Joe Gleason	Jog1@lubrizol.com	Lubrizol	

ASTM SEQUENCE VI

Name	Email/Phone	Company	Attend
James Matasik	James.Matasic@lubrizol.com	Lubrizol	
Greg Miranda	Greg.Miranda@lubrizol.com Phone: (440) 347.8516	Lubrizol	ATTEND
Kevin O'Malley	Kevin.OMalley@lubrizol.com Phone: (440) 347.4141	Lubrizol	ATTEND
Scott Rajala	srajala@ILAcorp.com	Idemitsu	
Dave Passmore	dpassmore@imtsind.com	IMTS	
Chris Castanien	chris.castanien@neste.com Phone: (440) 290-9766	Neste	
Dwight Bowden	dhbowden@ohtech.com	OHT	
Matt Bowden	mjbowden@ohtech.com	OHT	
Ricardo Affinito	affinito@chevron.com Phone: (510) 242-4625	Oronite	
Ian Elliot	IanElliott@chevron.com	Oronite	
Jo Martinez	jogm@chevron.com	Oronite	ATTEND
Robert Stockwell	rsto@chevron.com	Oronite	ATTEND
Christine Eickstead	christine.eickstead@swri.org	SwRI	ATTEND
Travis Kostan	travis.kostan@swri.org	SwRI	ATTEND
Patrick Lang	Patrick.lang@swRI.org Phone: (210) 522-2820	SwRI	ATTEND
Michael Lochte	mlochte@swri.org	SwRI	
Guy Stubbs	Guy.Stubbs@swri.org	SwRI	
Karen Haumann	Karen.Haumann@shell.com	Shell	
Scott Stap	Scott.stap@tgdirect.com	TG Direct	
Clayton Knight	cknight@tei-net.com	TEI	
Zack Bishop	zbishop@tei-net.com Phone: (210) 877-0223	TEI	
Jeff Clark	jac@astmtmc.cmu.edu	TMC	
Hirano Satoshi	satoshi_hirano_aa@mail.toyota.co.jp	Toyota	
Jim Linden	lindenjim@jlindenconsulting.com Phone: (248) 321-5343	Toyota	ATTEND
Mark Adams	mark@tribologytesting.com	Tribology Testing	
Tom Smith		Valvoline	
Hap Thompson	Hapjthom@aol.com	VIx Facilitator	ATTEND
Chris Taylor	Chris.taylor@vpracingfuels.com	VP Racing Fuels	

ASTM SEQUENCE VI

Name	Email/Phone	Company	Attend

Sequence VI Surveillance Panel
July 26, 2016 – July 27, 2016
8:30AM – 5:00PM
Intertek Automotive Research
San Antonio, TX

Motions and Action Items
As Recorded at the Meeting by Bill Buscher

July 26, 2016:

1. Action Item – Correct the short block kit quantities w/ and w/o right heads included in the previous surveillance panel meeting minutes.

2. Action Item – Review use of weighted fuel consumption for BL shift calculations.

3. Motion – Move forward with the Sequence VIE test allowing up to 4 full length tests with the last test starting no later than 900 hours.
   Tim Cushing / Nathan Moles / Passed Unanimously 14 – 0 – 0

4. Motion – After the completion of the last run on each of the first three calibrated engines installed in each lab, the test lab will run a donated 5th test on the same reference oil used in the first acceptable calibration test on that engine.
   Bill Buscher / Jeff Hsu / Passed Unanimously 14 – 0 – 0

5. Motion – Adopt a weighting factor of 1.0 for calculating SAs for both FEI1 and FEI2 for the Sequence VIE test.
   Andy Ritchie / Dave Glaenzer / Failed 5 – 8 – 1

6. Motion – Adopt a weighting factor of 0.6 for calculating SAs for both FEI1 and FEI2 for the Sequence VIE test.
   Robert Stockwell / Jeff Hsu / Passed 11 – 3 – 0

7. Motion – Set AL_1 acceptance limits for Sequence VIE calibration tests at 2.0 standard deviations.
   Dave Glaenzer / Amol Savant / Passed 8 – 5 – 1

8. Motion – Set AL_2 acceptance limits for Sequence VIE calibration tests at 2.8 standard deviations, set R (standard deviation ratio) at 1.0 for FEI1 and at 0.48 for FEI2 and use engine hour adjusted Yi data instead of an EIC (excessive influence cap).
   Dave Glaenzer / Dan Worcester / Passed 10 – 1 – 3

9. Motion – Set AL_3 acceptance limits for Sequence VIE calibration tests at 2.0 standard deviations.
   Kevin OMalley / Jo Martinez / Passed 13 – 0 – 1

10. Action Item – Statisticians Group to update the Sequence VIE LTMS flow chart diagram with the results of the motions from this meeting, and provide it to be included in the minutes for this meeting.

11. Action Item – Statisticians Group to update the Sequence VIE LTMS draft as per the motions from this meeting, and provide it to be included in the minutes for this meeting.

12. Motion – Accept the FEI1 and FEI2 LSMeans, the Standard Deviations for calculating Yi and the Pooled Standard Deviations for calculating SAs, included in slides 6 and 7 of the 7-26-16 VIE LTMS presentation.
Todd Dvorak / Doyle Boese / Passed Unanimously 14 – 0 – 0

13. Motion – Last non-reference test shall start no later than 100 days from the date of acceptable calibration.
Amol Savant / Dave Glaenzer / Passed 11 – 0 – 2

14. Motion – Set the Sequence VIE reference oil assignment protocol at equal proportion with random assignment for all three reference oils (1010-1, 542-2, 544).
Rich Grundza / Jason Bowden / Passed Unanimously 14 – 0 – 0

15. Motion – For a new lab (defined as a lab that did not participate in the precision matrix) to be calibrated, the lab must run four operationally valid tests on multiple reference oils, to be assigned by the TMC, in a single stand and engine combination, with at least one replicated reference oil.
Nathan Moles / Robert Stockwell / Passed Unanimously 14 – 0 – 0

July 27, 2016:

16. Motion – A lab must run a minimum of an additional 50 hours of break-in, following an unacceptable reference test, in order for an to be considered a new engine for calibration purposes.
Amol Savant / Robert Stockwell / Passed 13 – 0 – 1

17. Motion – Official Sequence VIE calibration will start on 8/10/2016 for stand/engines that have completed calibration testing following criteria established in the Sequence VIE LTMS document and using the Sequence VIE draft test procedure and associated surveillance panel meeting minutes.
Dan Worcester / Nathan Moles / Passed Unanimously 14 – 0 – 0

18. Motion – Sequence VIE LTMS industry control charts will consist of EWMA of the Yi results, using Lambda of 0.2 and level 1 alarm at ± 0.859 with an action for the TMC to inform the surveillance panel that the limit has been exceeded, and the surveillance panel then investigates and pursues resolution of the alarm
Rich Grundza / Bill Buscher / Passed Unanimously 14 – 0 – 0

19. Action Item – Statisticians group to provide the TMC guidance, prior to 8/10/2016, on reference oil assignments for the engines that will run a donated 5th test on the same reference oil used in the first acceptable calibration test on that engine.

20. Action Item – Create a task force, with Robert Stockwell as chair, to define a process, test matrix, timeline and funding to establish Sequence VIE and VIF equivalency to VID.
    Volunteers: Jim Linden, Mike Blumenfeld/Cliff Salvesen, Jason Bowden, Afton Rep., Statisticans Group, Andy Ritchie, Greg M, Rich Grundza, Valvoline Rep.

21. Action Item – Solicit funding for the Sequence VIE and VIF to VID equivalency matrices.

22. Action Item – Solicit Sequence VID oils, as recommended by the task force, to be used in the Sequence VIE and VIF to VID equivalency matrices.

23. Action Item – Toyota to follow up with their suppliers of the oils used in their Sequence VID 0W-16 matrix to see if additional quantities of these oils can be blended and provided for the Sequence VIE and VIF to VID equivalency matrices.

24. Motion – Lubrizol to conduct 4 donated supplemental Sequence VIF precision matrix tests on a new stand/engine. The oil run order will be 1) 1011, 2) 543, 3) 542-2 and 4) 1011.
    Nathan Moles / Rich Grundza / Passed Unanimously 14 – 0 – 0

25. Motion – Use MTAC to handle repeat candidate tests in Sequence VIE.
    Jo Martinez / Lisa Dingwell / Passed Unanimously 14 – 0 – 0

26. Motion – The Sequence VIE surveillance panel, having established severity and precision control charting via an LTMS system, having established test stand/engine calibration and reference periods, having secured sources for test parts, fuel and reference oils, having identified parameters that may be used for pass-fail criteria, having an up-to-date test procedure and having established continuous surveillance as noted in the Scope and Objectives of the Sequence VI surveillance panel, hereby wishes to inform the Passenger Car Engine Oil Classification Panel, the Auto Oil Advisory Panel and the American Chemistry Council PAPTG, that the Sequence VIE test is ready for inclusion in ILSAC oil category GF-6.
    Charlie Leverett / Nathan Moles / Passed Unanimously 14 – 0 – 0

27. Action Item – Update the Sequence VIE draft procedure to include test precision data and statement. To be completed by 8/10/2016.

VIE Precision Matrix Analysis

Statistics Group

Date: 07-22-2016

Statistics Group

- Arthur Andrews, ExxonMobil
- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Kevin O'Malley, Lubrizol
- Martin Chadwick, Intertek
- Richard Grundza, TMC
- Lisa Dingwell, Afton
- Todd Dvorak, Afton
- Travis Kostan, SwRI

VIE Analysis Check List – Answers to SP Questions

- Do we really need to run three RO tests to establish the new engine for LTMS? LTMS Topic
- Discussion of reducing the new reference requirement to two oils, then a third oil run after a defined number of candidates. LTMS Topic
- Discussion of using FEI 2 and FEI Sum for references to match candidate pass/fail criteria. LTMS – Consensus reached in Stats team to continue with FEI1 and FEI2
- Discussion of evaluating 80/20 ratio of BL before to after for FEI 1 and 10/90 for FEI 2. Consider evaluating FEI 1 vs 100% BLB2 (or 3) and evaluating FEI 2 vs 100% BLA. Included in this presentation
- 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. LTMS Topic
- SP chair and test sponsor to investigate what is needed to establish VID equivalent limits for VIE TBD
- Discussion of changing BLB1 to BLB2 delta acceptable limits. Included in this presentation
- Review impact of variable oil pressure of FEI (review prove out data to determine if it is stand or engine related) Included in operational data analysis (done with full dataset)
- Update Appendix K (update in San Antonio)

Executive Summary

Precision Matrix (PM) Analysis Highlights:

- This analysis includes the results of 29 valid precision matrix tests which reflects surveillance panel decisions to limit engine life and remove engine 128 results
- Within the shortened engine hours, data supports the use of no transformation
- Significant oil differences:
  - FEI1: 544 < 1010-1 < 542-2
  - FEI2: 544 < {1010-1 & 542-2}
- Significant labs differences are observed in FEI2 results; Engines within lab G also significantly differ in FEI2
  - Engine differences support an engine based LTMS
- Engine hour corrections:
  - FEI1 = FEI1_OR + 0.000518*(ENHREND – 675)
  - FEI2 = FEI2_OR + 0.000381*(ENHREND – 675)
- Estimated within engine test Precision
  - FEI1 = 0.29; FEI2 = 0.12
- Estimated test precision across labs and engines
  - FEI1 = 0.29; FEI2 = 0.25
- No compelling rationale to change current 80/20 baseline weighting for FEI1 and 10/90 baseline weighting for FEI2

[1] VIE contrast with VID (PM) RMSE of 0.12 and 0.14, respectively

Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Evaluating Engine Hour Adjustment
- Analyzing PM Data
  - FEI1
  - FEI2
  - Comparing VIE Precision and Oil Discrimination with other Tests

Agenda

- **Review PM Data for Analysis**
- Evaluating Baseline Weighting Scenarios
- Evaluating Engine Hour Adjustment
- Analyzing PM Data
  - FEI1
  - FEI2
  - Comparing VIE Precision and Oil Discrimination with other Tests

Review PM Data for Analysis

- Precision Matrix data summary:
  - 6 Labs {A, B, C, D, F, G}
  - 3 Reference Oils {1010-1, 542-2, 544}
  - 9 Engines {103, 11, 123, 128, 136, 29, 31, 55, 60}
  - Within lab statistical tests - 3 Labs each with 2 engines
    - Lab A: 103 vs. 128
    - Lab C: 29 vs. 31
    - Lab G: 55 vs. 60
  - Total number of tests = 53

Review PM Data for Analysis

- During May 24th-25th, 2016 face-to-face, the surveillance panel decided to only include, in the statistical analysis, the first 4 tests in each engine and exclude all A1 tests
- Data set includes the following:
  - 1st, 2nd, 3rd, and 4th Run Test Run data, exclusively
  - No engine 128 from Lab A (A1)
  - N = 29

Step	Run Order	A 1	A 2	G 1	G 2	B	D	C	F	
	SOT Engine Hours	150	150	150	150	150	150	150	150	Eng. Hrs
1	1	544 113244-VIE	1010-1 110587-VIE	542-2 105705-VIE	544 113224-VIE	542-2 110003-VIE	542-2 110588-VIE	544 113298-VIE 544 116040-VIE (new engine)	1010-1 113223-VIE	350
	2	544 113247-VIE	1010-1 110725-VIE	1010-1 113235-VIE	542-2 105704-VIE	544 113258-VIE	542-2 113293-VIE	1010-1 113300-VIE 1010-1 113301-VIE (new engine)	544 113220-VIE	550
	3	542-2 111451-VIE	542-2 111176-VIE	1010-1 113236-VIE	1010-1 108989-VIE	1010-1 110595-VIE	544 113292-VIE	542-2 113299-VIE Oil Con. Engine Abandoned 542-2 114421-VIE (new engine)	544 113221-VIE	750
	4	1010-1 110726-VIE	544 113243-VIE	544 113225-VIE	1010-1 113234-VIE	544 113259-VIE	1010-1 110589-VIE	542 114422-VIE (new engine)	542-2 113222-VIE	950
2	5	544 113246-VIE	544 113245-VIE Failed Eng		542-2 113229-VIE	544 113260-VIE				1150
	6	1010-1 110727-VIE	1010-1		542-2 113230-VIE	542-2 110004-VIE				1350
	7	1010-1 113252-VIE	544		544 113226-VIE	542-2 113261-VIE				1550
	8	542-2 113248-VIE	542-2		544 [illegible]	[illegible] 113265-VIE				1750
	9	542-2 113249-VIE	542-2		[illegible] 113238-VIE	1010-1 113266-VIE				1950
	10	544 [illegible]			542-2 113232-VIE	544 116027-VIE				2150
	11	[illegible] 113254-VIE	1010-1		544 113228-VIE					2350
	EOT Engine Hours	950	2350	950	2350	2150	950	950	950	Total Runs
	Runs/ Engine	4	11	4	11	10	4	4	4	52

Excluded from Analysis

Test Reported

Invalid

Review PM Data for Analysis

- Precision Matrix data summary (continued):
  - Average engine hour age[1]:
    - PM Average ENHREND = 675

		ENHREND		
LTMSLAB	ENGNO	N	Mean	Max
A	103	4	675.5	978
B	123	4	695.5	992
C	29	4	683	1005
	31	1	570	570
D	11	4	671.5	973
F	136	4	667.25	968
G	55	4	659.5	956
	60	4	699.25	1002

[1] *For reference: VID Ln(EngHrs) = 7.37 ($e^{7.37}$ = 1598 hours)*

Agenda

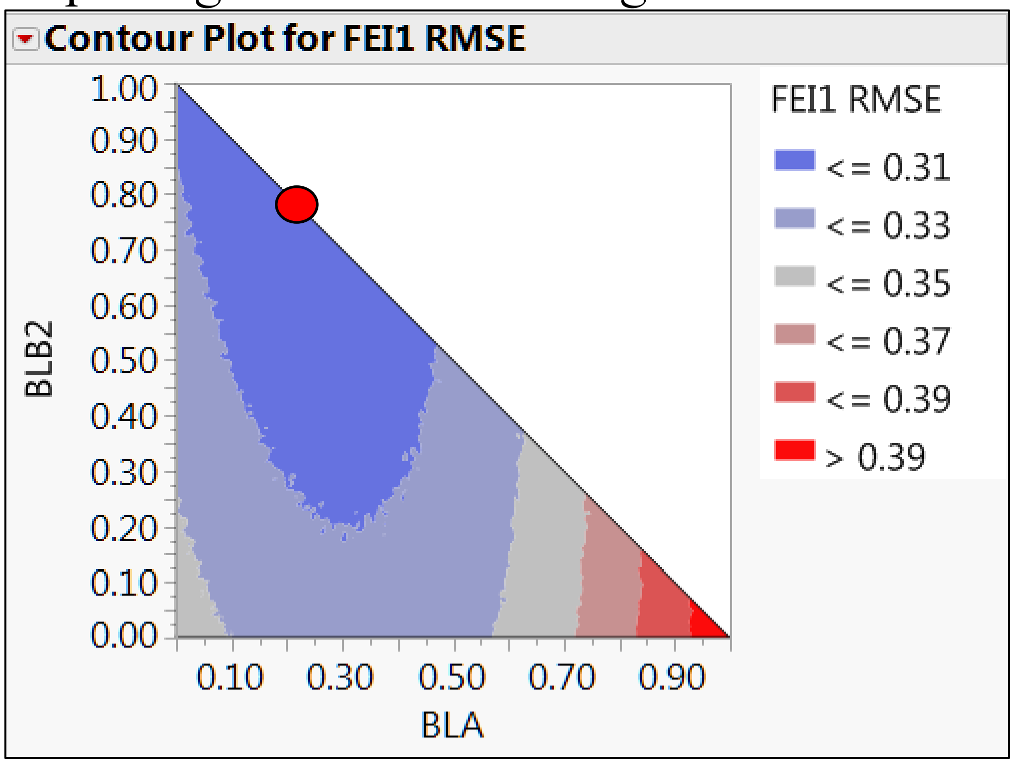
- Review PM Data for Analysis
- **Evaluating Baseline Weighting Scenarios**
- Evaluating Engine Hour Adjustment
- Analyzing PM Data
  - FEI1
  - FEI2
  - Comparing VIE Precision and Oil Discrimination with other Tests

Evaluating Baseline Weight Scenarios

- Excel Program developed to evaluate 10,000 different weight combinations of BLB1, BLB2, and BLA
- Excel based prediction model for precision (RMSE) included Lab, Eng(Lab), Oil, and Ln(EngHr) factors
- All BL weight combinations summed to a value of 1.0
- For those runs that included a BLB3, BL weights were applied to BLB2 & BLB3 in lieu of BLB1 & BLB2
- Results are shown on the following slides

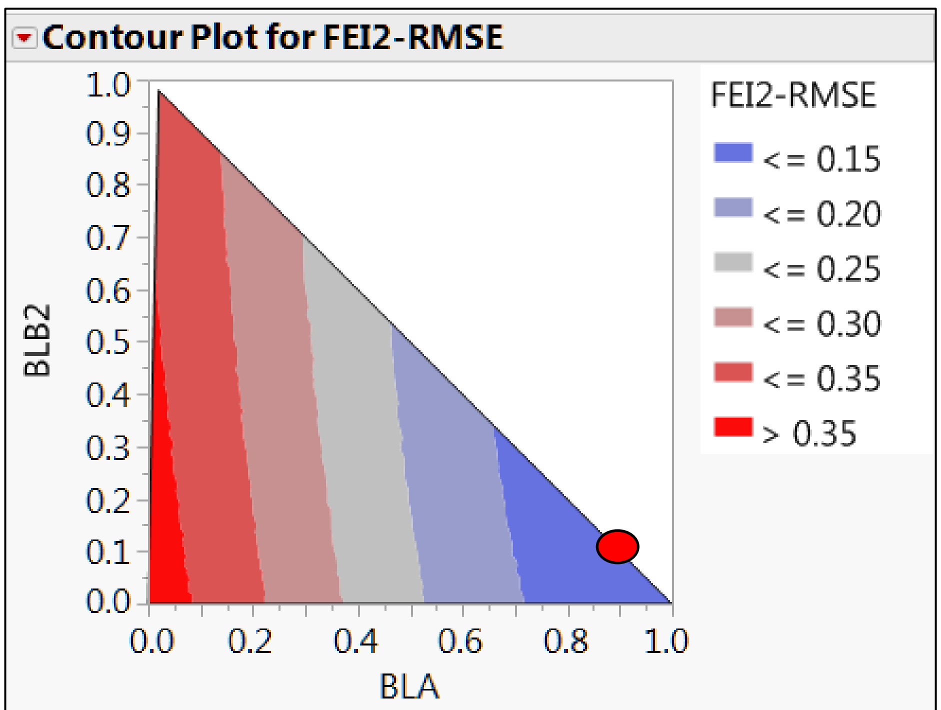
Evaluating Baseline Weight Scenarios

- Plot of RMSE vs. baseline weight combinations for FEI1 shown below
  - RMSE of weights can be interpreted from plot- if BL weights sum to 1.0
  - VID FEI1 Baseline weights of 80% & 20% shown in red circle
  - Other BL weighting combinations provide slight improvement to precision
  - No compelling rationale to change current FEI1 Baseline weights



Evaluating Baseline Weight Scenarios

- Plot of RMSE vs. baseline weight combinations for FEI2 shown below
  - RMSE of weights can be interpreted from plot- if BL weights sum to 1.0
  - VID FEI2 Baseline weights of 10% & 90% shown in red circle
  - Other BL weighting combinations provide slight improvement to precision
  - No compelling rationale to change current FEI2 Baseline weights



BL Shift

- Not enough data to change limits at this time
- BLB12 Shift Range: (-0.12, 0.41); BLB23 Shift Range: (-0.01, 0.36)
- BLA Shift Range: (-1.53, 1.03)

BLSFDT12

Quantiles

100.0%	maximum	0.41
99.5%		0.41
97.5%		0.41
90.0%		0.36
75.0%	quartile	0.295
50.0%	median	0.22
25.0%	quartile	0.13
10.0%		0.08
2.5%		-0.12
0.5%		-0.12
0.0%	minimum	-0.12

Summary Statistics

Mean	0.2093103
Std Dev	0.1244109
Std Err Mean	0.0231025
Upper 95% Mean	0.2566337
Lower 95% Mean	0.161987
N	29

BLSFDT23

Quantiles

100.0%	maximum	0.36
99.5%		0.36
97.5%		0.36
90.0%		0.36
75.0%	quartile	0
50.0%	median	0
25.0%	quartile	0
10.0%		-0.01
2.5%		-0.01
0.5%		-0.01
0.0%	minimum	-0.01

Summary Statistics

Mean	0.05
Std Dev	0.1367479
Std Err Mean	0.0516859
Upper 95% Mean	0.1764708
Lower 95% Mean	-0.076471
N	7

BLSFDT2A

Quantiles

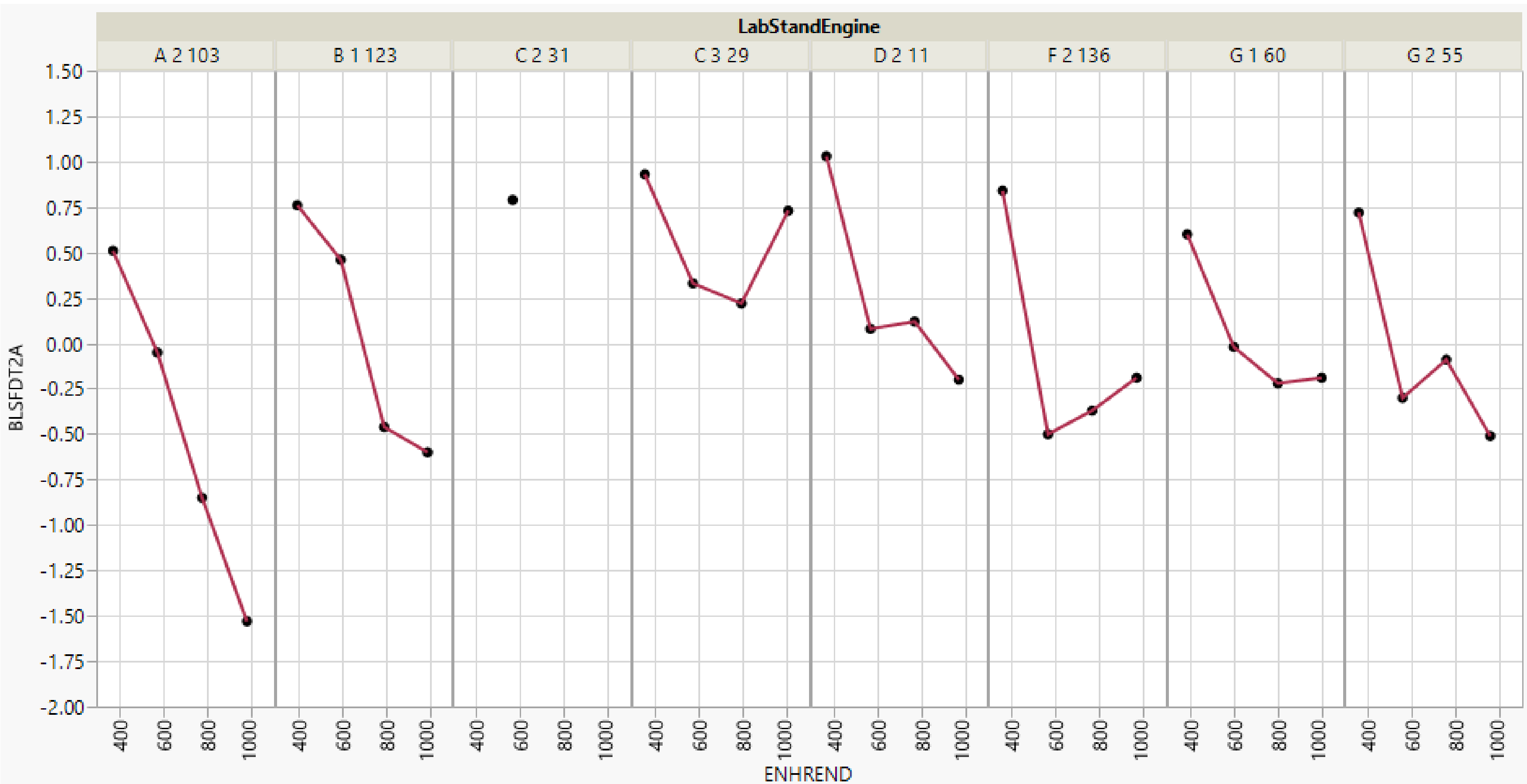
100.0%	maximum	1.03
99.5%		1.03
97.5%		1.03
90.0%		0.84
75.0%	quartile	0.66
50.0%	median	-0.02
25.0%	quartile	-0.335
10.0%		-0.6
2.5%		-1.53
0.5%		-1.53
0.0%	minimum	-1.53

Summary Statistics

Mean	0.0703448
Std Dev	0.6063443
Std Err Mean	0.1125953
Upper 95% Mean	0.3009859
Lower 95% Mean	-0.160296
N	29

BLB-BLA Shift by Engine

- The first BLB-BLA shift in each engine is the largest

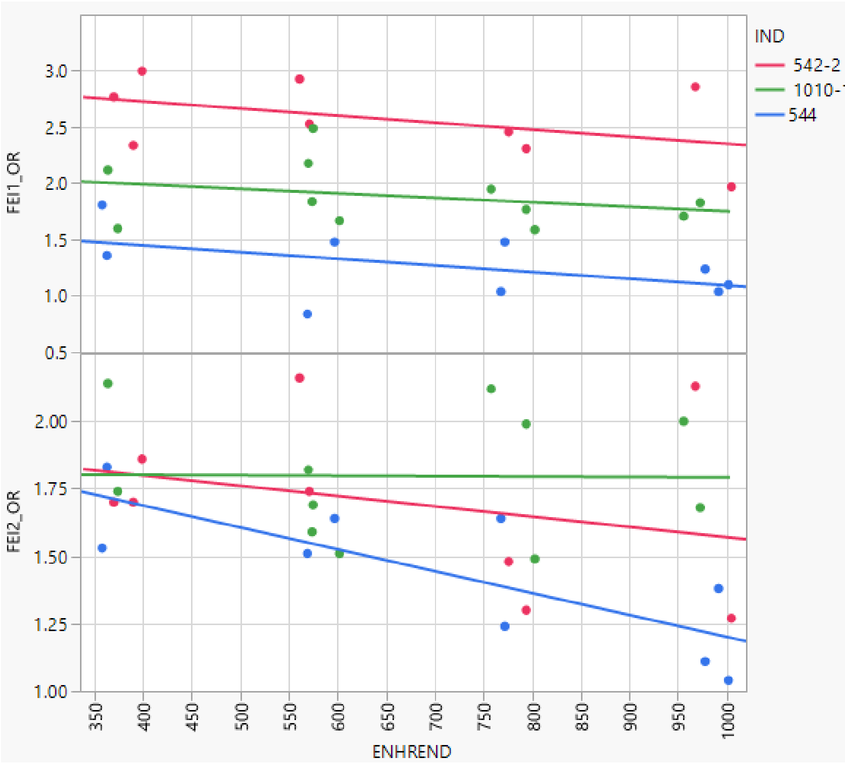


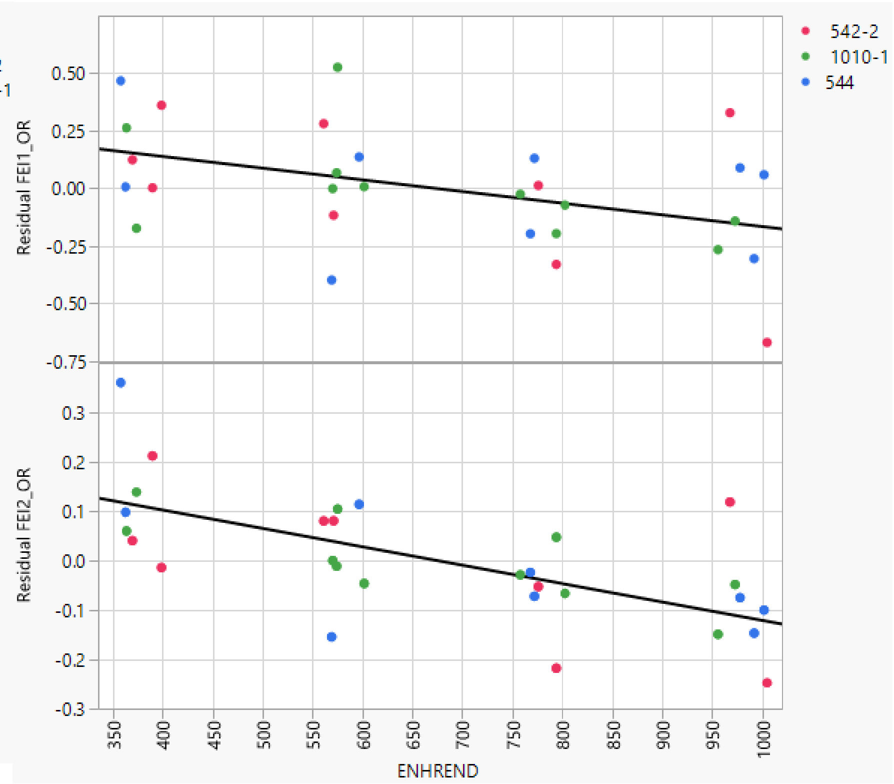
Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- **Evaluating Engine Hour Adjustment**
- Analyzing PM Data
  - FEI1
  - FEI2
  - Comparing VIE Precision and Oil Discrimination with other Tests

Evaluating Engine Hour Adjustment

- Analyses of FEI1 and FEI2 model *residuals* were explored to identify the best method for Engine Hour Adjustment
  - The residuals were based on a model fit with LTMSLAB, IND, and ENGNO(LTMSLAB) factors
- The use of no transformation is appropriate



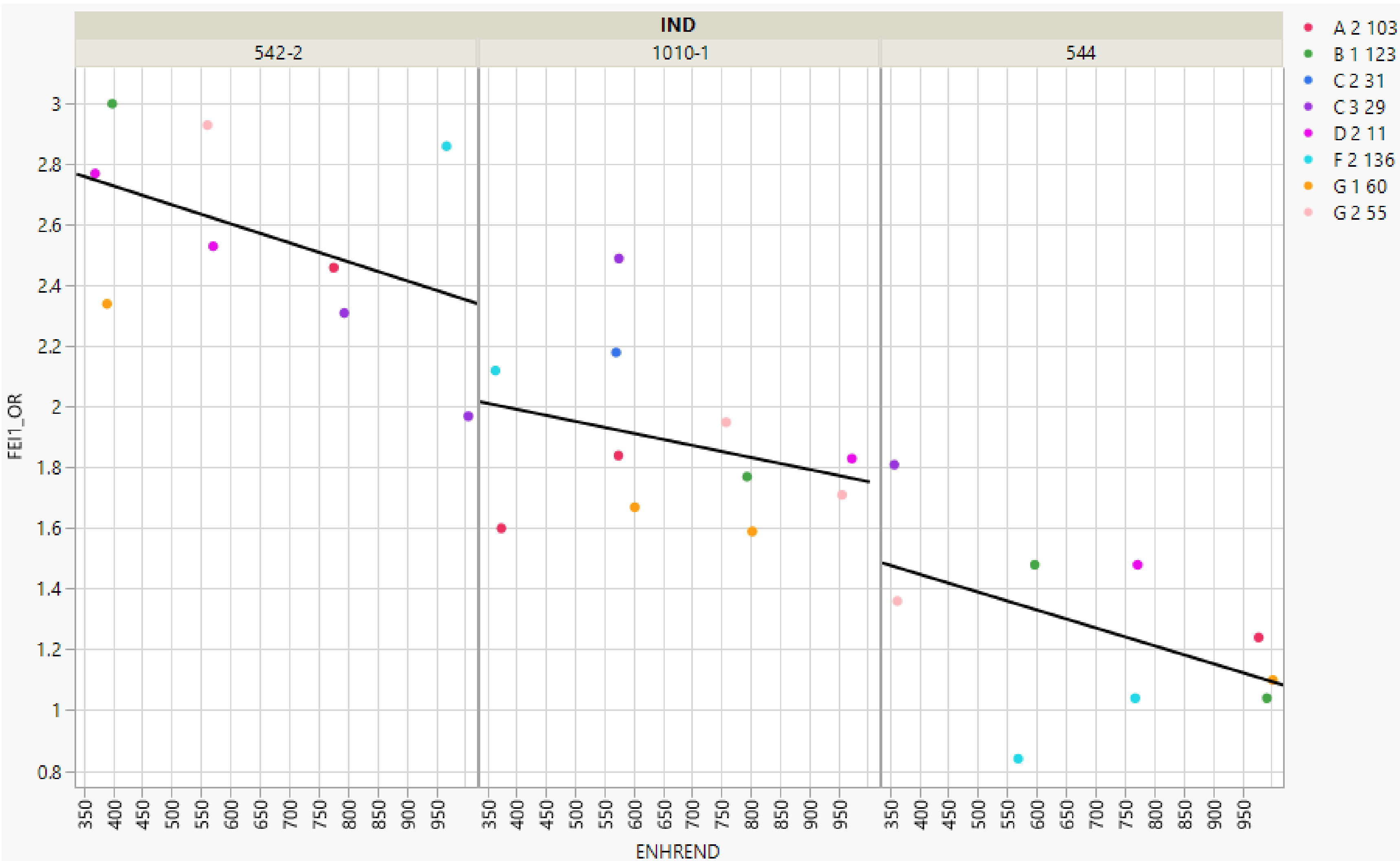


Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Evaluating Alternatives for Engine Hour Adjustment
- **Analyzing PM Data**
  - **FEI1**
  - FEI2
  - Comparing VIE Precision and Oil Discrimination with other Tests

Analyzing PM Data – FEI1

- Plot of FEI1_OR



Analyzing PM Data – FEI1

- Overall ANOVA Summary of FEI1 data:
  - Oils significantly differ
  - Engine Hours effect is marginally significant at 0.05 threshold
  - VIE PM Test Precision: 0.30 *(contrast w/ VID PM test precision of 0.12)*

Summary of Fit

RSquare	0.843489
RSquare Adj	0.756539
Root Mean Square Error	0.29684
Mean of Response	1.907241
Observations (or Sum Wgts)	29

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	10	8.547732	0.854773	9.7008
Error	18	1.586047	0.088114	Prob > F
C. Total	28	10.133779		<.0001*

Parameter Estimates

Term	Estimate	Prob>|t|
Intercept	2.272995	<.0001*
LTMSLAB[A]	-0.133491	0.3377
LTMSLAB[B]	0.0652443	0.6400
LTMSLAB[C]	0.1431912	0.3560
LTMSLAB[D]	0.0671773	0.6310
LTMSLAB[F]	-0.056888	0.6831
LTMSLAB[C]:ENGNO[29]	-0.077558	0.6591
LTMSLAB[G]:ENGNO[55]	0.1459557	0.1817
IND[542-2]	0.6405282	<.0001*
IND[1010-1]	-0.018512	0.8214
ENHREND	-0.000518	0.0522

Effect Tests

Source	DF	Prob > F
LTMSLAB	5	0.7500
ENGNO[LTMSLAB]	2	0.3661
IND	2	<.0001*
ENHREND	1	0.0522

FEI1 Engine Hours Adjustment:
FEI1 = FEI1_OR + 0.000518*(ENHREND – 675)

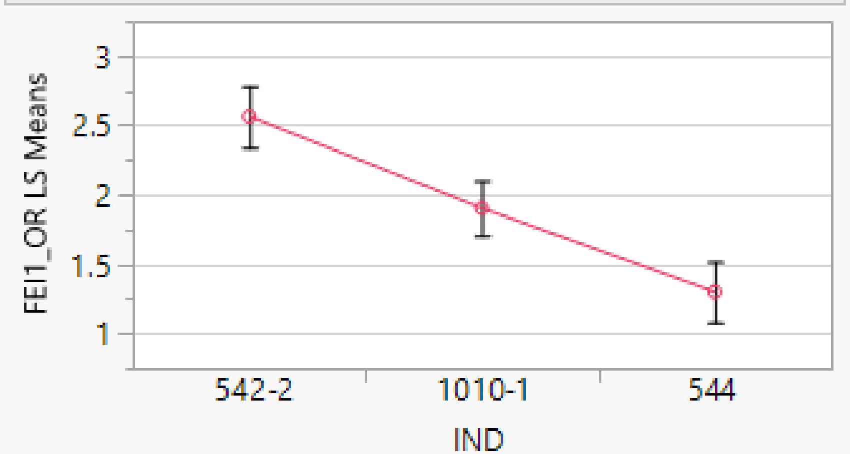
Analyzing PM Data – FEI1

- Oils significantly differ:
  - All oil contrasts are significantly different
  - 544 < 1010-1 < 542-2

Level		Least Sq Mean
542-2	A	2.5638882
1010-1	B	1.9048485
544	C	1.3013434

Levels not connected by same letter are significantly different.

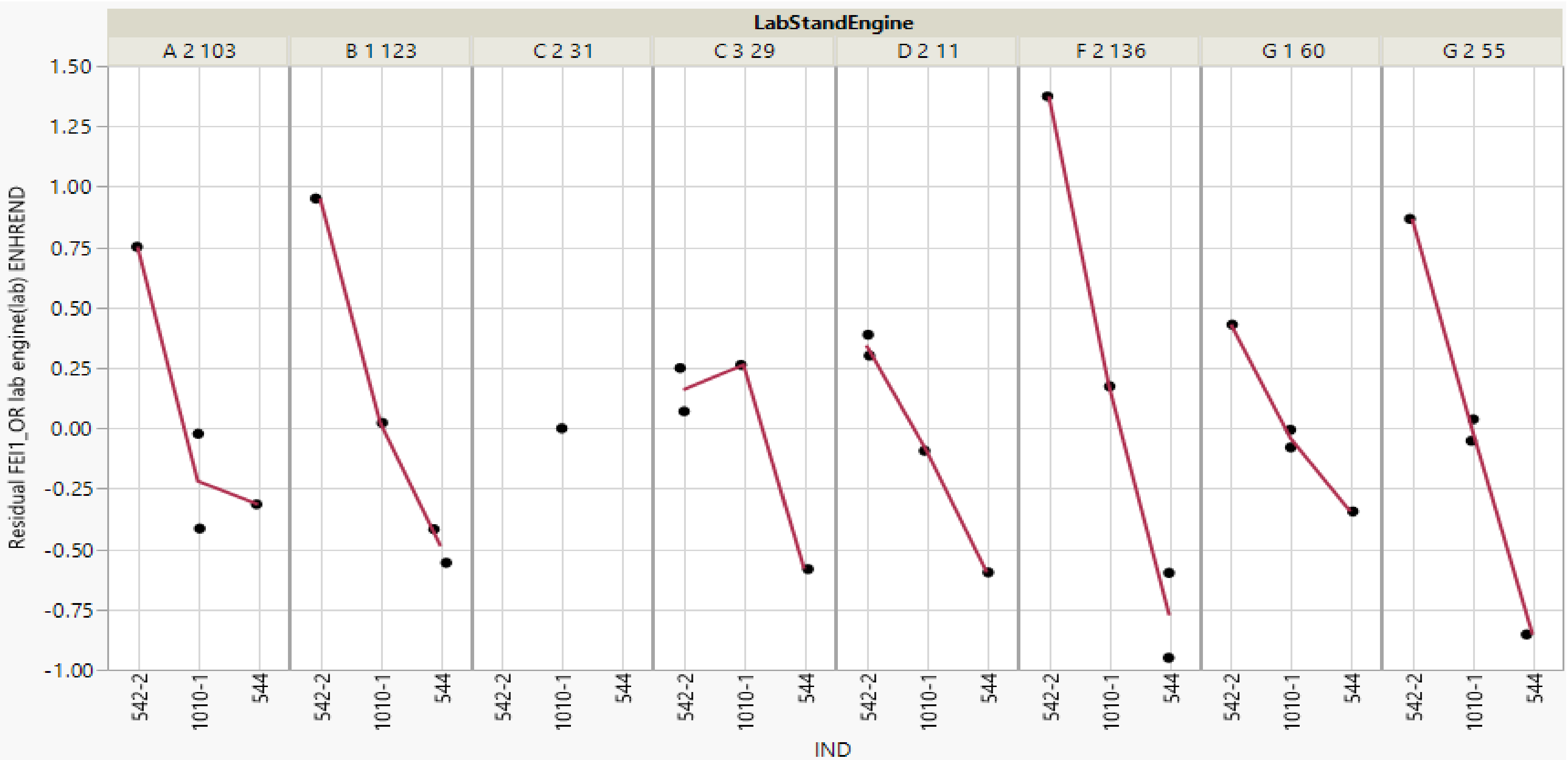
LS Means Plot



RefOil	VID FEI1 Target	VID FEI2 Target
542	1.49	0.8
1010	1.34	1.1

Analyzing PM Data – FEI1

- FEI1Adj Oil Discrimination by Engine
  - Contrast below plot with oil ranking of {544 < 1010-1 < 542-2}
  - Oil ranking is generally consistent across engines. Engines 103 and 29 do not appear to separate all oils, but caution should be used when basing conclusions on limited data.



These residuals are based on a model fit with LTMSLAB, ENGNO(LTMSLAB), and ENHREND

Analyzing PM Data – FEI1

- There are no significant differences among the labs

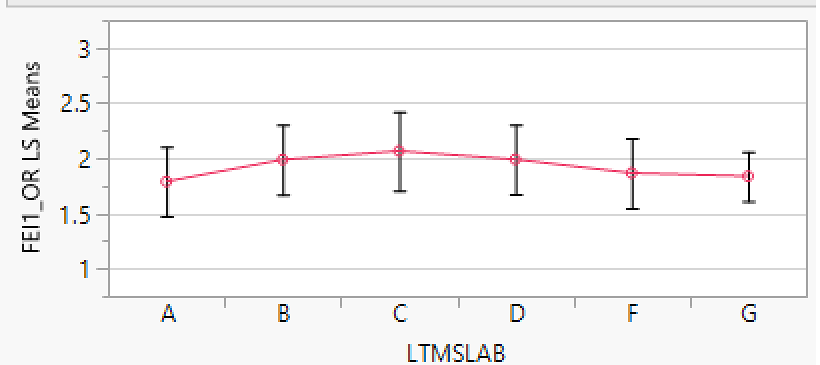
Effect Tests

Source	DF	Prob > F
LTMSLAB	5	0.7500
ENGNO[LTMSLAB]	2	0.3661
IND	2	<.0001*
ENHREND	1	0.0522

Level		Least Sq Mean
C	A	2.0665513
D	A	1.9905373
B	A	1.9886043
F	A	1.8664722
G	A	1.8381261
A	A	1.7898690

Levels not connected by same letter are significantly different.

LS Means Plot



Analyzing PM Data – FEI1

- Engine differences within the same Lab:
  - Comparisons: {C-29 vs. C-31} & {G-55 vs. G-60}
  - Conclusion: No Significant Difference between engines within a Lab

Parameter Estimates

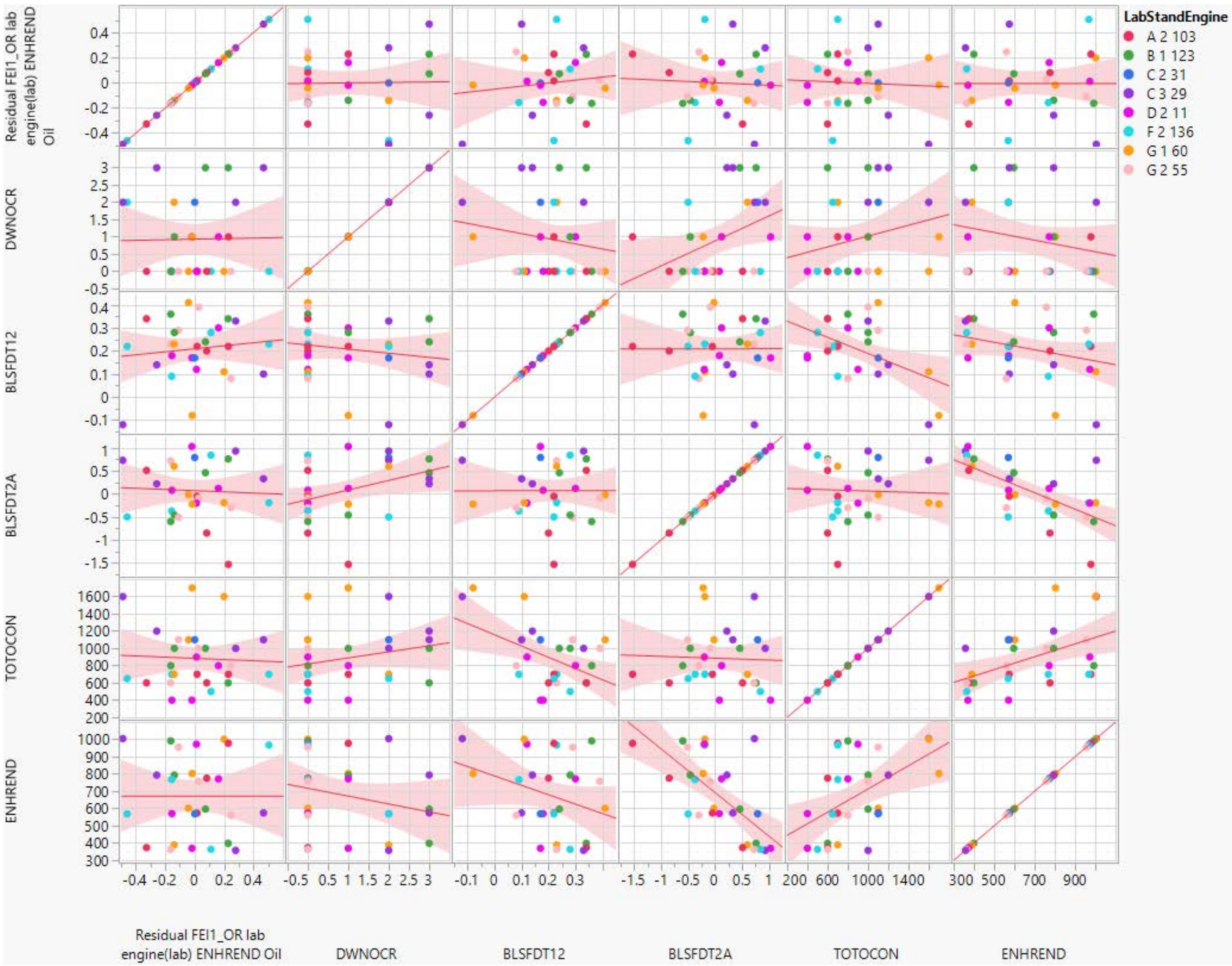
Term	Estimate	Prob>|t|
Intercept	2.272995	<.0001*
LTMSLAB[A]	-0.133491	0.3377
LTMSLAB[B]	0.0652443	0.6400
LTMSLAB[C]	0.1431912	0.3560
LTMSLAB[D]	0.0671773	0.6310
LTMSLAB[F]	-0.056888	0.6831
LTMSLAB[C]:ENGNO[29]	-0.077558	0.6591
LTMSLAB[G]:ENGNO[55]	0.1459557	0.1817
IND[542-2]	0.6405282	<.0001*
IND[1010-1]	-0.018512	0.8214
ENHREND	-0.000518	0.0522

Effect Tests

Source	DF	Prob > F
LTMSLAB	5	0.7500
ENGNO[LTMSLAB]	2	0.3661
IND	2	<.0001*
ENHREND	1	0.0522

Analyzing PM Data – FEI1

- Matrix Plot of FEI1 residuals vs. some other related test variables
  - No observable trends that correlate with FEI1 residuals



FEI1 Precision

Model: FEI1 vs. Oil, Lab, Engine(Lab)

Model RMSE

- s = 0.29

- VIE Prove-out s=0.21
- VID Precision Matrix s=0.14
- VID current data s=0.12

Repeatability

- s = 0.29
- r = 0.80

Model: FEI1 vs. Oil

Reproducibility

- s = 0.29
- R = 0.80

FEI1 Precision

Based upon the Seq. VIE and VID pooled standard deviations (s_r) and ASTM's repeatability (r), there is no significant difference between an FEI1 result[1] of 1.20 – 2.00 for the VIE and 1.61 – 2.00 for the VID.

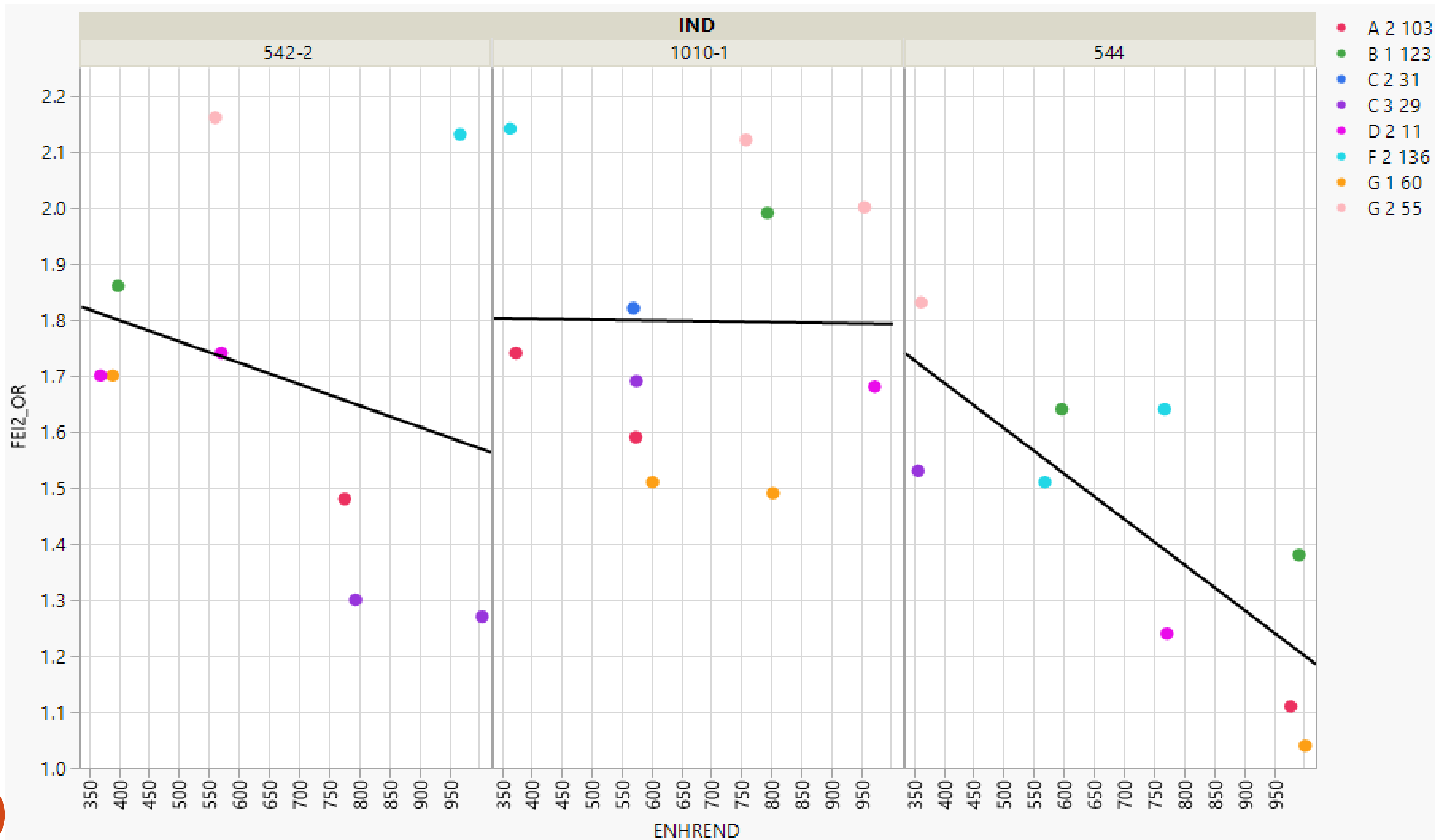
Note 1: An FEI1 of 2.0 was arbitrarily selected in the calculations as the upper pass/fail limit.

Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Evaluating Engine Hour Adjustment
- **Analyzing PM Data**
  - FEI1
  - **FEI2**
  - Comparing VIE Precision and Oil Discrimination with other Tests

Analyzing PM Data – FEI2

- Plot of FEI2_OR



Analyzing PM Data – FEI2

- Overall ANOVA Summary of FEI2 data:
  - Oil, lab, and engines within lab factors are statistically significant
  - Engine Hours effect is significant at 0.05 threshold
  - VIE PM Test Precision: 0.12 *(contrast w/ VID PM test precision of 0.14)*

Summary of Fit

RSquare	0.897781
RSquare Adj	0.840993
Root Mean Square Error	0.121536
Mean of Response	1.656207
Observations (or Sum Wgts)	29

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	10	2.3352039	0.233520	15.8093
Error	18	0.2658788	0.014771	Prob > F
C. Total	28	2.6010828		<.0001*

Parameter Estimates

Term	Estimate	Prob>|t|
Intercept	1.9108716	<.0001*
LTMSLAB[A]	-0.214084	0.0012*
LTMSLAB[B]	0.1317902	0.0306*
LTMSLAB[C]	-0.129363	0.0510
LTMSLAB[D]	-0.085523	0.1461
LTMSLAB[F]	0.2585393	0.0002*
LTMSLAB[C]:ENGNO[29]	-0.094284	0.1996
LTMSLAB[G]:ENGNO[55]	0.2886863	<.0001*
IND[542-2]	0.0807964	0.0286*
IND[1010-1]	0.1611275	0.0001*
ENHREND	-0.000381	0.0015*

Effect Tests

Source	DF	Prob > F
LTMSLAB	5	0.0004*
ENGNO[LTMSLAB]	2	<.0001*
IND	2	<.0001*
ENHREND	1	0.0015*

FEI2 Engine Hours Adjustment:

FEI2 = FEI2_OR + 0.000381*(ENHREND – 675)

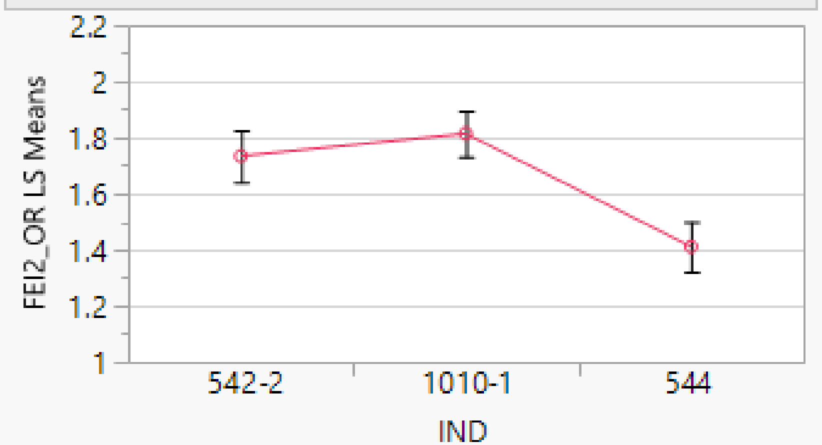
Analyzing PM Data – FEI2

- Oils significantly differ:
  - 544 < {1010-1 & 542-2}

Level		Least Sq Mean
1010-1	A	1.8151067
542-2	A	1.7347756
544	B	1.4120553

Levels not connected by same letter are significantly different.

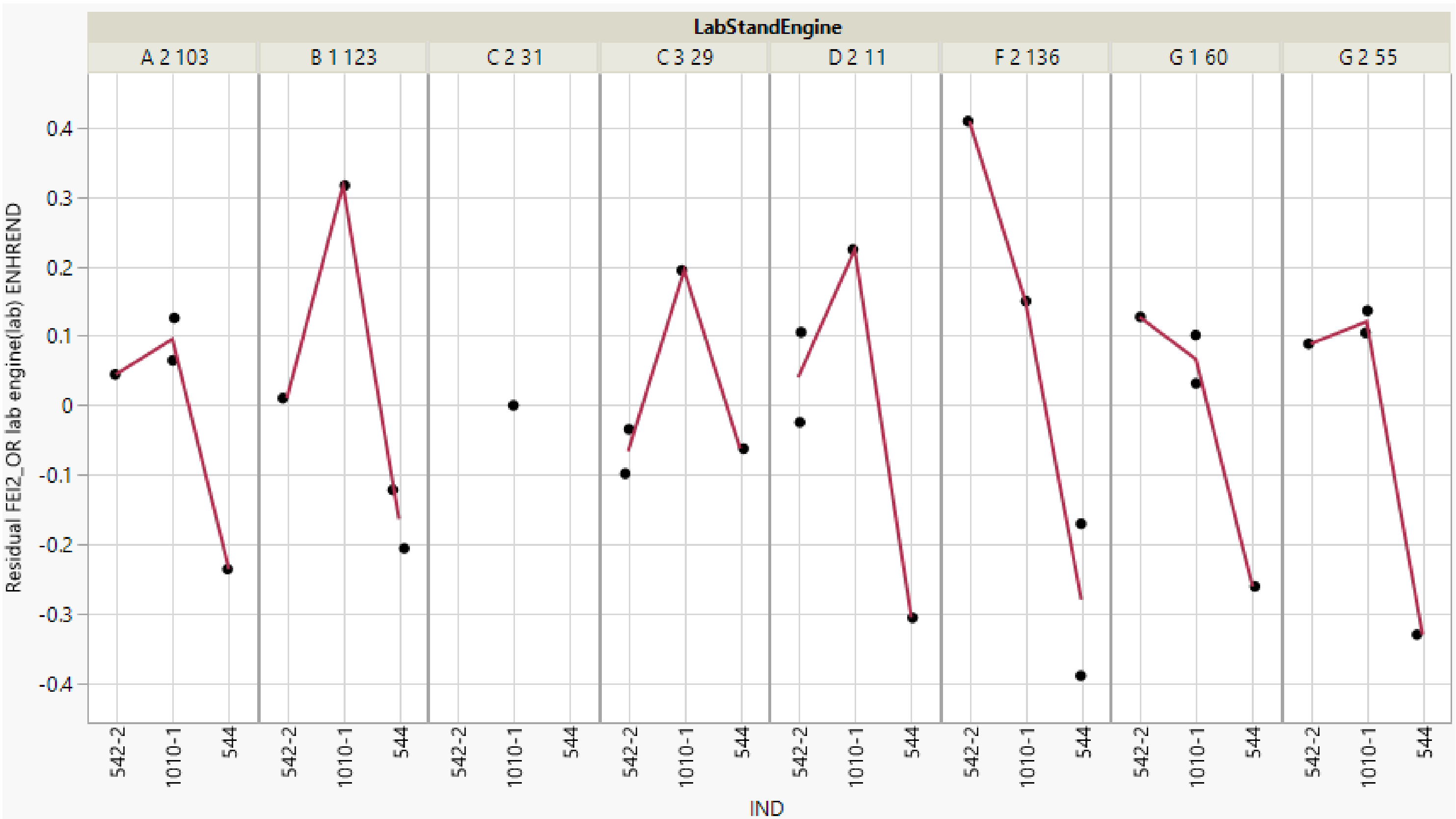
LS Means Plot



RefOil	VID FEI1 Target	VID FEI2 Target
542	1.49	0.8
1010	1.34	1.1

Analyzing PM Data – FEI2

- FEI2Adj Oil Discrimination by Engine
  - Contrast below plot with oil ranking: 544 < {1010-1 & 542-2}
  - 544 ranking is generally consistent across engines with the exception of engine 29, but caution should be used when basing conclusions on limited data.



These residuals are based on a model fit with LTMSLAB, ENGNO(LTMSLAB), and ENHREND

Analyzing PM Data – FEI2

- Labs significantly differ, on average.
  - Lab A < Labs F, B, and G; Labs C & D < Lab F

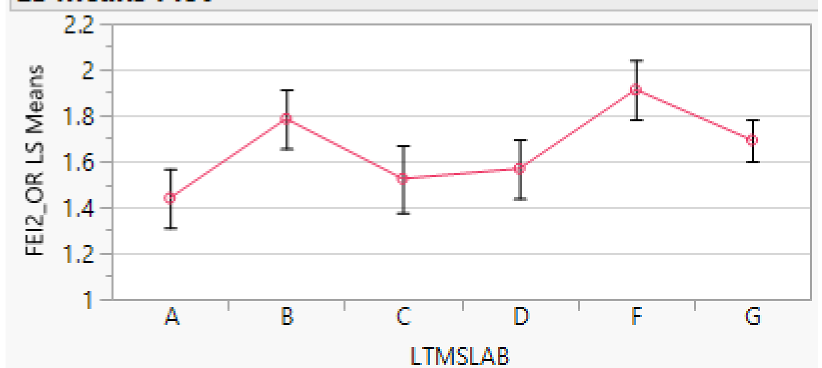
Effect Tests

Source	DF	Prob > F
LTMSLAB	5	0.0004*
ENGNO[LTMSLAB]	2	<.0001*
IND	2	<.0001*
ENHREND	1	0.0015*

Level				Least Sq Mean
F	A			1.9125185
B	A	B		1.7857694
G	A	B		1.6926200
D		B	C	1.5684558
C		B	C	1.5246163
A			C	1.4398953

Levels not connected by same letter are significantly different.

LS Means Plot



Analyzing PM Data – FEI2

- Engine differences within the same Lab:
  - Comparisons: {C-29 vs. C-31} & {G-55 vs. G-60}
  - Conclusion: Engines within lab G significantly differ from one another

Parameter Estimates

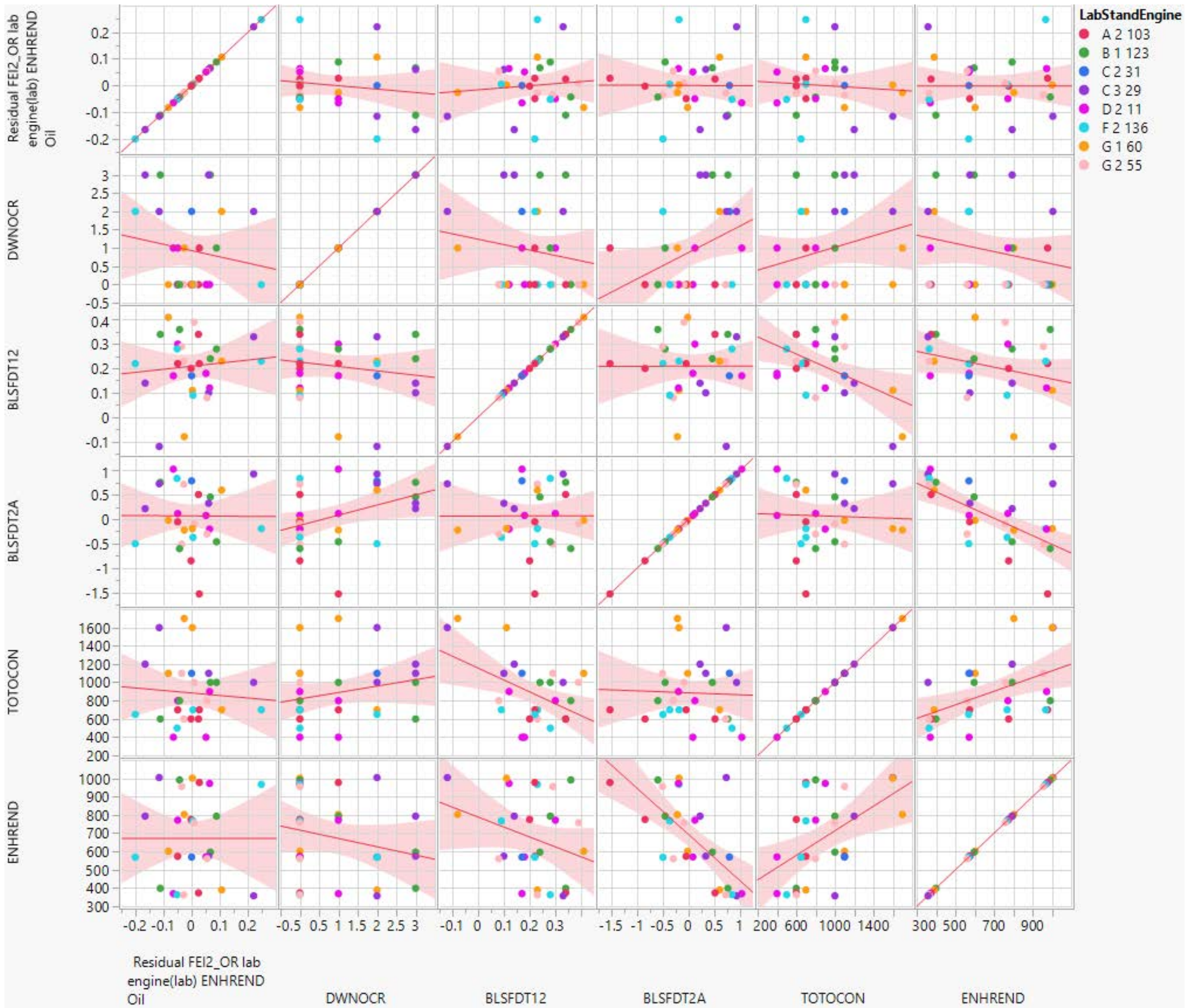
Term	Estimate	Prob>|t|
Intercept	1.9108716	<.0001*
LTMSLAB[A]	-0.214084	0.0012*
LTMSLAB[B]	0.1317902	0.0306*
LTMSLAB[C]	-0.129363	0.0510
LTMSLAB[D]	-0.085523	0.1461
LTMSLAB[F]	0.2585393	0.0002*
LTMSLAB[C]:ENGNO[29]	-0.094284	0.1996
LTMSLAB[G]:ENGNO[55]	0.2886863	<.0001*
IND[542-2]	0.0807964	0.0286*
IND[1010-1]	0.1611275	0.0001*
ENHREND	-0.000381	0.0015*

Effect Tests

Source	DF	Prob > F
LTMSLAB	5	0.0004*
ENGNO[LTMSLAB]	2	<.0001*
IND	2	<.0001*
ENHREND	1	0.0015*

Analyzing PM Data – FEI2

- Matrix Plot of FEI2 residuals vs. some other related test variables
  - No observable trends that correlate with FEI2 residuals



FEI2 Precision

Model: FEI2 vs. Oil, Lab, Engine(Lab)

Model RMSE

- s = 0.12
- VIE Prove-out s=0.16
- VID Precision Matrix s=0.16
- VID current data s=0.13

Repeatability

- s = 0.12
- r = 0.33

Model: FEI2 vs. Oil

Reproducibility

- s = 0.25
- R = 0.69

FEI2 Precision

Based upon the Seq. VIE and VID pooled standard deviations (s_r) and ASTM's repeatability (r), there is no significant difference between an FEI2 result[1] of 1.17 – 1.50 for the VIE and 1.06 – 1.50 for the VID.

Note 1: An FEI2 of 1.5 was arbitrarily selected in the calculations as the upper pass/fail limit.

Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Evaluating Engine Hour Adjustment
- **Analyzing PM Data**
  - FEI1
  - **FEI2**
  - **Comparing VIE Precision and Oil Discrimination with other Tests**

Comparing VIE Precision and Oil Discrimination with other Tests

Sequence VID FEI1

Oil		Target (LTMS)			
540	(GF5A)	1.32		Method Standard Deviation	0.13
541	(GF5D)	0.87		**Full span of results (st devs)**	4.77
542	(GF5X)	1.49		**Span of Oil 1010 - Oil 542 (st dev**	1.15
1010		1.34			

Sequence VID FEI2

Oil		Target (LTMS)		Method Standard Deviation	0.14
540	(GF5A)	1.04			
541	(GF5D)	0.71		**Full span of results (st devs)**	2.79
542	(GF5X)	0.8		**Span of Oil 1010 - Oil 542 (st dev**	2.14
1010		1.1			

Sequence VIE FEI1

Oil	LS Mean (Regression)		Regression RMSE	0.29
1010-1	1.90			
542-2	2.56		**Full span of results (st devs)**	4.34
544	1.30		**Span of Oil 1010 - Oil 542 (st dev**	2.28

Sequence VIE FEI2

Oil	LS Mean (Regression)		Regression RMSE	0.12
1010-1	1.82			
542-2	1.73		**Full span of results (st devs)**	3.42
544	1.41		**Span of Oil 1010 - Oil 542 (st dev**	0.75

Comments

- A method of measuring test precision and oil discrimination is to divide the (FEI difference of best and worst performing reference oils) by the (test precision)
- The result is the # *of standard deviations that separate reference oil performance*
- Comparing the standard deviation alone is not necessarily meaningful; what if the standard deviation is larger, but oils span a larger FEI range? This is what appears to be the case for VIE FEI1
- Granted, this approach is influenced by choice of reference oils
- Engine tests typically show reference oil discrimination of about 1-3 standard deviations (see next slide)

Comparing VIE Precision and Oil Discrimination with other Tests

- Sequence IIIG ln(PVIS): oils separated by 2.0 standard deviations
- Sequence IIIG WPD: oils separated by 2.3 standard deviations
- Sequence IVA wear: oils separated by 1.2 standard deviations
- Sequence VID FEI2: oils separated by 2.9 standard deviations

Seq IIIG

PERCENT VISCOSITY INCREASE
Unit of Measure: LN(PVIS)

Reference Oil	Mean	Standard Deviation
434	4.7269	0.3859
435	5.1838	0.3096
435-2	5.1838	0.3096
438	4.5706	0.1768

Seq IIIG

WEIGHTED PISTON DEPOSITS
Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
434	4.80	0.96
435	3.59	0.58
435-2	3.59	0.58
438	3.20	0.33

Seq IVA

AVERAGE CAMSHAFT WEAR
Unit of Measure: micrometers

Reference Oil	Mean	Standard Deviation
1006-2	102.18	13.54
1007	84.76	15.40

Seq VID

FUEL ECONOMY IMPROVEMENT at 100 Hours
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
540 (GF5A)	1.04	0.14
541 (GF5D)	0.71	0.14
542 (GF5X)	0.80	0.14
1010	1.10	0.18

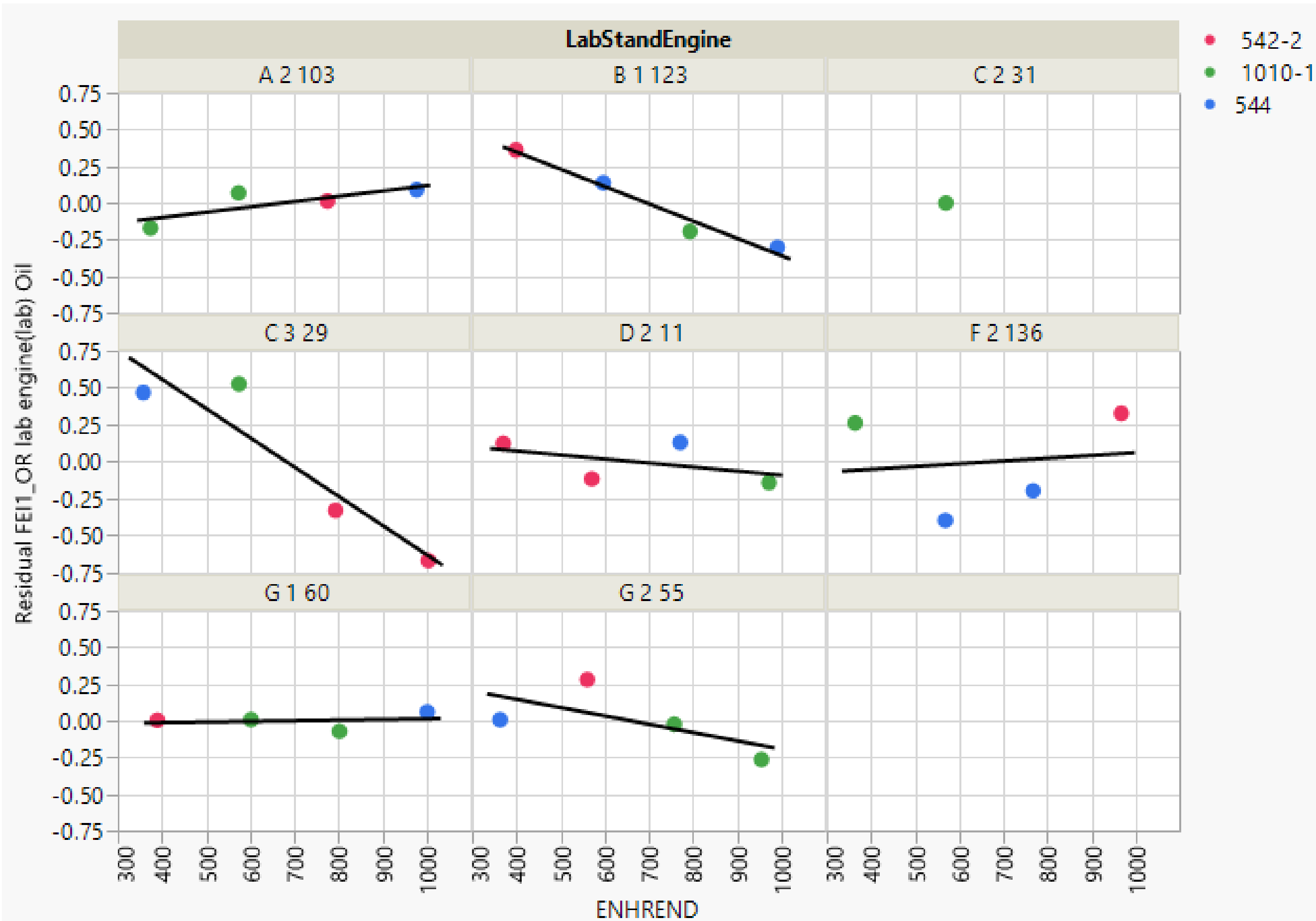
Questions/Comments?

Appendix A

Evaluating FEI1 Eng Hour Adjustment Approach

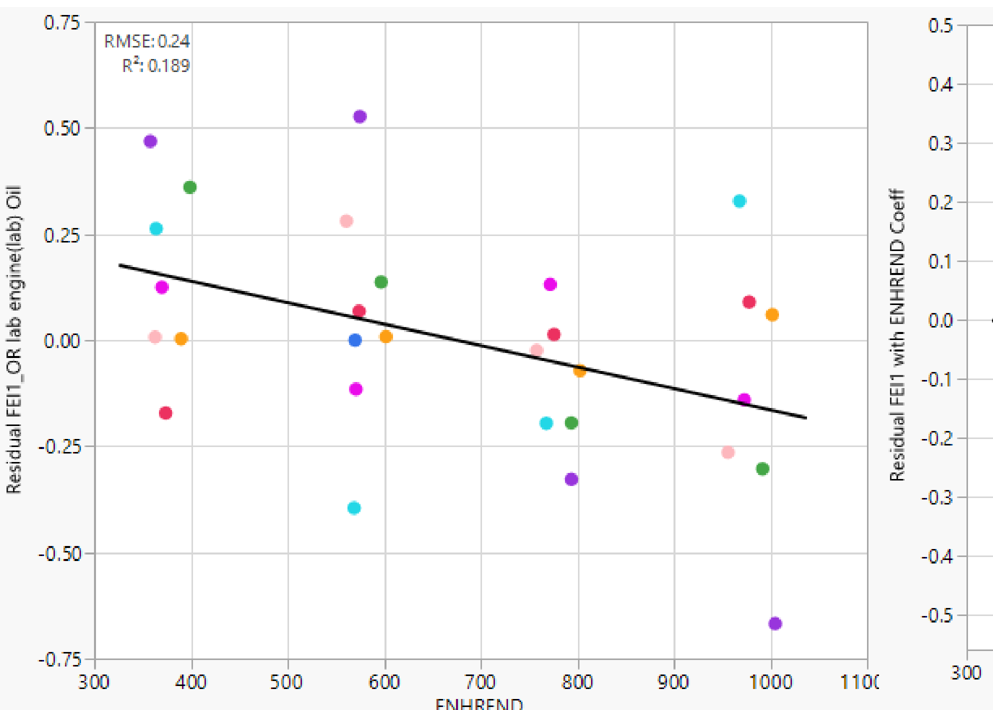
Evaluating Alternatives for FEI1 Engine Hour Adjustment

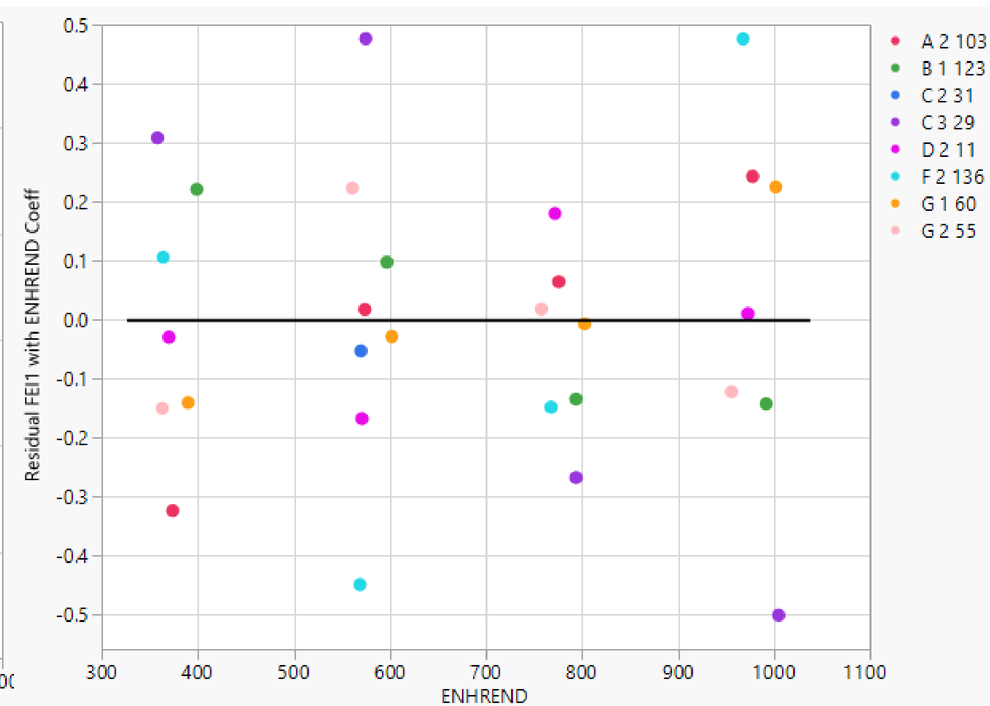
- Residuals vs. ENHREND by engine
- Residuals shown are from a model containing: Lab, Eng(LAB), & Oil



Evaluating Alternatives for FEI1 Engine Hour Adjustment

- Model factors: Lab, Eng(LAB), Oil
- FEI1 model residuals (*y*) vs. ENHREND *[No Transformation]* (*x*) data are shown below
- Model RMSE and Rsquare are 0.24 and 18.9, respectively

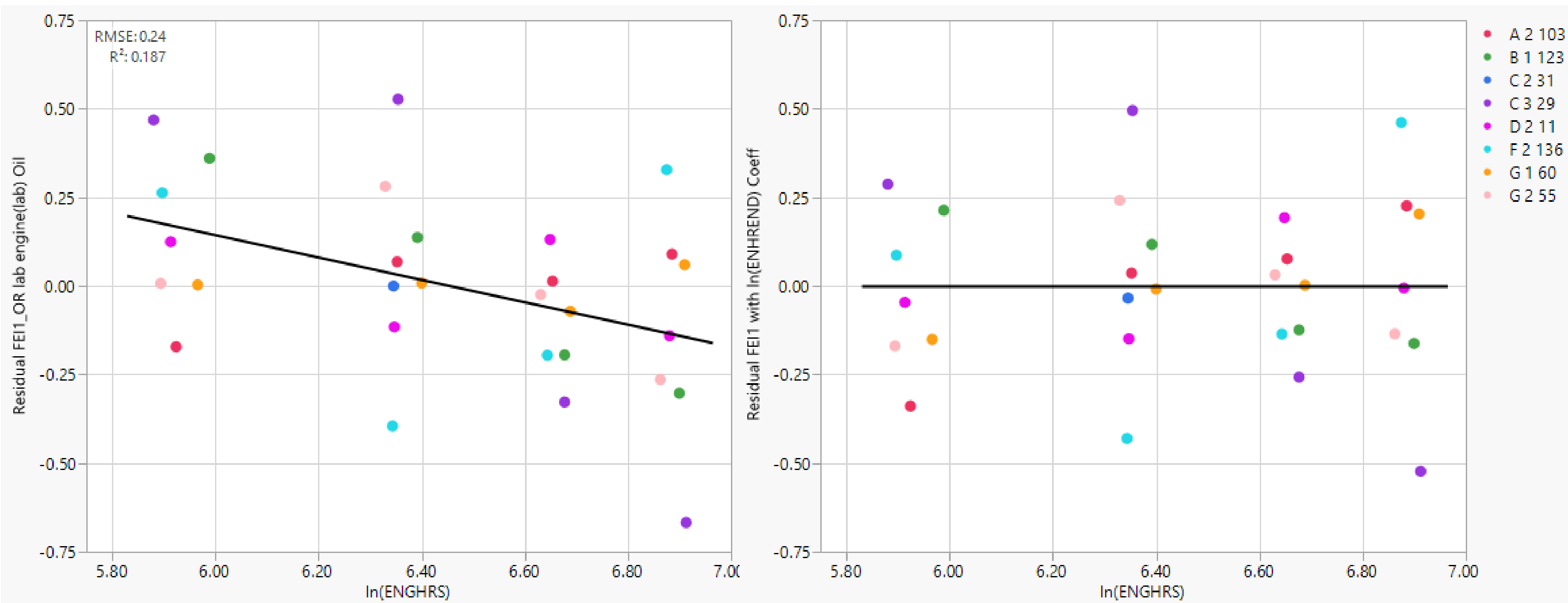




No Transform

Evaluating Alternatives for FEI1 Engine Hour Adjustment

- Model factors: Lab, Eng(Lab), Oil
- Fit of FEI1 model residuals (*y*) vs. Ln(ENHREND) (*x*) data are shown below
- Model RMSE and Rsquare are 0.24 and 18.7, respectively

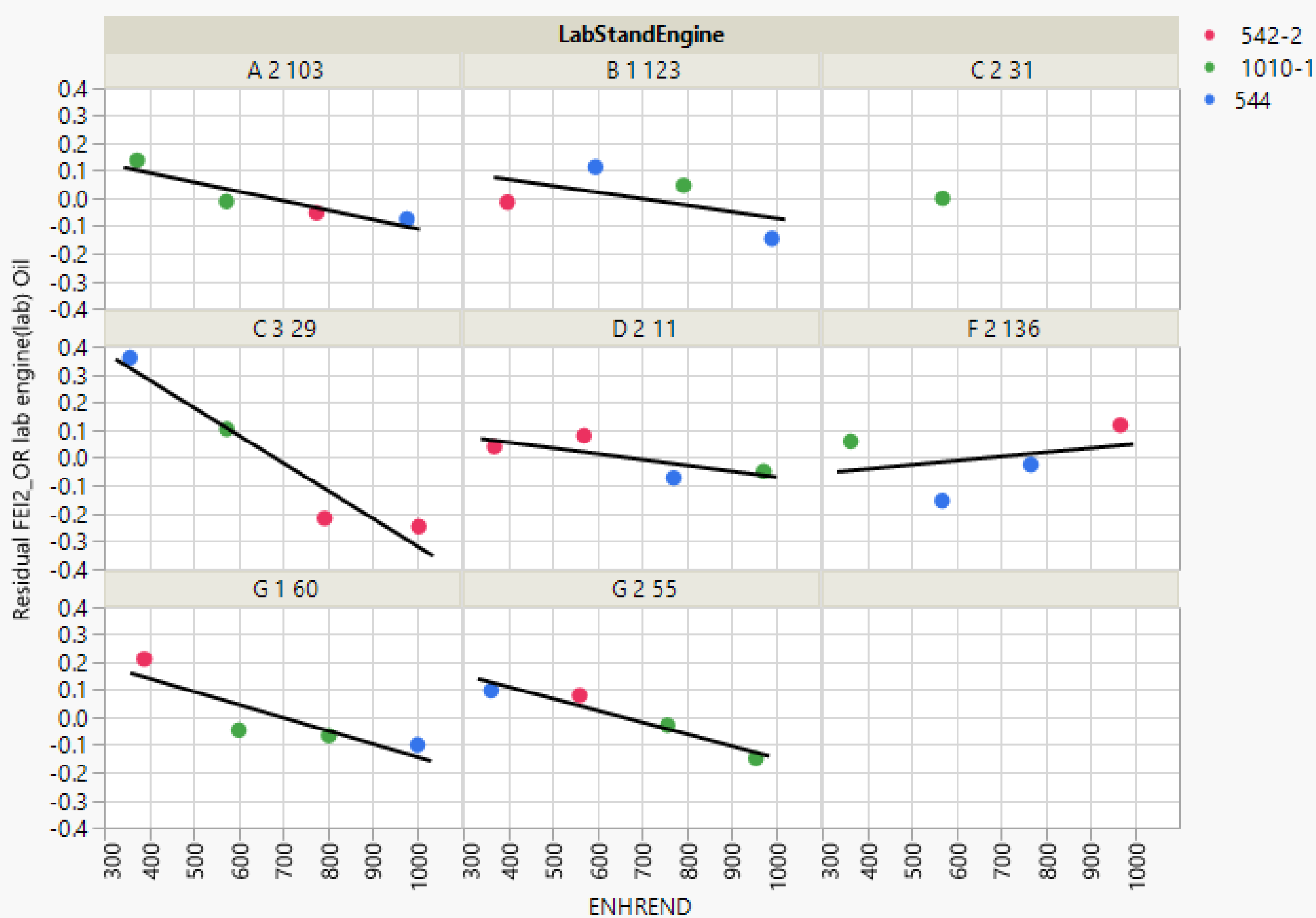


Ln(ENHREND) Transform

Evaluating FEI2 Eng Hour Adjustment

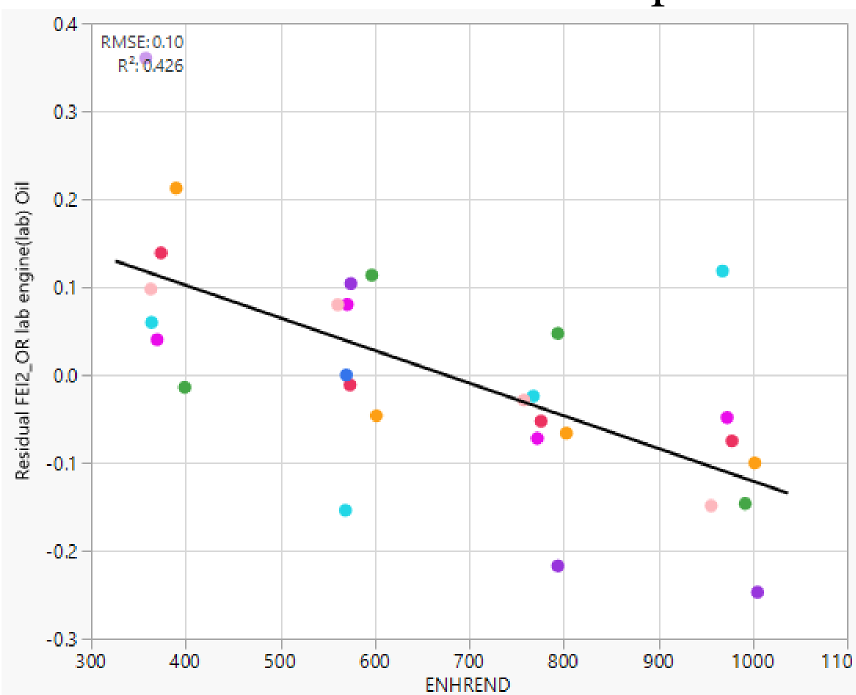
Evaluating Alternatives for FEI2 Engine Hour Adjustment

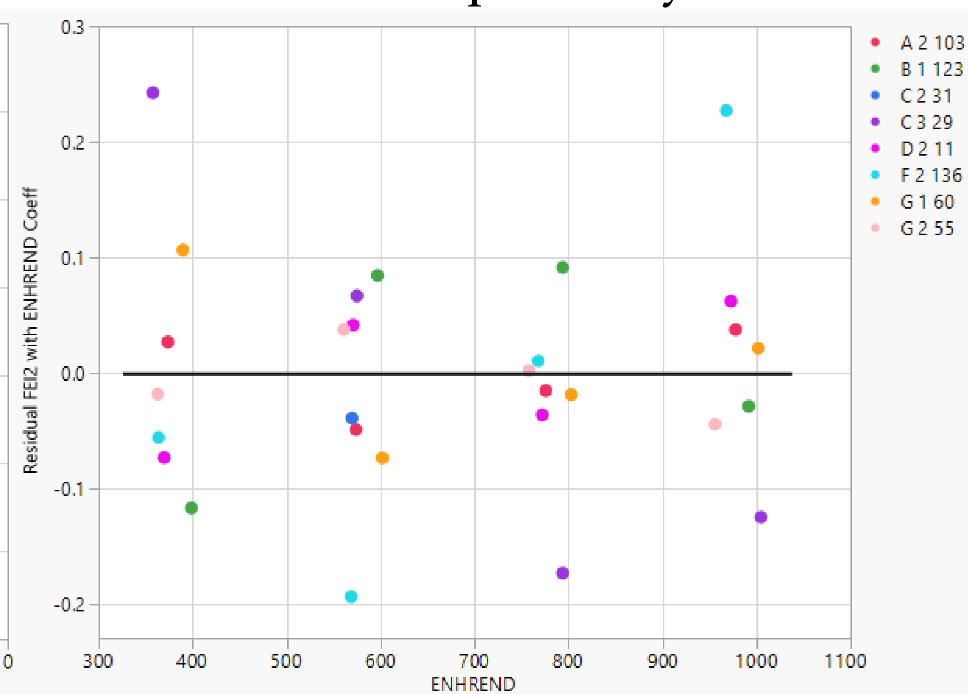
- Residuals vs. ENHREND by engine
- Residuals shown are from a model containing: Lab, Eng(LAB), & Oil



Evaluating Alternatives for FEI2 Engine Hour Adjustment

- Model factors: Lab, Eng(LAB), Oil
- FEI2 model residuals (*y*) vs. ENHREND *[No Transformation]* (*x*) data are shown below
- Model RMSE and Rsquare are 0.1 and 42.6, respectively

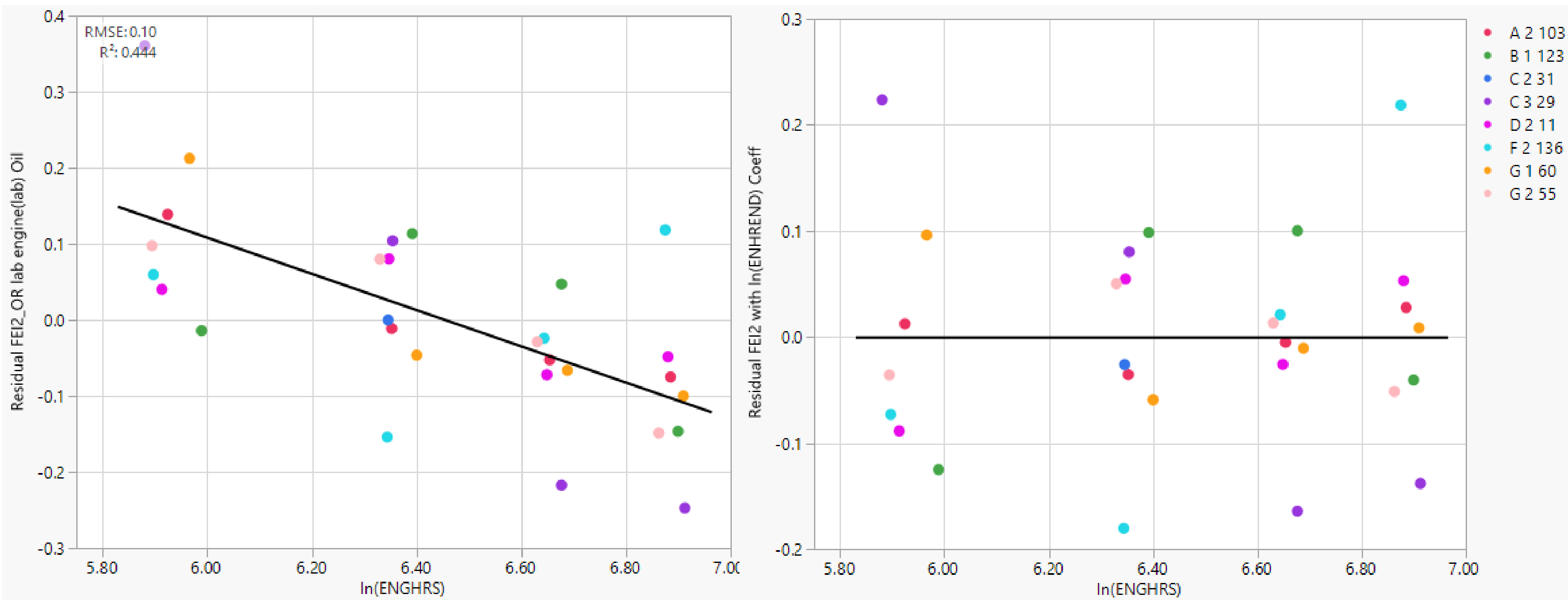




No Transform

Evaluating Alternatives for FEI2 Engine Hour Adjustment

- Model factors: Lab, Eng(LAB), Oil
- Fit of FEI2 model residuals (*y*) vs. Ln(ENHREND) (*x*) data are shown below
- Model RMSE and Rsquare are 0.1 and 44.4, respectively

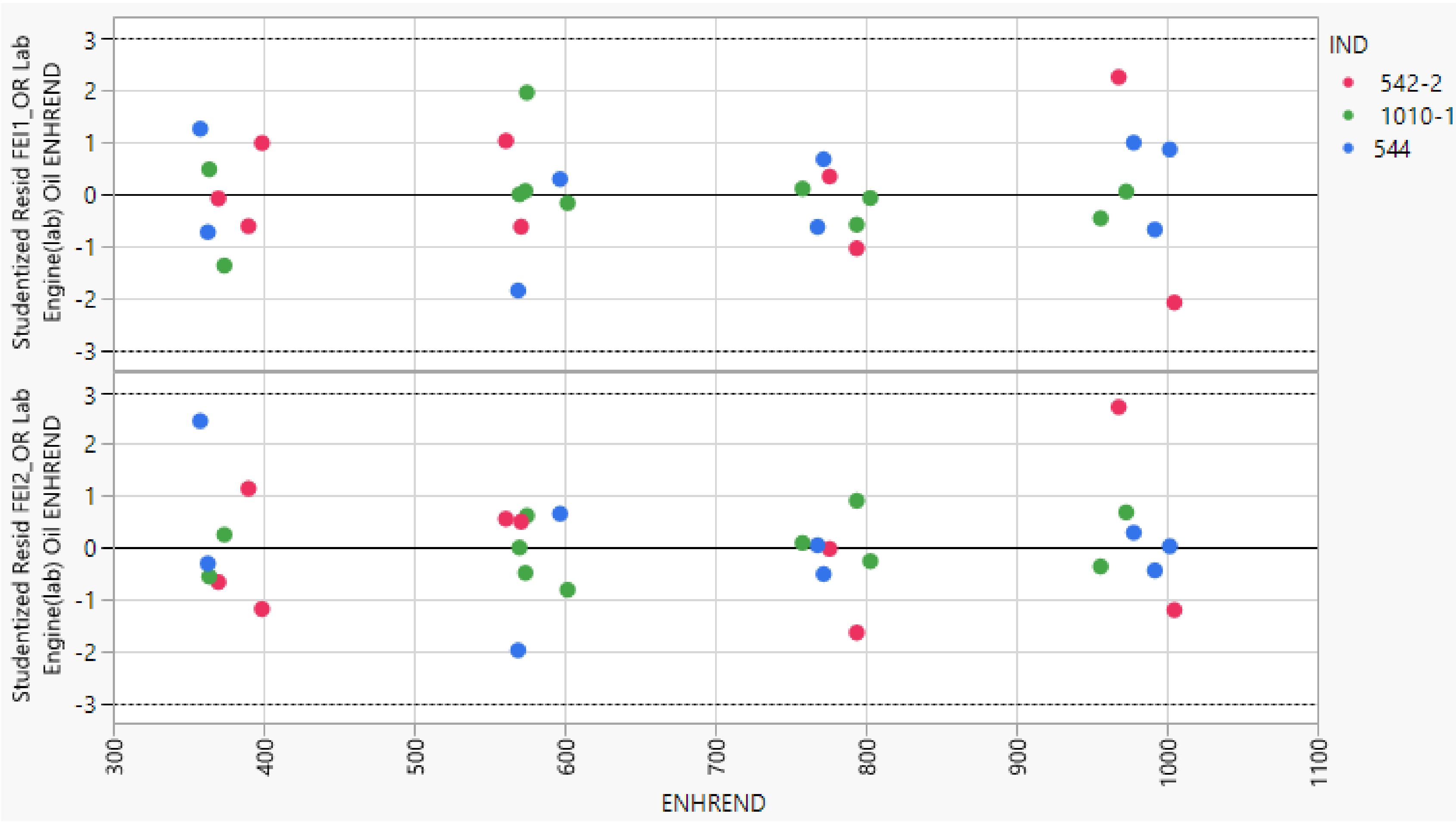


Ln(ENHREND) Transform

Appendix B

Residual Diagnostics Model

Residual Check
Model: Oil, Lab, Engine(Lab), ENHREND

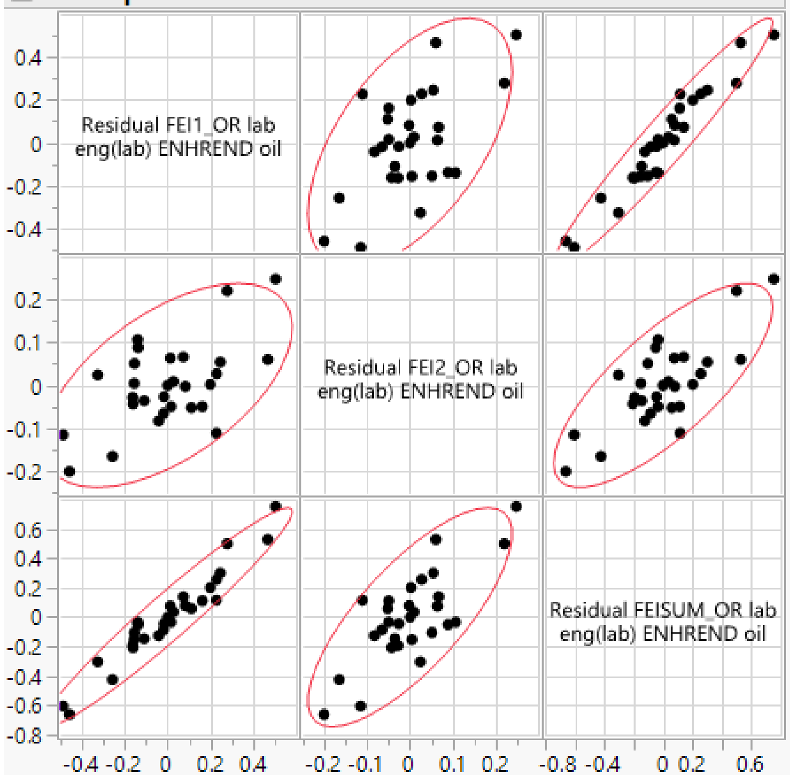


Correlation among parameters
Model: Oil, Lab, Engine(Lab), ENHREND

Correlations

	Residual FEI1_OR lab eng(lab) ENHREND oil	Residual FEI2_OR lab eng(lab) ENHREND oil	Residual FEISUM_OR lab eng(lab) ENHREND oil
Residual FEI1_OR lab eng(lab) ENHREND oil	1.0000	0.5687	0.9647
Residual FEI2_OR lab eng(lab) ENHREND oil	0.5687	1.0000	0.7654
Residual FEISUM_OR lab eng(lab) ENHREND oil	0.9647	0.7654	1.0000

Scatterplot Matrix



VIE LTMS

Statistics Group

Date: 07-26-2016-Rev-B

Statistics Group

- Arthur Andrews, ExxonMobil
- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Kevin O'Malley, Lubrizol
- Martin Chadwick, Intertek
- Richard Grundza, TMC
- Lisa Dingwell, Afton
- Todd Dvorak, Afton
- Travis Kostan, SwRI

VIE LTMS

- Traditional LTMS Severity Adjustments (SAs) for Labs or Stand/Engine Combinations are based on multiple calibration runs for the test entity.
- Calculations for the VID LTMS based severity adjustments include Y_i, lambda values, exponentially weighted moving average (EWMA), Fast Start, and RO targets & standard deviations.
- With a limited VIE engine life, the Sequence VI Surveillance Panel asked the Statistics Team to establish an LTMS that is based on a single calibration run.

VIE LTMS

- With a single test LTMS, members of the Statistics Team could not reach a consensus on one method for the lab-engine-stand calibration.
  - The use of one reference to determine acceptance of a calibrated entity and set severity adjustments is not normal in the LTMS. This process is not recommended. This is an attempt to help select a reference system based on the basic framework the stats group has discussed.
- Statistics Team has reached a consensus on 2 possible options
- Each of the options differ by the criteria requiring more than 1 reference test, how the SA is calculated, the weight factors, and possible "capping" of the Y_i results.
- The first step is to review how Y_i values will be calculated.

Engine Hour Adjustment for VIE LTMS

- LTMS proposals are based on the below engine hour adjustments:
  - FEI1 EngHr Adjustment:

$$FEI1 = 0.000518*(EngHr - 675)+FEI1\_Original$$

  - FEI2 EngHr Adjustment:

$$FEI2 = 0.000381*(EngHr - 675)+FEI2\_Original$$

How are Yi's Calculated?

- Y_i calculation method equation:

$$Y_i = \frac{FEI\_HrsAdj - RO\_Target\_FEI}{RO\_StdDev}$$

- As indicated in the above equation, the Y_i calculation is based on engine hour adjusted FEI results and LSMean[1] targets (shown in below table) for each reference oil.

Targets	FEI1	FEI2
RO1010-1	1.90	1.82
RO542-2	2.56	1.73
RO544	1.30	1.41

Note 1: FEI1 and FEI2 LSMeans were based on the n = 29 EngHr adj result data with Oil, Lab, and Eng(Lab) in the model

How are Yi's Calculated?

- For the denominator part of the Y_i the equation, the standard deviations of the engine hour adjusted FEI results by reference oil (shown in below table) will be used for the calculation

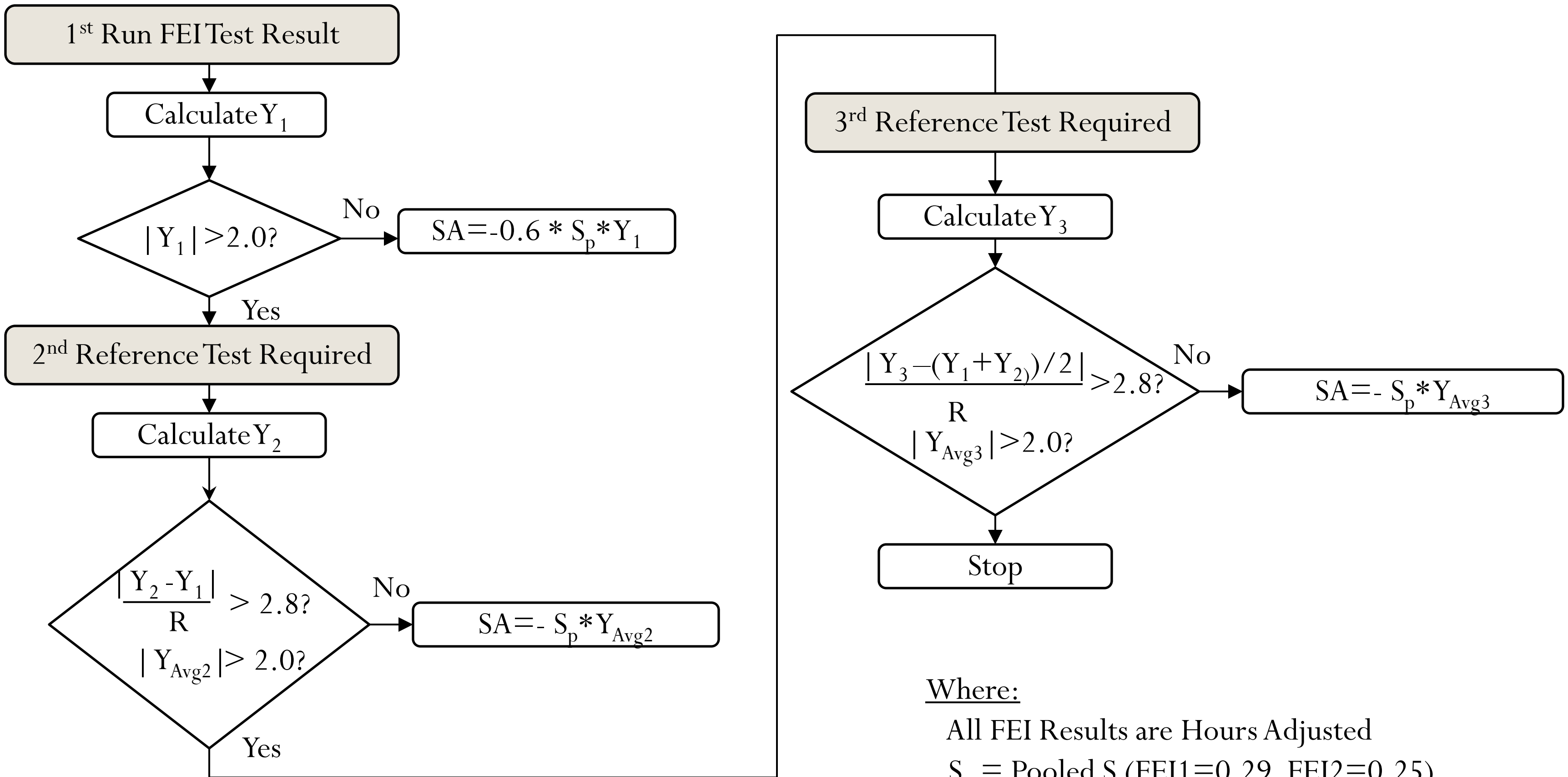
Raw FEI SD	FEI1	FEI2
1010-1	0.27	0.25
542-2	0.31	0.30
544	0.26	0.20

- Note that severity adjustment calculation will be based on S_p rather than the individual standard deviation for the oil.
  - FEI1 $S_p = 0.29$
  - FEI2 $S_p = 0.25$

VIE LTMS

- A detailed flow chart with examples will be provided in the following slides to explain and clarify the several options proposed by the members of the Statistics Team.

Option 1 Flow Chart – No Capping of Severity Adj.



Where:

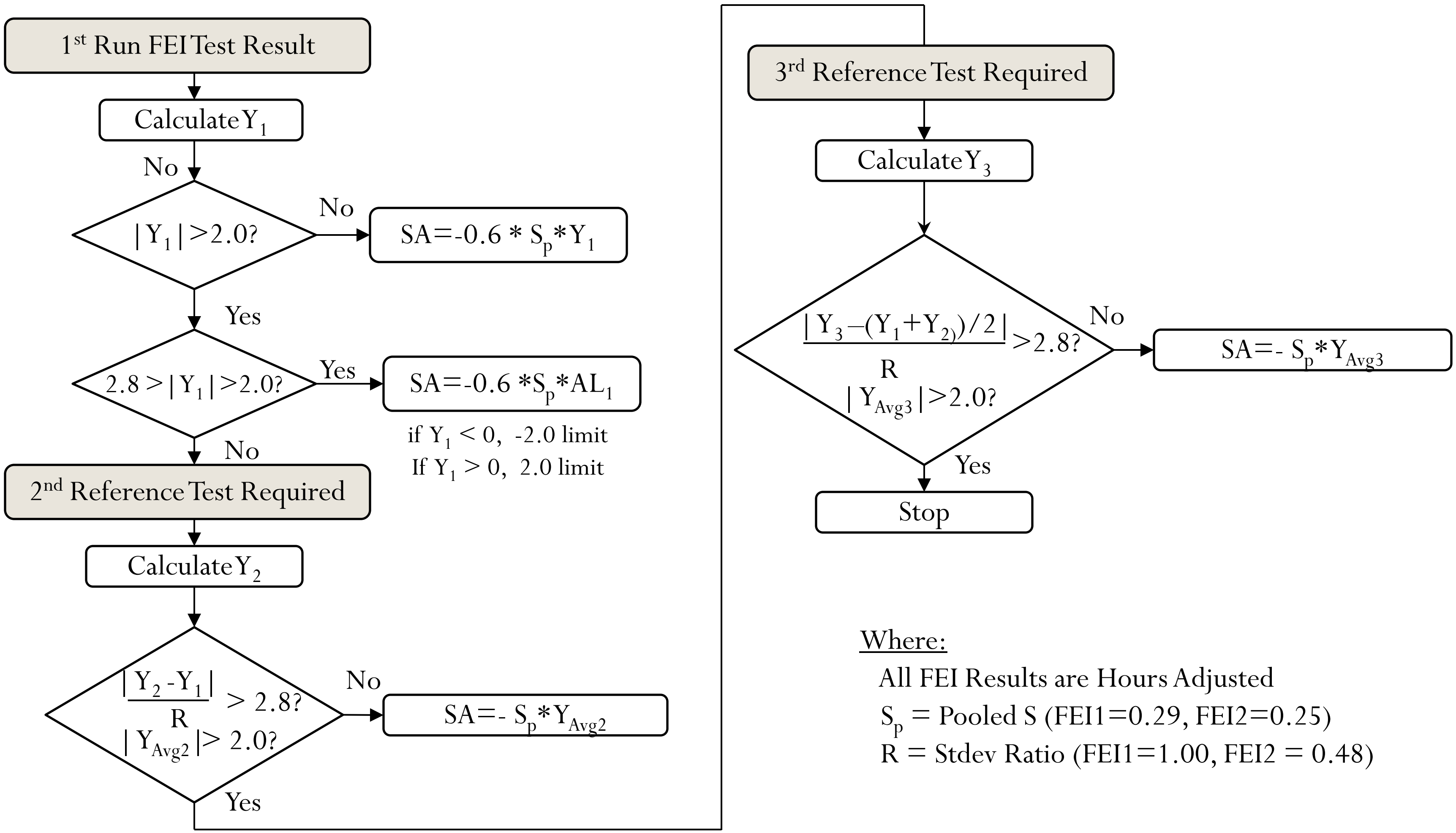
All FEI Results are Hours Adjusted

S_p = Pooled S (FEI1=0.29, FEI2=0.25)

R = Stdev Ratio (FEI1=1.00, FEI2 = 0.48)

SELECTED OPTION

Option 2 Flow Chart – Capping of Severity Adj.



<u>Where:</u>

All FEI Results are Hours Adjusted

S_p = Pooled S (FEI1=0.29, FEI2=0.25)

R = Stdev Ratio (FEI1=1.00, FEI2 = 0.48)

Appendix

1. Selecting a Yi limit (delta/s) for first run reference test acceptance.
   a. If you think there is a good chance that each engine is different then 1.645 is the point at which there is a 95% chance that this engine has a mean that is different from the target. An additional reference should be conducted to determine the mean of this engine.
      i. If all labs, stands, and engines are similar this would mean about 10% of tests would require a second reference. Since we know differences exist the expectation is it will be somewhat higher than 10%. This rate can be lowered with higher limits.
   b. If you think that all stand-engines are from the same process then 1.96 is the point at which there is a 95% chance this combination is not performing as expected.
      i. If all labs, stands, and engines are similar this would mean about 5% of tests would require a second reference. Since we know differences exist the expectation is it will be somewhat higher than 5%. This rate can be lowered with higher limits.

2. Selecting a severity adjustment based on a single reference result.
   a. If you believe the current data point is the best possible estimate of the stand-engine severity available a severity adjustment equal to the deviation from target of the current test can be elected. Essentially set Zi equal to Yi and calculate the SA as normal.
   b. If you believe the current result is a combination of stand-engine bias and normal variability and that the tendency in the long run is for results to approach target then a weight factor can be applied to the current result to generate a severity adjustment. A weight factor of 0.5 has been suggested but any value is possible. Essentially set Zi = weight factor * Yi and compute the SA.
   c. If you are concerned about overly large severity adjustments based on one result then a cap in terms of Yi or simply in terms of maximum severity adjustment possible can be added to either of the choices above.
   d. If you believe one data point is insufficient to adequately determine stand-engine severity for the purposes of adjusting future candidates or that severity adjustments with minimal information can lead to increased candidate variation in the long run then no severity adjustments for tests that qualify on one run is an option.

SUMMARY

Limits used in this comparison

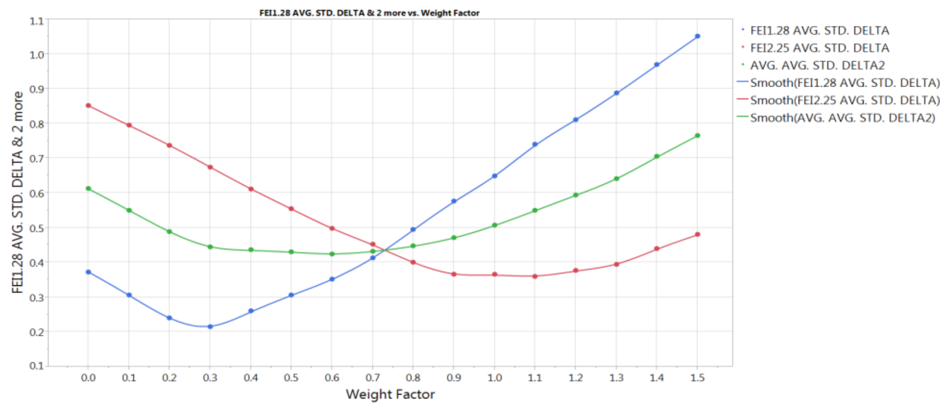
	FEI1	FEI2
R	1.08	0.47
Weight	Varies	Varies
SA Yi Cap	NA	NA
AL1	2.00	2.00
AL2	2.00	2.00
AL3	2.60	2.60

OPTIMAL WF BY ENGINE BASED ON MINIMIZING AVERAGE(FEI1 STD. DELTA, FEI2 STD. DELTA)

		WEIGHT FACTORS															
LAB	**ENGNO**	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
D	11	0.303	0.283	0.245	0.205	0.167	0.147	0.109	0.109	0.111	0.131	0.134	0.154	0.176	0.196	0.198	0.218
C	29	0.559	0.487	0.434	0.398	0.469	0.541	0.594	0.666	0.737	0.809	0.862	0.934	1.005	1.059	1.130	1.201
G	55	0.767	0.705	0.643	0.601	0.539	0.476	0.432	0.390	0.328	0.306	0.404	0.481	0.579	0.677	0.775	0.853
G	60	0.913	0.839	0.748	0.674	0.581	0.489	0.416	0.378	0.429	0.463	0.476	0.528	0.561	0.595	0.629	0.680
A	103	0.672	0.543	0.431	0.338	0.387	0.436	0.468	0.517	0.566	0.616	0.667	0.716	0.806	0.917	1.046	1.176
B	123	0.407	0.354	0.318	0.316	0.369	0.405	0.459	0.512	0.528	0.581	0.635	0.689	0.724	0.758	0.811	0.847
F	136	0.663	0.641	0.601	0.579	0.539	0.516	0.494	0.454	0.432	0.392	0.370	0.348	0.308	0.286	0.344	0.384

ALL ENGINES

WEIGHT FACTORS	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
FEI1 AVG. STD.(DELTA)	0.372	0.306	0.240	0.214	0.260	0.306	0.352	0.413	0.495	0.577	0.648	0.740	0.811	0.888	0.969	1.051
FEI2 AVG. STD.(DELTA)	0.851	0.794	0.737	0.674	0.611	0.554	0.497	0.451	0.400	0.366	0.366	0.360	0.377	0.394	0.440	0.480
AVG. OF AVG. STD(DELTA)	0.612	0.550	0.488	0.444	0.436	0.430	0.425	0.432	0.447	0.471	0.507	0.550	0.594	0.641	0.705	0.766



FEI1

FEI1 SEVERITY ADJUSTMENTS BY WEIGHT FACTOR & ENGINE

			WEIGHT FACTORS															
LAB	**ENGNO**	**4 TEST FEI1 SA**	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
D	11	-0.08	0	0	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05	-0.05	-0.06	-0.06	-0.07	-0.07
C	29	-0.10	0	-0.04	-0.07	-0.11	-0.15	-0.19	-0.22	-0.26	-0.3	-0.34	-0.37	-0.41	-0.45	-0.48	-0.52	-0.56
G	55	-0.06	0	0.01	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15	0.16
G	60	0.22	0	0.03	0.07	0.1	0.13	0.17	0.2	0.23	0.27	0.3	0.33	0.37	0.4	0.43	0.46	0.5
A	103	0.13	0	0.05	0.09	0.14	0.19	0.24	0.28	0.33	0.38	0.43	0.47	0.52	0.57	0.61	0.66	0.71
B	123	-0.06	0	-0.03	-0.05	-0.08	-0.11	-0.13	-0.16	-0.19	-0.21	-0.24	-0.27	-0.3	-0.32	-0.35	-0.38	-0.4
F	136	0.08	0	-0.01	-0.01	-0.02	-0.02	-0.03	-0.04	-0.04	-0.05	-0.05	-0.06	-0.07	-0.07	-0.08	-0.09	-0.09

DELTA OF 4 TEST SA AND 1 TEST SA WITH WF

0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
-0.08	-0.08	-0.07	-0.07	-0.06	-0.06	-0.05	-0.05	-0.04	-0.04	-0.03	-0.03	-0.02	-0.02	-0.01	-0.01
-0.1	-0.06	-0.03	0.01	0.05	0.09	0.12	0.16	0.2	0.24	0.27	0.31	0.35	0.38	0.42	0.46
-0.06	-0.07	-0.08	-0.09	-0.1	-0.11	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.19	-0.2	-0.21	-0.22
0.22	0.19	0.15	0.12	0.09	0.05	0.02	-0.01	-0.05	-0.08	-0.11	-0.15	-0.18	-0.21	-0.24	-0.28
0.13	0.08	0.04	-0.01	-0.06	-0.11	-0.15	-0.2	-0.25	-0.3	-0.34	-0.39	-0.44	-0.48	-0.53	-0.58
-0.06	-0.03	-0.01	0.02	0.05	0.07	0.1	0.13	0.15	0.18	0.21	0.24	0.26	0.29	0.32	0.34
0.08	0.09	0.09	0.1	0.1	0.11	0.12	0.12	0.13	0.13	0.14	0.15	0.15	0.16	0.17	0.17

ABS(DELTA)/FEI1 STANDARD DEVIATION

LAB	**ENGNO**	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
D	11	0.29	0.29	0.25	0.25	0.21	0.21	0.18	0.18	0.14	0.14	0.11	0.11	0.07	0.07	0.04	0.04
C	29	0.36	0.21	0.11	0.04	0.18	0.32	0.43	0.57	0.71	0.86	0.96	1.11	1.25	1.36	1.50	1.64
G	55	0.21	0.25	0.29	0.32	0.36	0.39	0.46	0.50	0.54	0.57	0.61	0.64	0.68	0.71	0.75	0.79
G	60	0.79	0.68	0.54	0.43	0.32	0.18	0.07	0.04	0.18	0.29	0.39	0.54	0.64	0.75	0.86	1.00
A	103	0.46	0.29	0.14	0.04	0.21	0.39	0.54	0.71	0.89	1.07	1.21	1.39	1.57	1.71	1.89	2.07
B	123	0.21	0.11	0.04	0.07	0.18	0.25	0.36	0.46	0.54	0.64	0.75	0.86	0.93	1.04	1.14	1.21

F	136	0.29	0.32	0.32	0.36	0.36	0.39	0.43	0.43	0.46	0.46	0.50	0.54	0.54	0.57	0.61	0.61

SUMMARY OF STANDARDIZED DELTAS BY WF

Weight Factor	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
Avg. SD(Delta)	0.37	0.31	0.24	0.21	0.26	0.31	0.35	0.41	0.49	0.58	0.65	0.74	0.81	0.89	0.97	1.05
Range SD(Delta)	0.21-0.79	0.11-0.68	0.04-0.54	0.04-0.43	0.18-0.36	0.18-0.39	0.07-0.54	0.04-0.71	0.14-0.89	0.14-1.07	0.11-1.21	0.11-1.39	0.07-1.57	0.07-1.71	0.04-1.89	0.04-2.07

FEI2

FEI2 SEVERITY ADJUSTMENTS BY WEIGHT FACTOR & ENGINE

			WEIGHT FACTORS															
LAB	ENGNO	4 TEST FEI2 SA	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
D	11	0.08	0	0.01	0.02	0.04	0.05	0.06	0.07	0.09	0.1	0.11	0.12	0.13	0.15	0.16	0.17	0.18
C	29	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	55	-0.33	0	-0.04	-0.08	-0.11	-0.15	-0.19	-0.23	-0.26	-0.3	-0.34	-0.38	-0.41	-0.45	-0.49	-0.53	-0.56
G	60	0.26	0	0.01	0.02	0.03	0.05	0.06	0.07	0.08	0.09	0.1	0.12	0.13	0.14	0.15	0.16	0.17
A	103	0.22	0	0.02	0.04	0.06	0.08	0.1	0.12	0.14	0.16	0.18	0.19	0.21	0.23	0.25	0.27	0.29
B	123	-0.15	0	0	0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03
F	136	-0.26	0	-0.02	-0.04	-0.06	-0.08	-0.1	-0.12	-0.14	-0.16	-0.18	-0.2	-0.22	-0.24	-0.26	-0.28	-0.3

DELTA OF 4 TEST SA AND 1 TEST SA WITH WF

0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
0.08	0.07	0.06	0.04	0.03	0.02	0.01	-0.01	-0.02	-0.03	-0.04	-0.05	-0.07	-0.08	-0.09	-0.1
0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
-0.33	-0.29	-0.25	-0.22	-0.18	-0.14	-0.1	-0.07	-0.03	0.01	0.05	0.08	0.12	0.16	0.2	0.23
0.26	0.25	0.24	0.23	0.21	0.2	0.19	0.18	0.17	0.16	0.14	0.13	0.12	0.11	0.1	0.09
0.22	0.2	0.18	0.16	0.14	0.12	0.1	0.08	0.06	0.04	0.03	0.01	-0.01	-0.03	-0.05	-0.07
-0.15	-0.15	-0.15	-0.14	-0.14	-0.14	-0.14	-0.14	-0.13	-0.13	-0.13	-0.13	-0.13	-0.12	-0.12	-0.12
-0.26	-0.24	-0.22	-0.2	-0.18	-0.16	-0.14	-0.12	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04

ABS(DELTA)/FEI2 STANDARD DEVIATION

LAB	ENGNO	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
D	11	0.32	0.28	0.24	0.16	0.12	0.08	0.04	0.04	0.08	0.12	0.16	0.20	0.28	0.32	0.36	0.40
C	29	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
G	55	1.32	1.16	1.00	0.88	0.72	0.56	0.40	0.28	0.12	0.04	0.20	0.32	0.48	0.64	0.80	0.92
G	60	1.04	1.00	0.96	0.92	0.84	0.80	0.76	0.72	0.68	0.64	0.56	0.52	0.48	0.44	0.40	0.36
A	103	0.88	0.80	0.72	0.64	0.56	0.48	0.40	0.32	0.24	0.16	0.12	0.04	0.04	0.12	0.20	0.28
B	123	0.60	0.60	0.60	0.56	0.56	0.56	0.56	0.56	0.52	0.52	0.52	0.52	0.52	0.48	0.48	0.48
F	136	1.04	0.96	0.88	0.80	0.72	0.64	0.56	0.48	0.40	0.32	0.24	0.16	0.08	0.00	0.08	0.16

Weight Factor	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
Avg. SD(Delta)	0.85	0.79	0.74	0.67	0.61	0.55	0.50	0.45	0.40	0.37	0.37	0.36	0.38	0.39	0.44	0.48
Range SD(Delta)	0.32-1.32	0.28-1.16	0.24-1	0.16-0.92	0.12-0.84	0.08-0.8	0.04-0.76	0.04-0.76	0.08-0.76	0.04-0.76	0.12-0.76	0.04-0.76	0.04-0.76	0-0.76	0.08-0.8	0.16-0.92

SUMMARY

Limits used in this comparison

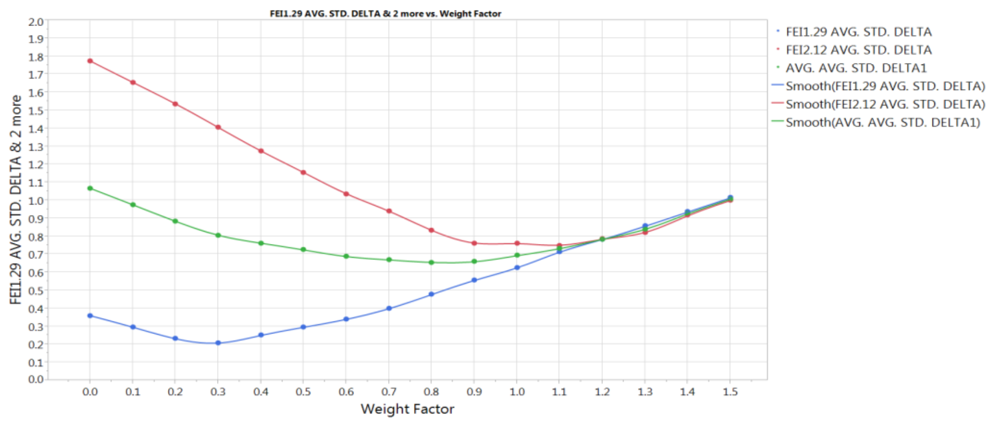
	FEI1	FEI2
R	1.08	0.47
Weight	Varies	Varies
SA Yi Cap	NA	NA
AL1	2.00	2.00
AL2	2.00	2.00
AL3	2.60	2.60

OPTIMAL WF BY ENGINE BASED ON MINIMIZING AVERAGE(FEI1 STD. DELTA, FEI2 STD. DELTA)

		WEIGHT FACTORS															
LAB	ENGNO	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
D	11	0.471	0.430	0.371	0.287	0.228	0.187	0.128	0.128	0.152	0.194	0.218	0.260	0.326	0.368	0.392	0.434
C	29	0.964	0.895	0.843	0.809	0.878	0.947	0.999	1.068	1.136	1.205	1.257	1.326	1.395	1.447	1.516	1.585
G	55	1.478	1.329	1.180	1.072	0.922	0.773	0.641	0.533	0.384	0.318	0.501	0.644	0.828	1.011	1.195	1.338
G	60	1.463	1.369	1.259	1.165	1.030	0.920	0.826	0.767	0.795	0.805	0.773	0.800	0.810	0.820	0.830	0.858
A	103	1.141	0.971	0.819	0.684	0.687	0.690	0.675	0.678	0.681	0.684	0.711	0.714	0.800	0.953	1.122	1.292
B	123	0.728	0.677	0.642	0.618	0.670	0.704	0.756	0.807	0.800	0.852	0.904	0.955	0.990	1.000	1.052	1.086
F	136	1.221	1.155	1.072	1.006	0.922	0.856	0.790	0.707	0.641	0.557	0.491	0.425	0.342	0.276	0.376	0.460

ALL ENGINES

WEIGHT FACTORS	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
FEI1 AVG. STD.(DELTA)	0.360	0.296	0.232	0.207	0.251	0.296	0.340	0.399	0.478	0.557	0.626	0.714	0.783	0.857	0.936	1.015
FEI2 AVG. STD.(DELTA)	1.774	1.655	1.536	1.405	1.274	1.155	1.036	0.940	0.833	0.762	0.762	0.750	0.786	0.821	0.917	1.000
AVG. OF AVG. STD(DELTA)	1.067	0.975	0.884	0.806	0.763	0.725	0.688	0.670	0.656	0.659	0.694	0.732	0.784	0.839	0.926	1.007



FEI1

FEI1 SEVERITY ADJUSTMENTS BY WEIGHT FACTOR & ENGINE

			WEIGHT FACTORS															
LAB	ENGNO	4 TEST FEI1 SA	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
D	11	-0.08	0	0	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05	-0.05	-0.06	-0.06	-0.07	-0.07
C	29	-0.10	0	-0.04	-0.07	-0.11	-0.15	-0.19	-0.22	-0.26	-0.3	-0.34	-0.37	-0.41	-0.45	-0.48	-0.52	-0.56
G	55	-0.06	0	0.01	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15	0.16
G	60	0.22	0	0.03	0.07	0.1	0.13	0.17	0.2	0.23	0.27	0.3	0.33	0.37	0.4	0.43	0.46	0.5
A	103	0.13	0	0.05	0.09	0.14	0.19	0.24	0.28	0.33	0.38	0.43	0.47	0.52	0.57	0.61	0.66	0.71
B	123	-0.06	0	-0.03	-0.05	-0.08	-0.11	-0.13	-0.16	-0.19	-0.21	-0.24	-0.27	-0.3	-0.32	-0.35	-0.38	-0.4
F	136	0.08	0	-0.01	-0.01	-0.02	-0.02	-0.03	-0.04	-0.04	-0.05	-0.05	-0.06	-0.07	-0.07	-0.08	-0.09	-0.09

DELTA OF 4 TEST SA AND 1 TEST SA WITH WF

0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
-0.08	-0.08	-0.07	-0.07	-0.06	-0.06	-0.05	-0.05	-0.04	-0.04	-0.03	-0.03	-0.02	-0.02	-0.01	-0.01
-0.1	-0.06	-0.03	0.01	0.05	0.09	0.12	0.16	0.2	0.24	0.27	0.31	0.35	0.38	0.42	0.46
-0.06	-0.07	-0.08	-0.09	-0.1	-0.11	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.19	-0.2	-0.21	-0.22
0.22	0.19	0.15	0.12	0.09	0.05	0.02	-0.01	-0.05	-0.08	-0.11	-0.15	-0.18	-0.21	-0.24	-0.28
0.13	0.08	0.04	-0.01	-0.06	-0.11	-0.15	-0.2	-0.25	-0.3	-0.34	-0.39	-0.44	-0.48	-0.53	-0.58
-0.06	-0.03	-0.01	0.02	0.05	0.07	0.1	0.13	0.15	0.18	0.21	0.24	0.26	0.29	0.32	0.34
0.08	0.09	0.09	0.1	0.1	0.11	0.12	0.12	0.13	0.13	0.14	0.15	0.15	0.16	0.17	0.17

ABS(DELTA)/FEI1 STANDARD DEVIATION

LAB	ENGNO	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
D	11	0.28	0.28	0.24	0.24	0.21	0.21	0.17	0.17	0.14	0.14	0.10	0.10	0.07	0.07	0.03	0.03
C	29	0.34	0.21	0.10	0.03	0.17	0.31	0.41	0.55	0.69	0.83	0.93	1.07	1.21	1.31	1.45	1.59
G	55	0.21	0.24	0.28	0.31	0.34	0.38	0.45	0.48	0.52	0.55	0.59	0.62	0.66	0.69	0.72	0.76
G	60	0.76	0.66	0.52	0.41	0.31	0.17	0.07	0.03	0.17	0.28	0.38	0.52	0.62	0.72	0.83	0.97
A	103	0.45	0.28	0.14	0.03	0.21	0.38	0.52	0.69	0.86	1.03	1.17	1.34	1.52	1.66	1.83	2.00
B	123	0.21	0.10	0.03	0.07	0.17	0.24	0.34	0.45	0.52	0.62	0.72	0.83	0.90	1.00	1.10	1.17

F	136	0.28	0.31	0.31	0.34	0.34	0.38	0.41	0.41	0.45	0.45	0.48	0.52	0.52	0.55	0.59	0.59

SUMMARY OF STANDARDIZED DELTAS BY WF

Weight Factors	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
Avg. STD.(Delta)	0.36	0.30	0.23	0.21	0.25	0.30	0.34	0.40	0.48	0.56	0.63	0.71	0.78	0.86	0.94	1.01
Range STD.(Delta)	0.21-0.76	0.1-0.66	0.03-0.52	0.03-0.41	0.17-0.34	0.17-0.38	0.07-0.52	0.03-0.69	0.14-0.86	0.14-1.03	0.1-1.17	0.1-1.34	0.07-1.52	0.07-1.66	0.03-1.83	0.03-2

FEI2

FEI2 SEVERITY ADJUSTMENTS BY WEIGHT FACTOR & ENGINE

			WEIGHT FACTORS															
LAB	ENGNO	4 TEST FEI2 SA	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
D	11	0.08	0	0.01	0.02	0.04	0.05	0.06	0.07	0.09	0.1	0.11	0.12	0.13	0.15	0.16	0.17	0.18
C	29	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	55	-0.33	0	-0.04	-0.08	-0.11	-0.15	-0.19	-0.23	-0.26	-0.3	-0.34	-0.38	-0.41	-0.45	-0.49	-0.53	-0.56
G	60	0.26	0	0.01	0.02	0.03	0.05	0.06	0.07	0.08	0.09	0.1	0.12	0.13	0.14	0.15	0.16	0.17
A	103	0.22	0	0.02	0.04	0.06	0.08	0.1	0.12	0.14	0.16	0.18	0.19	0.21	0.23	0.25	0.27	0.29
B	123	-0.15	0	0	0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03
F	136	-0.26	0	-0.02	-0.04	-0.06	-0.08	-0.1	-0.12	-0.14	-0.16	-0.18	-0.2	-0.22	-0.24	-0.26	-0.28	-0.3

DELTA OF 4 TEST SA AND 1 TEST SA WITH WF

0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
0.08	0.07	0.06	0.04	0.03	0.02	0.01	-0.01	-0.02	-0.03	-0.04	-0.05	-0.07	-0.08	-0.09	-0.1
0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
-0.33	-0.29	-0.25	-0.22	-0.18	-0.14	-0.1	-0.07	-0.03	0.01	0.05	0.08	0.12	0.16	0.2	0.23
0.26	0.25	0.24	0.23	0.21	0.2	0.19	0.18	0.17	0.16	0.14	0.13	0.12	0.11	0.1	0.09
0.22	0.2	0.18	0.16	0.14	0.12	0.1	0.08	0.06	0.04	0.03	0.01	-0.01	-0.03	-0.05	-0.07
-0.15	-0.15	-0.15	-0.14	-0.14	-0.14	-0.14	-0.14	-0.13	-0.13	-0.13	-0.13	-0.13	-0.12	-0.12	-0.12
-0.26	-0.24	-0.22	-0.2	-0.18	-0.16	-0.14	-0.12	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04

ABS(DELTA)/FEI2 STANDARD DEVIATION

LAB	ENGNO	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
D	11	0.67	0.58	0.50	0.33	0.25	0.17	0.08	0.08	0.17	0.25	0.33	0.42	0.58	0.67	0.75	0.83
C	29	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
G	55	2.75	2.42	2.08	1.83	1.50	1.17	0.83	0.58	0.25	0.08	0.42	0.67	1.00	1.33	1.67	1.92
G	60	2.17	2.08	2.00	1.92	1.75	1.67	1.58	1.50	1.42	1.33	1.17	1.08	1.00	0.92	0.83	0.75
A	103	1.83	1.67	1.50	1.33	1.17	1.00	0.83	0.67	0.50	0.33	0.25	0.08	0.08	0.25	0.42	0.58
B	123	1.25	1.25	1.25	1.17	1.17	1.17	1.17	1.17	1.08	1.08	1.08	1.08	1.08	1.00	1.00	1.00
F	136	2.17	2.00	1.83	1.67	1.50	1.33	1.17	1.00	0.83	0.67	0.50	0.33	0.17	0.00	0.17	0.33

SUMMARY OF STANDARDIZED DELTAS BY WF

Weight Factors	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
Avg. STD.(Delta)	1.77	1.65	1.54	1.40	1.27	1.15	1.04	0.94	0.83	0.76	0.76	0.75	0.79	0.82	0.92	1.00
Range STD.(Delta)	0.67-2.75	0.58-2.42	0.5-2.08	0.33-1.92	0.25-1.75	0.17-1.67	0.08-1.58	0.08-1.58	0.17-1.58	0.08-1.58	0.25-1.58	0.08-1.58	0.08-1.58	0-1.58	0.17-1.67	0.33-1.92

Limits used in this comparison

	FEI1	FEI2
R	1.08	0.47
Weight	Varies	Varies
SA Yi Cap	NA	NA
AL1	2.00	2.00
AL2	2.00	2.00
AL3	2.60	2.60

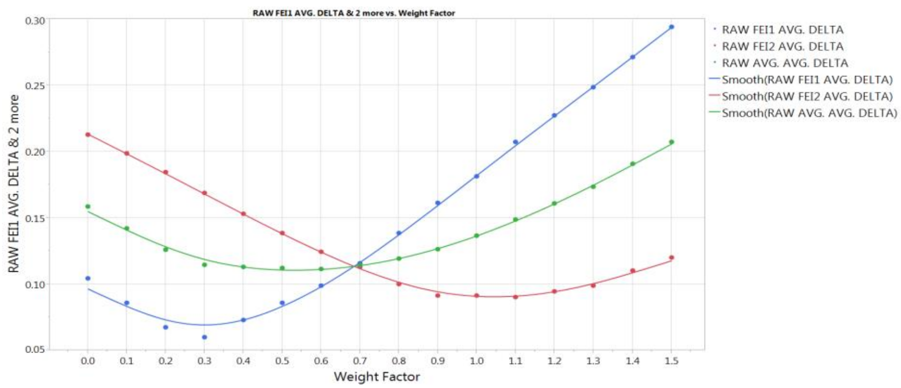
SUMMARY

OPTIMAL WF BY ENGINE BASED ON MINIMIZING AVERAGE(FEI1 DELTA, FEI2 DELTA)

		WEIGHT FACTORS															
LAB	**ENGNO**	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
D	11	0.080	0.075	0.065	0.055	0.045	0.040	0.030	0.030	0.030	0.035	0.035	0.040	0.045	0.050	0.050	0.055
C	29	0.145	0.125	0.110	0.100	0.120	0.140	0.155	0.175	0.195	0.215	0.230	0.250	0.270	0.285	0.305	0.325
G	55	0.195	0.180	0.165	0.155	0.140	0.125	0.115	0.105	0.090	0.085	0.110	0.130	0.155	0.180	0.205	0.225
G	60	0.240	0.220	0.195	0.175	0.150	0.125	0.105	0.095	0.110	0.120	0.125	0.140	0.150	0.160	0.170	0.185
A	103	0.175	0.140	0.110	0.085	0.100	0.115	0.125	0.140	0.155	0.170	0.185	0.200	0.225	0.255	0.290	0.325
B	123	0.105	0.090	0.080	0.080	0.095	0.105	0.120	0.135	0.140	0.155	0.170	0.185	0.195	0.205	0.220	0.230
F	136	0.170	0.165	0.155	0.150	0.140	0.135	0.130	0.120	0.115	0.105	0.100	0.095	0.085	0.080	0.095	0.105

ALL ENGINES

WEIGHT FACTORS	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
FEI1 AVG. (DELTA)	0.104	0.086	0.067	0.060	0.073	0.086	0.099	0.116	0.139	0.161	0.181	0.207	0.227	0.249	0.271	0.294
FEI2 AVG. (DELTA)	0.213	0.199	0.184	0.169	0.153	0.139	0.124	0.113	0.100	0.091	0.091	0.090	0.094	0.099	0.110	0.120
AVG. OF AVG. (DELTA)	0.159	0.142	0.126	0.114	0.113	0.112	0.111	0.114	0.119	0.126	0.136	0.149	0.161	0.174	0.191	0.207



FEI1

FEI1 SEVERITY ADJUSTMENTS BY WEIGHT FACTOR & ENGINE

			WEIGHT FACTORS															
LAB	**ENGNO**	**4 TEST FEI1 SA**	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
D	11	-0.08	0	0	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05	-0.05	-0.06	-0.06	-0.07	-0.07
C	29	-0.10	0	-0.04	-0.07	-0.11	-0.15	-0.19	-0.22	-0.26	-0.3	-0.34	-0.37	-0.41	-0.45	-0.48	-0.52	-0.56
G	55	-0.06	0	0.01	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15	0.16
G	60	0.22	0	0.03	0.07	0.1	0.13	0.17	0.2	0.23	0.27	0.3	0.33	0.37	0.4	0.43	0.46	0.5
A	103	0.13	0	0.05	0.09	0.14	0.19	0.24	0.28	0.33	0.38	0.43	0.47	0.52	0.57	0.61	0.66	0.71
B	123	-0.06	0	-0.03	-0.05	-0.08	-0.11	-0.13	-0.16	-0.19	-0.21	-0.24	-0.27	-0.3	-0.32	-0.35	-0.38	-0.4
F	136	0.08	0	-0.01	-0.01	-0.02	-0.02	-0.03	-0.04	-0.04	-0.05	-0.05	-0.06	-0.07	-0.07	-0.08	-0.09	-0.09

DELTA OF 4 TEST SA AND 1 TEST SA WITH WF

LAB	**ENGNO**	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
D	11	-0.08	-0.08	-0.07	-0.07	-0.06	-0.06	-0.05	-0.05	-0.04	-0.04	-0.03	-0.03	-0.02	-0.02	-0.01	-0.01
C	29	-0.1	-0.06	-0.03	0.01	0.05	0.09	0.12	0.16	0.2	0.24	0.27	0.31	0.35	0.38	0.42	0.46
G	55	-0.06	-0.07	-0.08	-0.09	-0.1	-0.11	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.19	-0.2	-0.21	-0.22
G	60	0.22	0.19	0.15	0.12	0.09	0.05	0.02	-0.01	-0.05	-0.08	-0.11	-0.15	-0.18	-0.21	-0.24	-0.28
A	103	0.13	0.08	0.04	-0.01	-0.06	-0.11	-0.15	-0.2	-0.25	-0.3	-0.34	-0.39	-0.44	-0.48	-0.53	-0.58
B	123	-0.06	-0.03	-0.01	0.02	0.05	0.07	0.1	0.13	0.15	0.18	0.21	0.24	0.26	0.29	0.32	0.34
F	136	0.08	0.09	0.09	0.10	0.10	0.11	0.12	0.12	0.13	0.13	0.14	0.15	0.15	0.16	0.17	0.17

WEIGHT FACTOR	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
AVERAGE DELTA	0.10	0.09	0.07	0.06	0.07	0.09	0.10	0.12	0.14	0.16	0.18	0.21	0.23	0.25	0.27	0.29
RANGE	0.06-0.22	0.03-0.19	0.01-0.15	0.01-0.12	0.05-0.1	0.05-0.11	0.02-0.15	0.01-0.2	0.04-0.25	0.04-0.3	0.03-0.34	0.03-0.39	0.02-0.44	0.02-0.48	0.01-0.53	0.01-0.58

FEI2

FEI2 SEVERITY ADJUSTMENTS BY WEIGHT FACTOR & ENGINE

			WEIGHT FACTORS															
LAB	ENGNO	4 TEST FEI2 SA	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
D	11	0.08	0	0.01	0.02	0.04	0.05	0.06	0.07	0.09	0.1	0.11	0.12	0.13	0.15	0.16	0.17	0.18
C	29	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	55	-0.33	0	-0.04	-0.08	-0.11	-0.15	-0.19	-0.23	-0.26	-0.3	-0.34	-0.38	-0.41	-0.45	-0.49	-0.53	-0.56
G	60	0.26	0	0.01	0.02	0.03	0.05	0.06	0.07	0.08	0.09	0.1	0.12	0.13	0.14	0.15	0.16	0.17
A	103	0.22	0	0.02	0.04	0.06	0.08	0.1	0.12	0.14	0.16	0.18	0.19	0.21	0.23	0.25	0.27	0.29
B	123	-0.15	0	0	0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03
F	136	-0.26	0	-0.02	-0.04	-0.06	-0.08	-0.1	-0.12	-0.14	-0.16	-0.18	-0.2	-0.22	-0.24	-0.26	-0.28	-0.3

DELTA OF 4 TEST SA AND 1 TEST SA WITH WF

LAB	ENGNO	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
D	11	0.08	0.07	0.06	0.04	0.03	0.02	0.01	-0.01	-0.02	-0.03	-0.04	-0.05	-0.07	-0.08	-0.09	-0.1
C	29	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G	55	-0.33	-0.29	-0.25	-0.22	-0.18	-0.14	-0.1	-0.07	-0.03	0.01	0.05	0.08	0.12	0.16	0.2	0.23
G	60	0.26	0.25	0.24	0.23	0.21	0.2	0.19	0.18	0.17	0.16	0.14	0.13	0.12	0.11	0.1	0.09
A	103	0.22	0.2	0.18	0.16	0.14	0.12	0.1	0.08	0.06	0.04	0.03	0.01	-0.01	-0.03	-0.05	-0.07
B	123	-0.15	-0.15	-0.15	-0.14	-0.14	-0.14	-0.14	-0.14	-0.13	-0.13	-0.13	-0.13	-0.13	-0.12	-0.12	-0.12
F	136	-0.26	-0.24	-0.22	-0.2	-0.18	-0.16	-0.14	-0.12	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04

WEIGHT FACTOR	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
AVERAGE DELTA	0.21	0.20	0.18	0.17	0.15	0.14	0.12	0.11	0.10	0.09	0.09	0.09	0.09	0.10	0.11	0.12
RANGE	0.08-0.33	0.07-0.29	0.06-0.25	0.04-0.23	0.03-0.21	0.02-0.2	0.01-0.19	0.01-0.19	0.02-0.19	0.01-0.19	0.03-0.19	0.01-0.19	0.01-0.19	0-0.19	0.02-0.2	0.04-0.23

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY
2565 PLYMOUTH ROAD
ANN ARBOR, MICHIGAN 48105-2498

OFFICE OF
AIR AND RADIATION

September 18, 2008

CISD-08-11 (LDV/LDT/MDPV/HDV)

Dear Manufacturer:

Subject: Use of 0W Multi-grade Engine Oils in Gasoline Fueled EPA Test Vehicles

This letter provides guidance on the use of 0W multi-grade oils in 2009 and later model year gasoline fueled EPA certification and fuel economy test vehicles.

Background

On March 2, 2004 EPA issued guidance letter CCD-04-7 with the subject title: Use of GF-4 Engine Oil in EPA Test Vehicles. That guidance letter approved the use of GF-4 5W-20, 5W-30, and 10W-30 oils in the certification process for 2005 and later model year gasoline fueled vehicles contingent upon satisfying the set of criteria attached to the guidance letter.

More recently, CCD has received inquiries from several vehicle manufacturers who desire to use 0W multi-grade oils in the certification process, and/or use 0W multi-grade oils as the factory fill oil and also recommend the same oil to the vehicle owner.

This letter addresses the issue of using 0W multi-grade oils in the certification process, should a manufacturer desire to use them. The basic guidance in the March 2, 2004 guidance letter applies to 0W multi-grade oils, and may be summarized as follows:

> EPA does not specify which oils vehicle manufactures use as factory fill oils nor what oils are recommend to the vehicle owner. EPA's only role is in determining that appropriate oils are used in the certification process.
>
> It is EPA's responsibility to ensure that the oil used in certification test vehicles is no more fuel efficient than the oil that is used as the factory fill, or the oil recommended to the vehicle owner.
>
> The oil used in the certification process must be widely available throughout the oil distribution network, including dealerships, independent service providers, quick oil change facilities, and the do-it-yourself retail market.

Determination

EPA will allow use of 0W multi-grade oil in certification and fuel economy test vehicles providing the criteria in the attachment to this letter are satisfied. A decision to allow use of 0W oils in the certification process will be made by EPA on a case by case basis prior to the start of official certification testing. EPA may rescind approval to use 0W oils in the certification process if the criteria in the attachment are not satisfied.

If you have questions concerning this guidance letter, please contact Martin Reineman at (734) 214-4430.

Sincerely,

Karl Simon, Director
Compliance and Innovative Strategies Division
Office of Transportation and Air Quality

Enclosure

Enclosure to CISD-08-11
Approval Criteria for Use of 0W-Multi-grade Oils

1. Use of Least Fuel Efficient Oil   If a manufacturer recommends a 0W multi-grade oil and a non-zero multi-grade oil to dealers and vehicle owners, the manufacturer is expected to use the higher viscosity oil in certification and fuel economy test vehicles.

2. Owner's Manual Language   The manufacturer shall provide recommendations in the owner's manual that clearly and unambiguously identifies the 0W multi-grade oil (identified by the presence of the American Petroleum Institute (API) "Starburst" logo if the oil meets the International Lubricant Standardization and Approval Committee (ILSAC) GF-4 Standard for Passenger Car Engine Oils, and is licensed by API) to be used in the vehicle's engine under normal ambient temperature and driving conditions. If the API starburst logo is used in the owner's manual in lieu of reference to GF-4, the manufacturer should include a brief explanation of the importance of its meaning. If a manufacturer recommends a 0W multi-grade oil or a 5W multi-grade oil for normal temperature and driving conditions, this must be clearly stated in the owner's manual. Inclusion of any qualifier word, "preferred" for example, associated with the oil viscosity is considered to introduce ambiguity into the instruction, and is not permitted. The recommended oil(s) for a particular vehicle must be clearly communicated to all principal oil service providers.

Similar guidance applies to manufacturers which use 0W multi-grade oils that adopt other performance standards than those approved by ILSAC, for example specifications developed by ACEA.

If a vehicle owner wishes to use a synthetic, or partial synthetic oil, EPA does not expect a vehicle manufacturer to preclude use of such oil if it meets all vehicle manufacturer requirements.

3. Labeling the Oil Filler Cap   The manufacturer clearly indicates on the engine oil filler cap, by label or other permanently attached means, that oil of a specific viscosity grade (e.g. 0W-20) is to be used in the engine. Alternatively, affixing a permanent easily visible label under hood is also acceptable.

4. Limits on the Sum of 16-hour plus 96-hour Fuel Economy Improvement Factors   The engine oil to be used in emissions and fuel economy test vehicles must have a combined fuel economy improvement factor using the ASTM Sequence VI-B (or its replacement procedure), which does not exceed the following limits.

GF-4 0W-20	4.8 %
GF-4 0W-30	3.8 %

These limits are the sum of the 16-hour and 96-hour limits plus 0.5 percent. The 0.5 percent value represents about two standard deviations of the distribution of fuel economy improvement rates measured by the ASTM procedures. EPA is setting this limit because it is inappropriate for a manufacturer to select significantly better oil for fuel economy testing than the typical customer will be using in their vehicle in the field.

5. Factory Fill Oil Requirements   The manufacturer uses 0W multi-grade oil of the same viscosity rating for the factory fill that it recommends in its production vehicles. Furthermore, the fuel economy performance of the factory fill oil must be equivalent or superior to the oils used in EPA emissions and fuel economy test vehicles.

6. Oils Available at Dealerships   Manufacturers must unequivocally recommend to their affiliated dealerships that the fuel economy performance of the oils used by its dealers must be equivalent or superior to the oils used in emissions and fuel economy test vehicles.

7. Commitments from Oil Manufacturers to Market 0W Multi-grade Oils
Prior to the start of 2009 MY production, commitments from major and independent marketers of the passenger car motor oils that they will manufacture 0W multi-grade engine oil in sufficient quantity to meet demand in all segments of the oil service/supply network. Vehicle manufacturers may obtain this information jointly through their trade associations or forward this information directly to EPA. If a trade association collects this information it should be retained for three years and copies provided to EPA upon request. EPA needs assurance of the availability of 0W multi-grade oils only once, at the time the first manufacturer wishes to use it in EPA certification vehicles.

8. Plan for Effective Rollout of 0W Multi-grade Oils in the Distribution Service/Supply Network   The manufacturer commits to providing EPA an effective rollout plan for the introduction of 0W multi-grade oils prior to the production of 2009 MY vehicles. EPA's expectation is that this rollout plan will consult with all principal oil service providers from dealers to quick oil change facilities to service providers to the major retailers servicing the do-it-your-self market segment. This rollout plan may be coordinated through manufacturers' trade associations.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY
2565 PLYMOUTH ROAD
ANN ARBOR, MICHIGAN 48105-2498

OFFICE OF
AIR AND RADIATION

May 2, 2016

CD-16-06 (HDE/HDV)

SUBJECT: Use of FA-4 Engine Oil for Testing of Heavy-Duty Highway Engines

Dear Manufacturer:

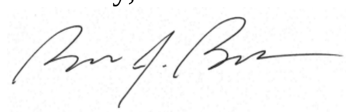
The purpose of this letter is to provide guidance regarding the use of FA-4 engine oil for certification testing of 2017 and later model year heavy-duty highway engines. EPA has promulgated regulations for the control of GHG emissions from heavy-duty highway engines that include a more stringent emissions standard beginning with the 2017 model year. API Service Category FA-4 oil, which has been developed as a lower GHG emissions oil for use in heavy-duty diesel engines, is scheduled to be available in the marketplace no later than December 1, 2016. Engine manufacturers seeking to certify their engines to the more stringent GHG emissions standards effective with the 2017 model year have requested guidance from EPA about utilizing FA-4 oils in engines used to demonstrate compliance with those standards.

40 CFR Part 1065 specifies procedures that apply generally to testing of various categories of engines, including testing of heavy-duty highway engines for the purpose of obtaining a certificate of conformity. As per 40 CFR Part 1065.10(c)(1), the objective of these procedures is to produce emission measurements equivalent to those that would result from measuring emissions during in-use operation using the same engine configuration as installed in a vehicle. 40 CFR § 1065.740 outlines the requirements for lubricants to be used during testing and reads as follows: "Use commercially available lubricating oil that represents the oil that will be used in your engine in use." Given that FA-4 oil will be readily available in the marketplace (to both manufacturers and consumers) no later than December 1, 2016, EPA would consider this oil to be acceptable for use in certification testing of 2017 model year and newer heavy-duty highway engines, contingent upon manufacturers taking measures to ensure the oil is used in production and in-use engines.

EPA has previously issued guidance letters CCD-04-07 and CISD-10-11 that addressed the use of particular oils in the certification process for light-duty test vehicles to ensure that the oil used during certification testing remains representative of oil used in production vehicles. Similar to those letters, we're providing in the enclosure to this letter a set of steps we think are the best way heavy-duty highway engine manufacturers can ensure that FA-4 oil used in engines for certification testing is representative of the oil that will be used in your engines in use.

If you have questions concerning this matter, please contact Justin Greuel at greuel.justin@epa.gov or (734) 214-4210.

Sincerely,



Byron J. Bunker, Director
Compliance Division
Office of Transportation and Air Quality

Enclosure

Appendix to CD-16-06
Use of FA-4 Engine Oil for Testing of Heavy-Duty Highway Engines

1. Oil Viscosity: If a manufacturer recommends multiple viscosities of FA-4 oils, then the manufacturer should use the viscosity it recommends for normal ambient temperature and driving conditions in certification test engines. Given that the same viscosity grade of heavy-duty engine oil may exist in the marketplace with different API service categories, manufacturer recommendations should clearly specify the use of FA-4 oil and include a brief explanation of the reasons for using FA-4 oil as well as specifying viscosity grade recommendations.

2. Owner's Manual Language: The manufacturer should specify the use of FA-4 oil in the owner's manual and include a brief explanation of the importance of the FA-4 oil. Manufacturer recommendations for oil viscosity grade should also be clearly stated in the owner's manual. It continues to be appropriate for a manufacturer to specify the use of a lower viscosity grade in extremely low temperatures at which the normally specified oil may not flow adequately. Inclusion of any qualifier word, "preferred" for example, associated with the oil viscosity grade is considered to introduce ambiguity into the instruction, and is not appropriate.[1]

3. Factory Fill Oil Requirements: The manufacturer should use FA-4 oil of the same viscosity grade for the factory fill that it specifies in its production engines/vehicles. Furthermore, the GHG emission performance of the factory fill oil should be equivalent or superior to that of the oils used in EPA emissions test engines/vehicles.

4. Labeling the Oil Filler Cap: The manufacturer should clearly indicate on the engine oil filler cap, by label or other permanently attached means, that API service category FA-4 oil is to be used in the engine. Alternatively, affixing a permanent and easily visible label under hood is also acceptable.

5. Oils Available at Dealerships: The manufacturer should inform their affiliated dealerships of the timing of the introduction of FA-4 oil and the need to use it as recommended in order to avoid the possibility of GHG emission increases.

6. Oils in other Segments of the Supply Network: The lubricant manufacturer or its trade association should consult with quick oil change facilities and suppliers to the major retailers servicing the do-it-your-self market segment to inform these organizations of the purpose of the new FA-4 oil and its market entry timing. In addition, the lubricant manufacturer or its trade association should provide educational materials regarding the differentiation between FA-4 oil and other API heavy-duty engine oil service categories that have the same viscosity grade in the marketplace.

---

[1] If a vehicle owner wishes to use a synthetic, or partial synthetic oil, EPA does not expect an engine/vehicle manufacturer to preclude use of such oil if it meets all engine/vehicle manufacturer requirements.

VIE Operational Data Analysis

Statistics Group

July 25, 2016

Statistics Group

- Arthur Andrews, ExxonMobil
- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Kevin O'Malley, Lubrizol
- Martin Chadwick, Intertek
- Richard Grundza, TMC
- Lisa Dingwell, Afton
- Todd Dvorak, Afton
- Travis Kostan, SwRI

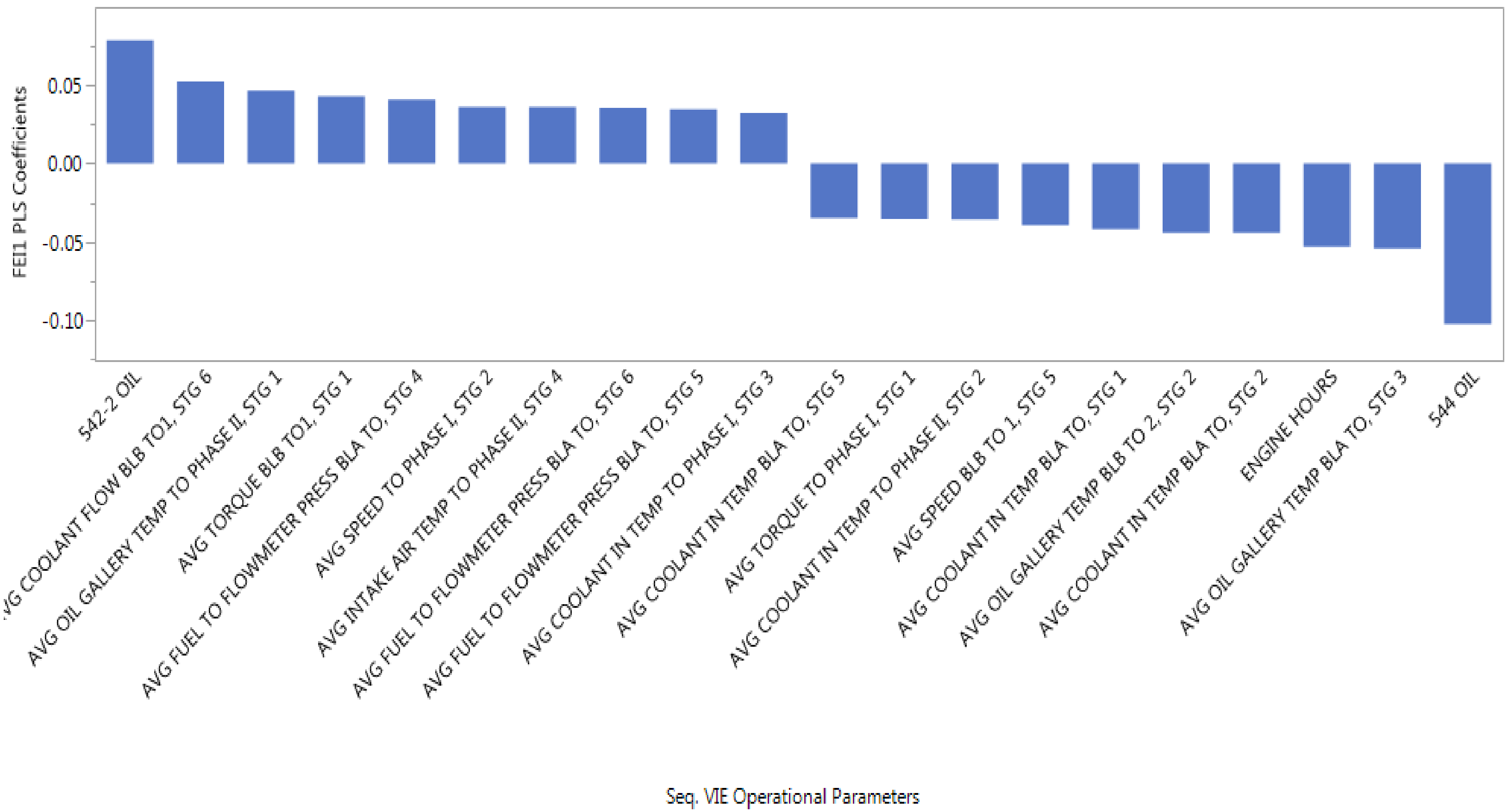
Executive Summary

- Precision Matrix (PM) Analysis Highlights:
  - This analysis includes the results of 29 valid precision matrix tests which reflects surveillance panel decision to limit engine life and remove engine 128 results
    - Within the shortened engine hours, data supports the use of no transformation
  - This PLS analysis includes 1039 operational parameters in the initial model fit, which is reduced to 491 variables in the final model
    - Conclusions may not be significant due to large number of operational parameters compared to size of data set
  - A similar analysis was completed for Sequence VIF data; however, a useable model could not be fit to the data
    - This analysis includes the results of 14 valid precision matrix tests which reflects surveillance panel decision to limit engine life
    - Possibly due to the large number of operational parameters ($k = 1196$) and small data set ($n = 14$)
  - An analysis was also completed for Baseline Oil Pressure to determine if there were any relationships between oil pressure and FEI

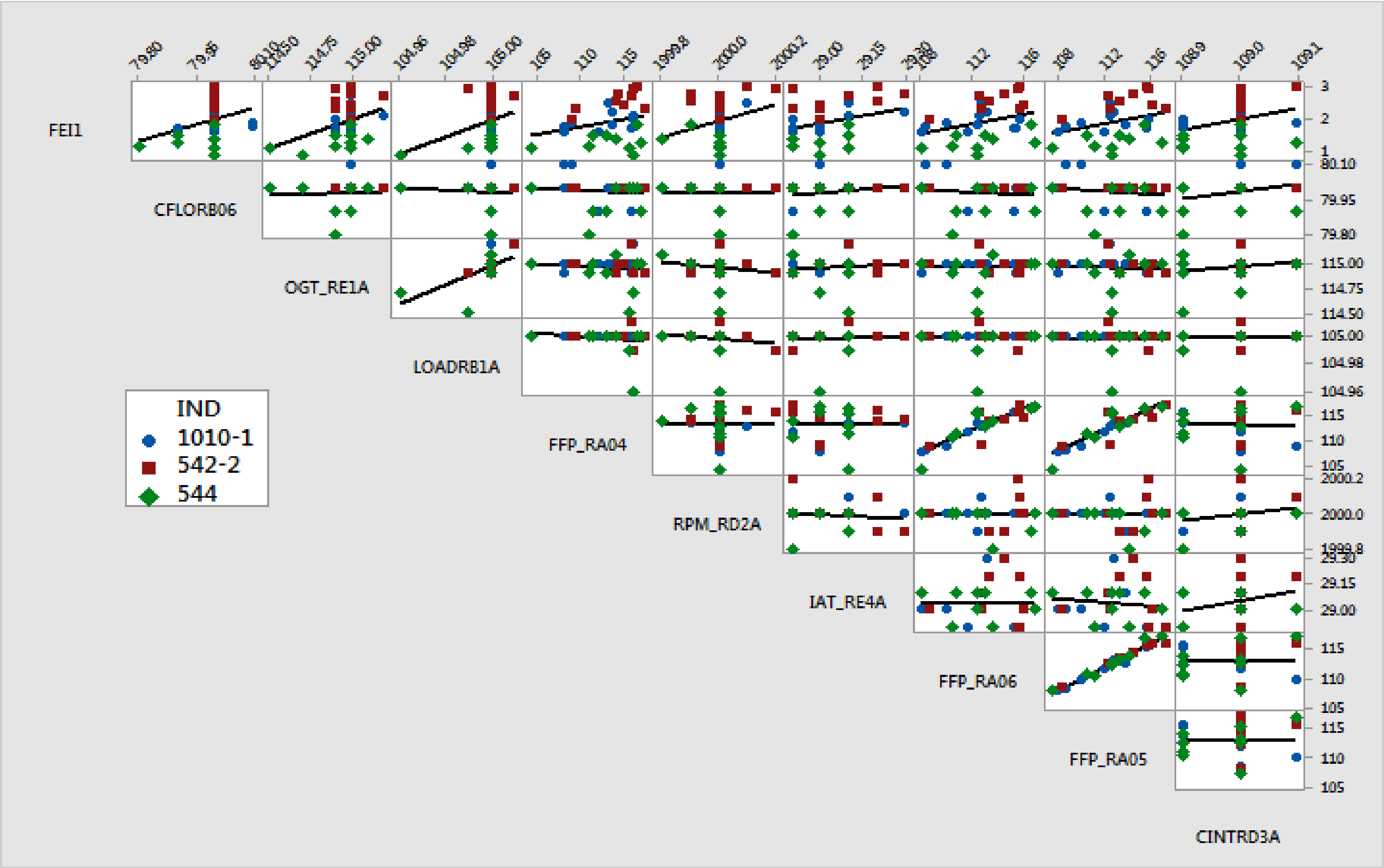
Agenda

- Review Analysis of PM Data
  - FEI1 Model Coefficients
  - FEI2 Model Coefficients
  - Oil Pressure Data Analysis Results

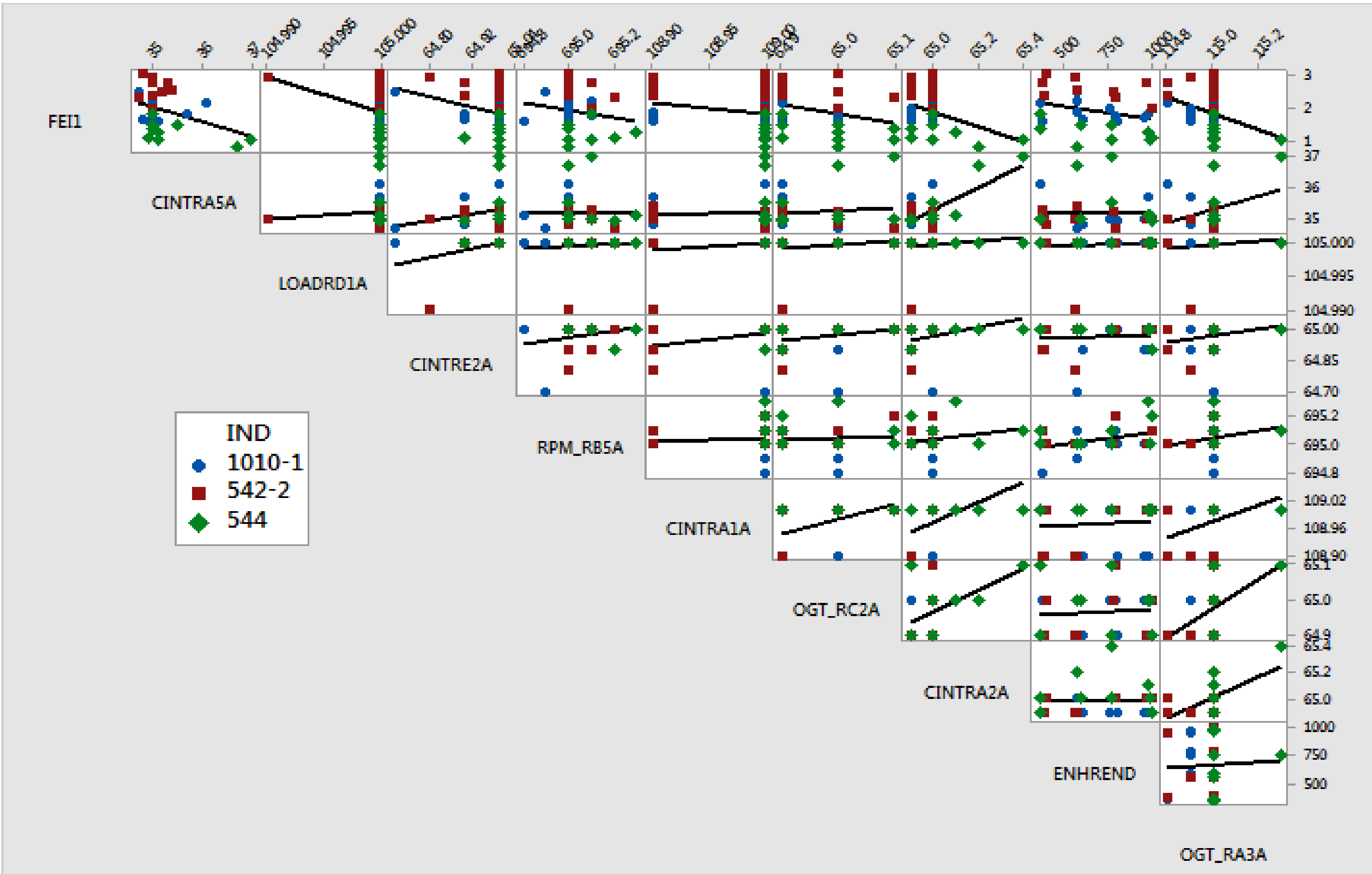
FEI1 Model Coefficients for Influential Operational Parameters



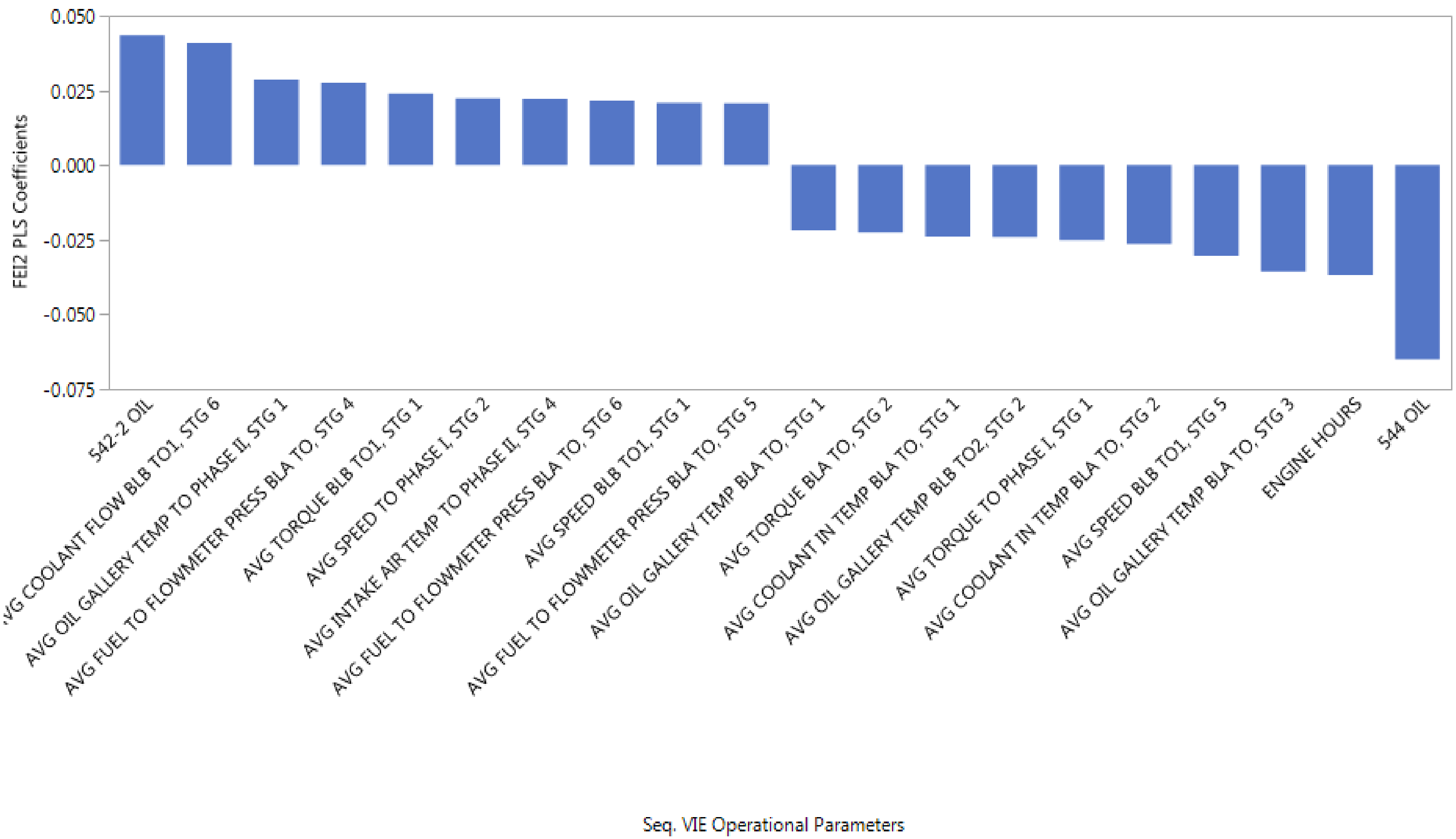
FEI1 – Positive Model Coefficients



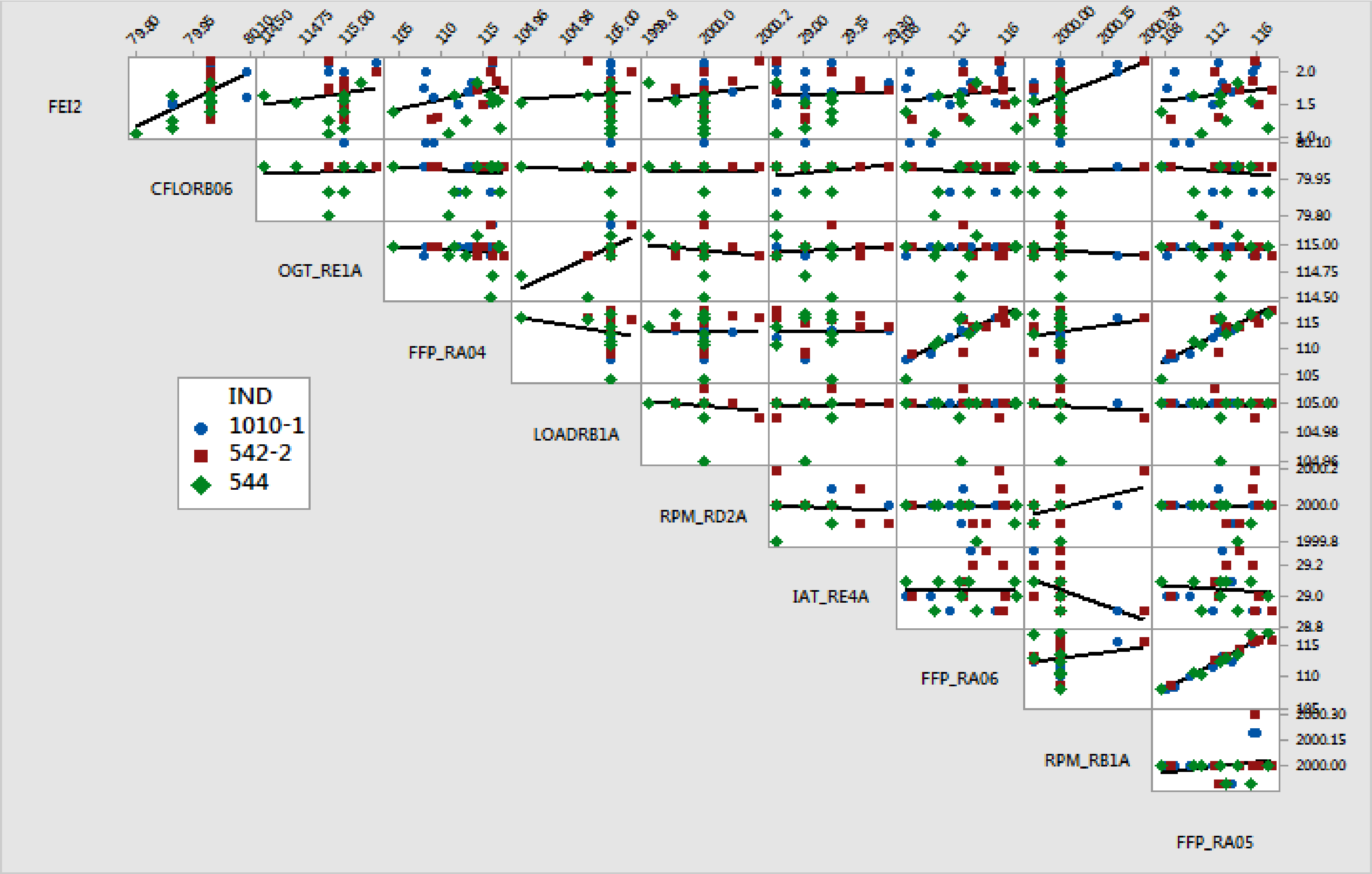
FEI1 – Negative Model Coefficients



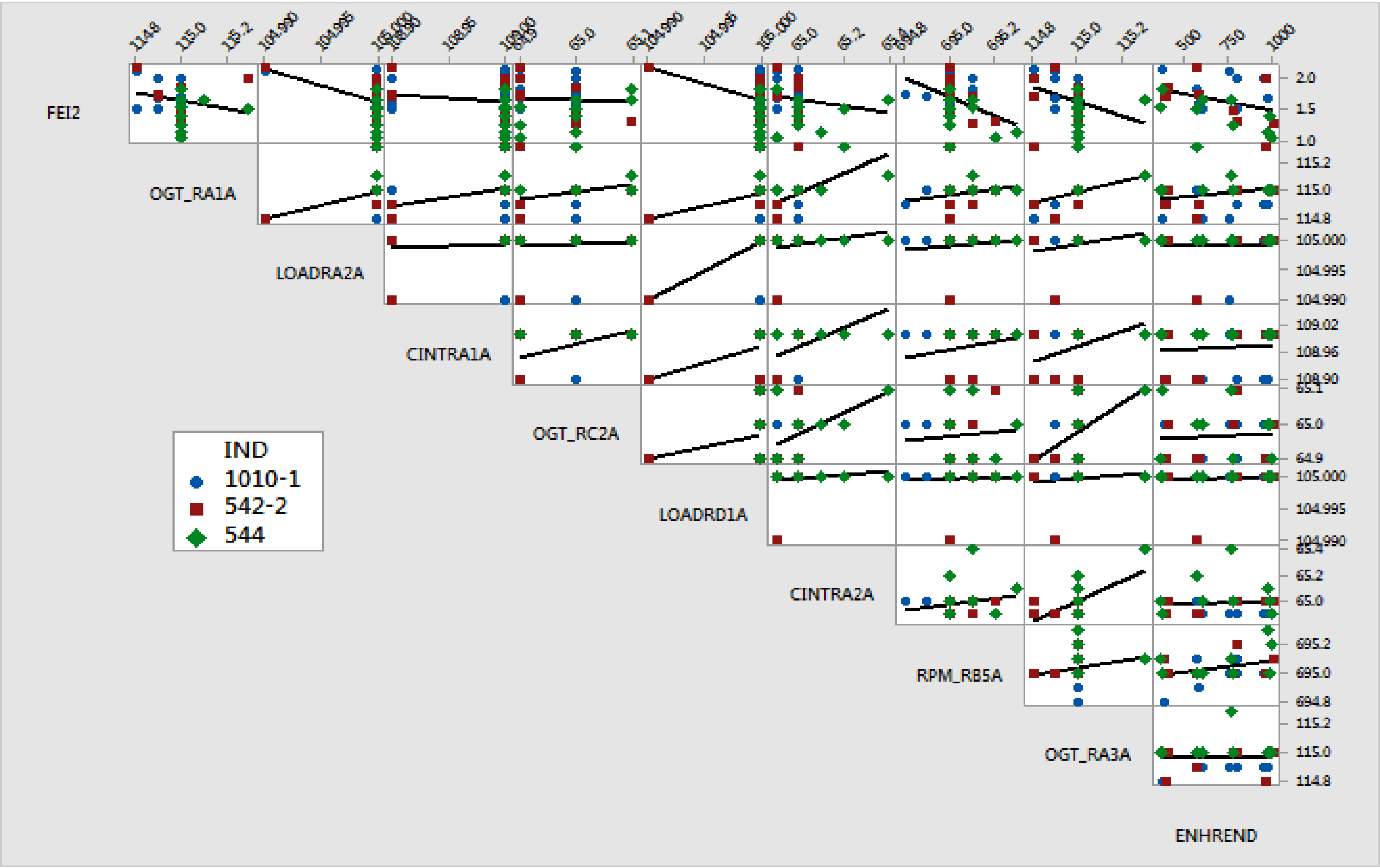
FEI2 Model Coefficients for Influential Operational Parameters



FEI2 – Positive Model Coefficients



FEI2 – Negative Model Coefficients



Baseline Oil Pressure – FEI2

The SAS System

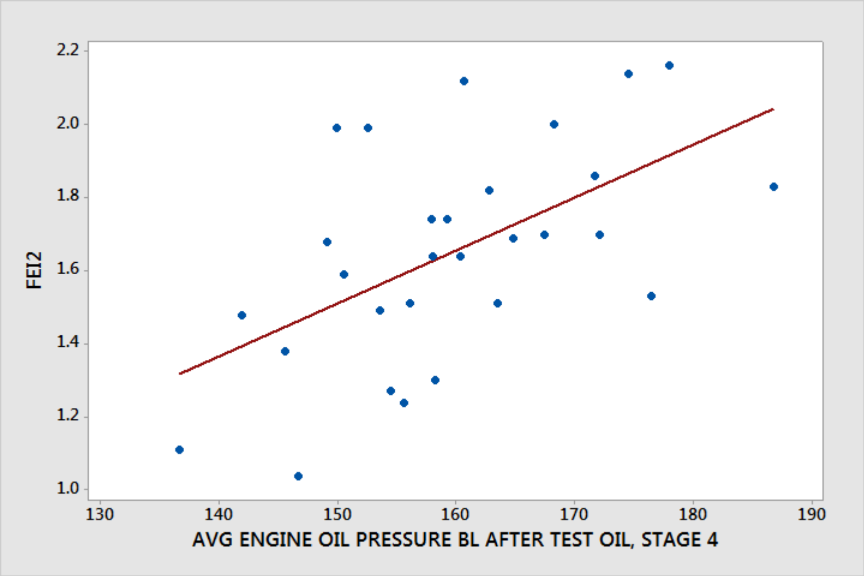
The REG Procedure
Model: MODEL1
Dependent Variable: FEI2 FEI2

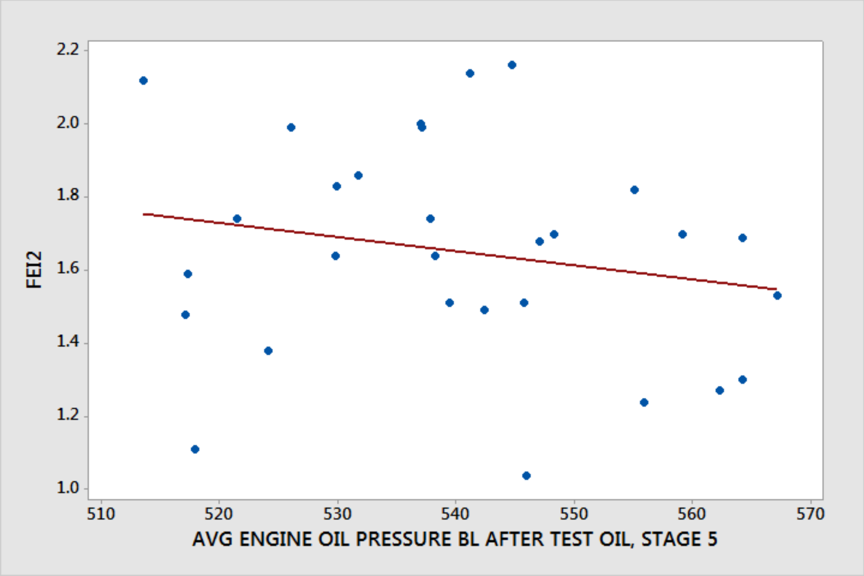
Number of Observations Read	29
Number of Observations Used	29

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1.24086	0.41362	8.30	0.0005
Error	25	1.24649	0.04986		
Corrected Total	28	2.48734			

Root MSE	0.22329	R-Square	0.4989
Dependent Mean	1.65138	Adj R-Sq	0.4387
Coeff Var	13.52158		

Parameter Estimates							
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	Intercept	1	2.83234	1.56762	1.81	0.0828	0
ENHREND	ENHREND	1	0.00022623	0.00027904	0.81	0.4252	2.27199
EOP_RA04	EOP_RA04	1	0.02181	0.00582	3.75	0.0009	2.52621
EOP_RA05	EOP_RA05	1	-0.00892	0.00294	-3.03	0.0056	1.17765





Approaches to Estimating VID and VIE Equivalency

Statistics Group

07-22-2016

Statistics Group

- Art Andrews, Exxon Mobil
- Martin Chadwick, Intertek
- Jo Martinez, Chevron Oronite
- Richard Grundza, TMC
- Travis Kostan, SwRI
- Lisa Dingwell, Afton Chemical
- Todd Dvorak, Afton Chemical
- Doyle Boese, Infineum
- Kevin O'Malley, Lubrizol

Conclusion

- Several methods were used to estimate VID and VIE equivalency using reference oil data. Each method used different combinations of these data. Note that not all reference oils are GF-5 capable oils.

- Note that these methods did not consider the reversal in performance between reference oils in the two tests.
  - FEISUM reversal between 542 and 1010
  - Reversal between xW-30 and 10W-30/Other groupings

- **More meaningful equivalency estimation will be obtained with paired sets of GF-5 capable candidate data.**

Summary of Estimates

SN+RC Limits		xW-20		xW-30		10W-30 & all others	
		FEI2	FEISUM	FEI2	FEISUM	FEI2	FEISUM
		1.2	2.6	0.9	1.9	0.6	1.5
Approaches		**Equivalent Limits in VIE**					
1	Severity Approach	2.0	4.2	1.5	3.1	1.0	2.4
2	Means Approach (542-2,1010-1)	1.8	4.0	1.5	3.3	1.2	2.9
3	Probability of Pass Approach	2.1	4.5	1.5	2.8	1.6	3.3
4	Mean Difference Approach	2.0	4.2	1.6	2.8	1.6	3.3
5	Proportional Change Approach	2.3	4.4	1.8	2.9	1.5	3.2
	Range	1.8-2.3	4.0-4.5	1.5-1.8	2.8-3.3	1.0-1.6	2.4-3.3
	Average	2.0	4.3	1.6	3.0	1.4	3.0

Due to reversals of oil performance in the two tests, the Statistics Group needs technical guidance in how to best approach the equivalency estimation.

Understanding the Data

VID vs VIE

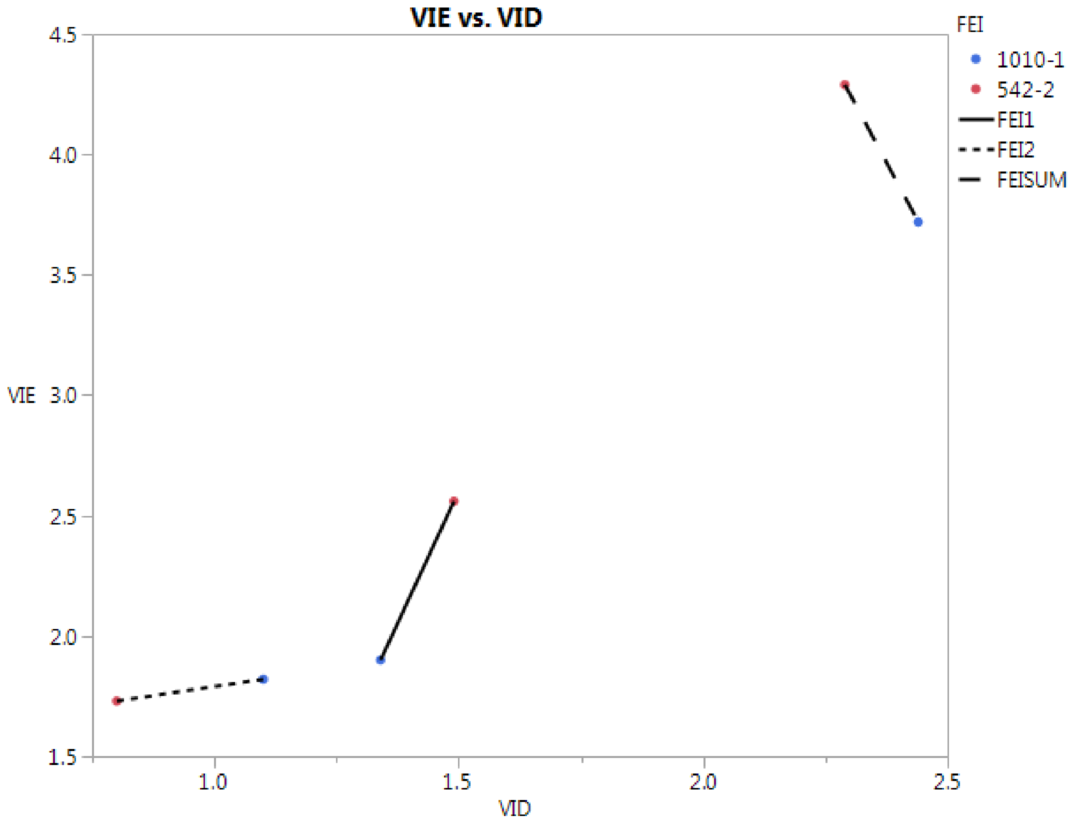
FEISUM Rankings Reversed for 542 and 1010

Test	Oil	FEI1	FEI2	FEISUM
VID	542	1.49	0.80	2.29
	1010	1.34	1.10	2.44
	542 - 1010	0.15	-0.30	-0.15
VIE	542-2	2.56	1.73	4.29
	1010-1	1.90	1.82	3.72
	542 - 1010	0.66	-0.09	0.57

Oil	FEI1	FEI2	FEISUM
542	1.51	0.81	2.32
542-2	1.48	0.72	2.21
1010	1.34	1.04	2.38
1010-1	1.36	0.98	2.34

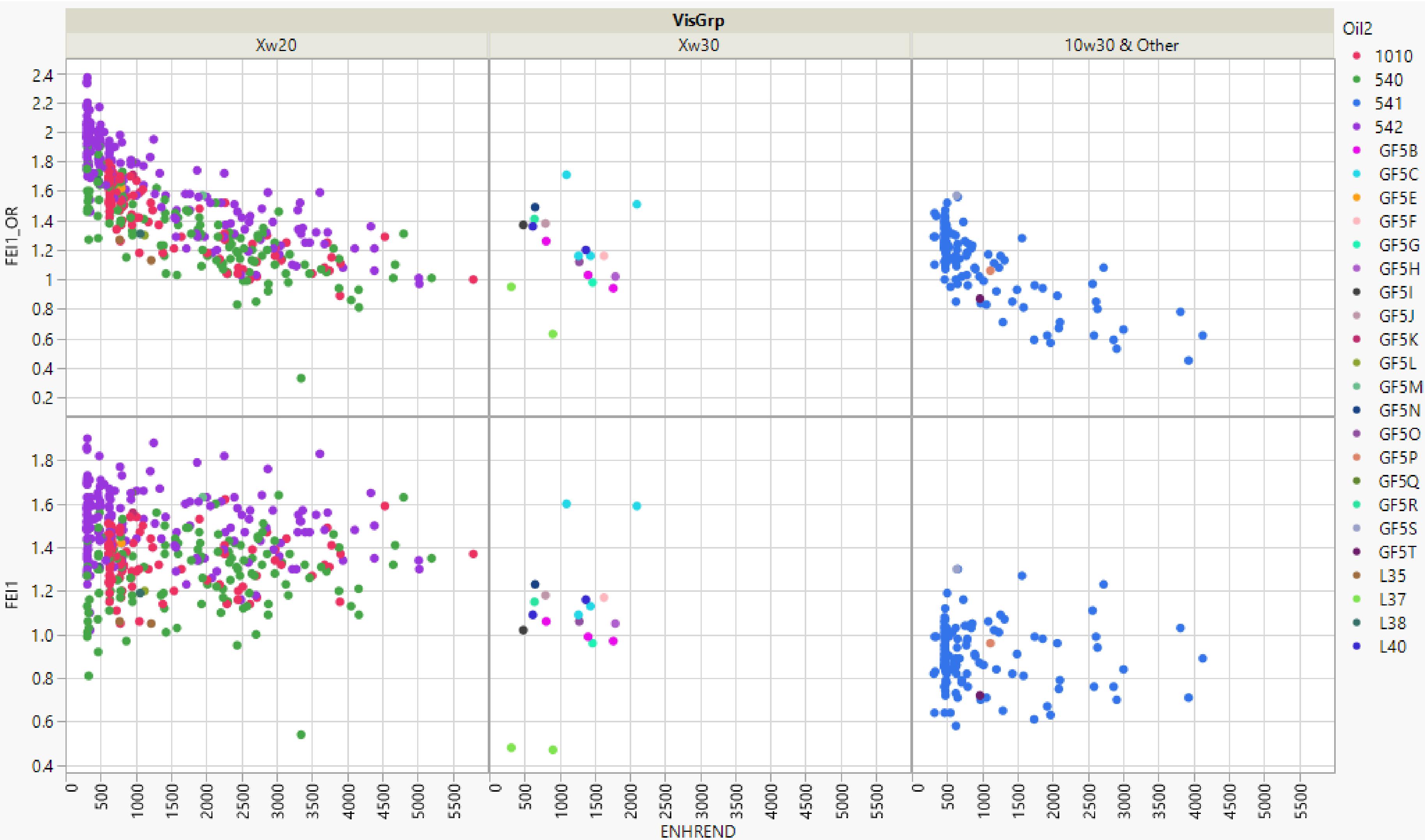
- Tabulated to the left are the LS Means for VIE are the targets (LS Means) for the two common oils.
- Note that the targets for the VID specify the original blends while reblends of each are run in the VIE. Those reblends were also run in the VID though the targets were not updated for those specific reblends.
- Oil comparison:
  - FEI1 – For both the VID and VIE, 542 exceeds 1010.
  - FEI2 – For both the VID and VIE, 1010 exceeds 542.
  - FEISUM – In the VIE, 542 outperforms 1010 by nearly 0.6% whereas in the VID, 1010 has the higher FEI.
- Is the reversal in FEISUM due to oil blends?
  - Regressed VID results from 2014 to current on Oil Blend and Year.
  - LS Means for 542-2 FEISUM may be slightly severe relative to 542
  - LS Means for 1010 blends are practically identical.
  - FEISUM reversal does not appear to be due to re-blend differences.

VID to VIE Mapping



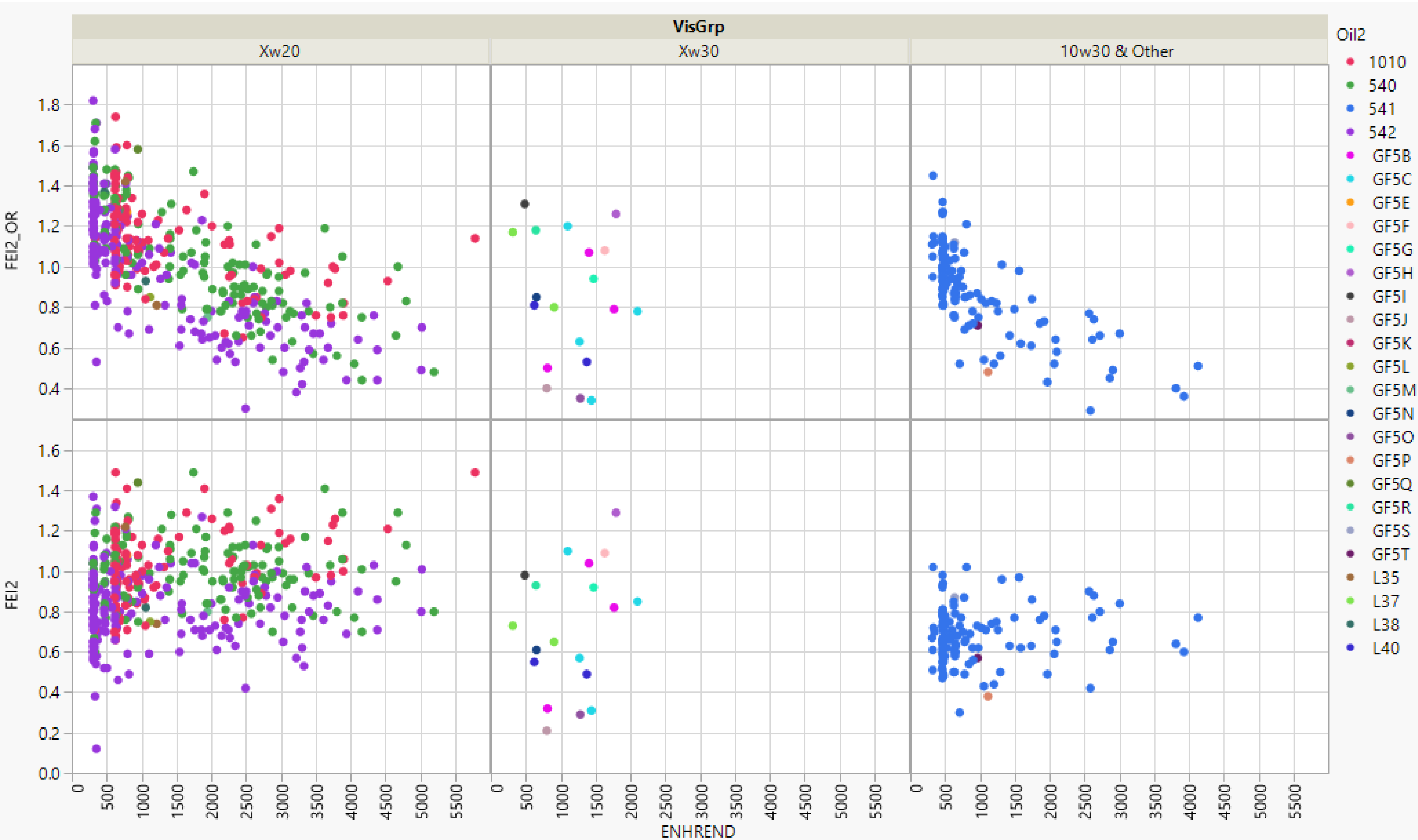
- The plot provides potential mappings from VID to VIE based on 542 and 1010 targets.
- Mappings should have positive slope, i.e., an increase in VID should map to an increase in the VIE.
  - Consistent with the noted reversal in rankings FEISUM has a negative slope (non-sensical).

VID FEI1



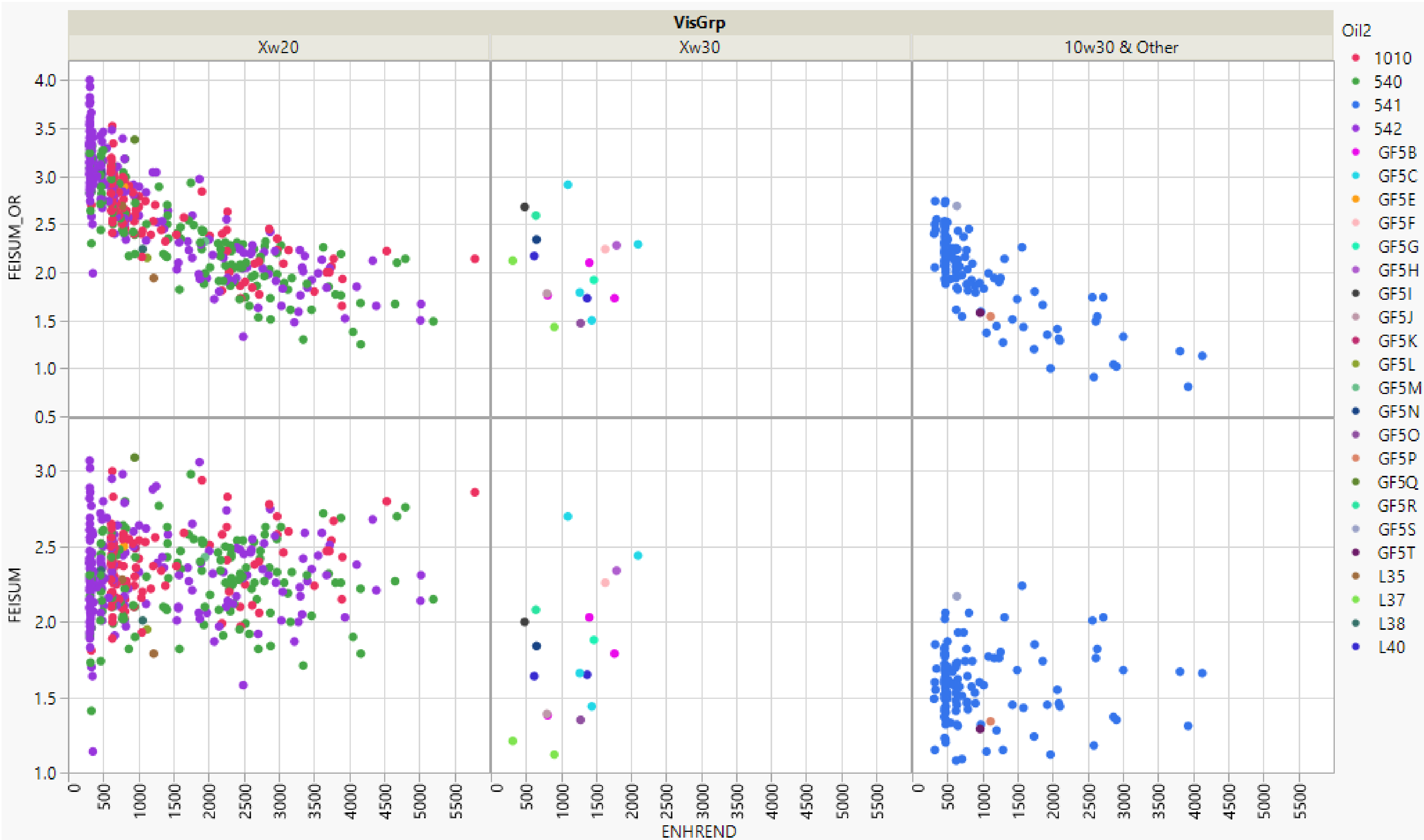
Oil Ranking highest to lowest: Xw20, Xw30, 10w30&Other

VID FEI2



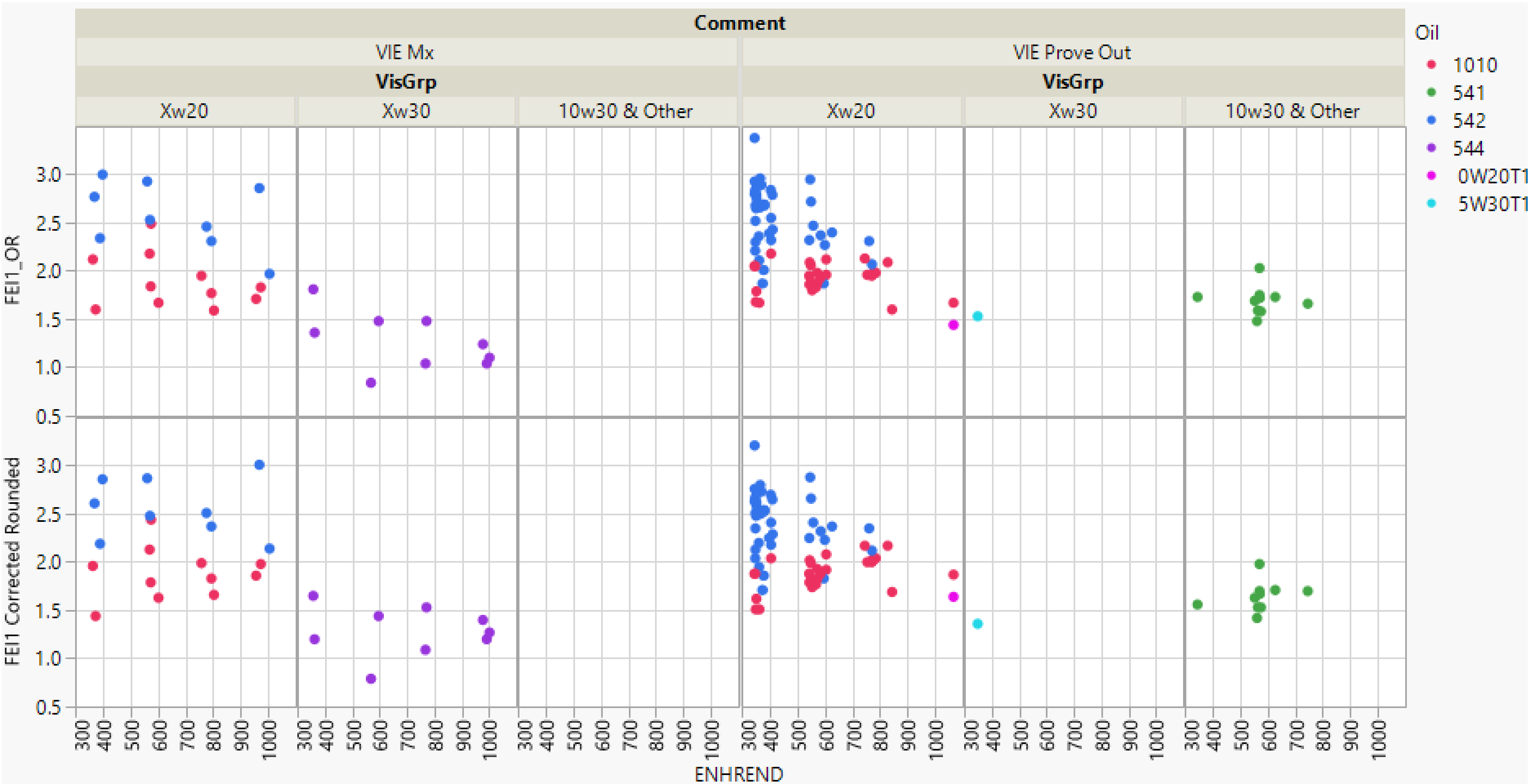
Oil Ranking highest to lowest: Xw20, Xw30, 10w30&Other

VID FEISUM



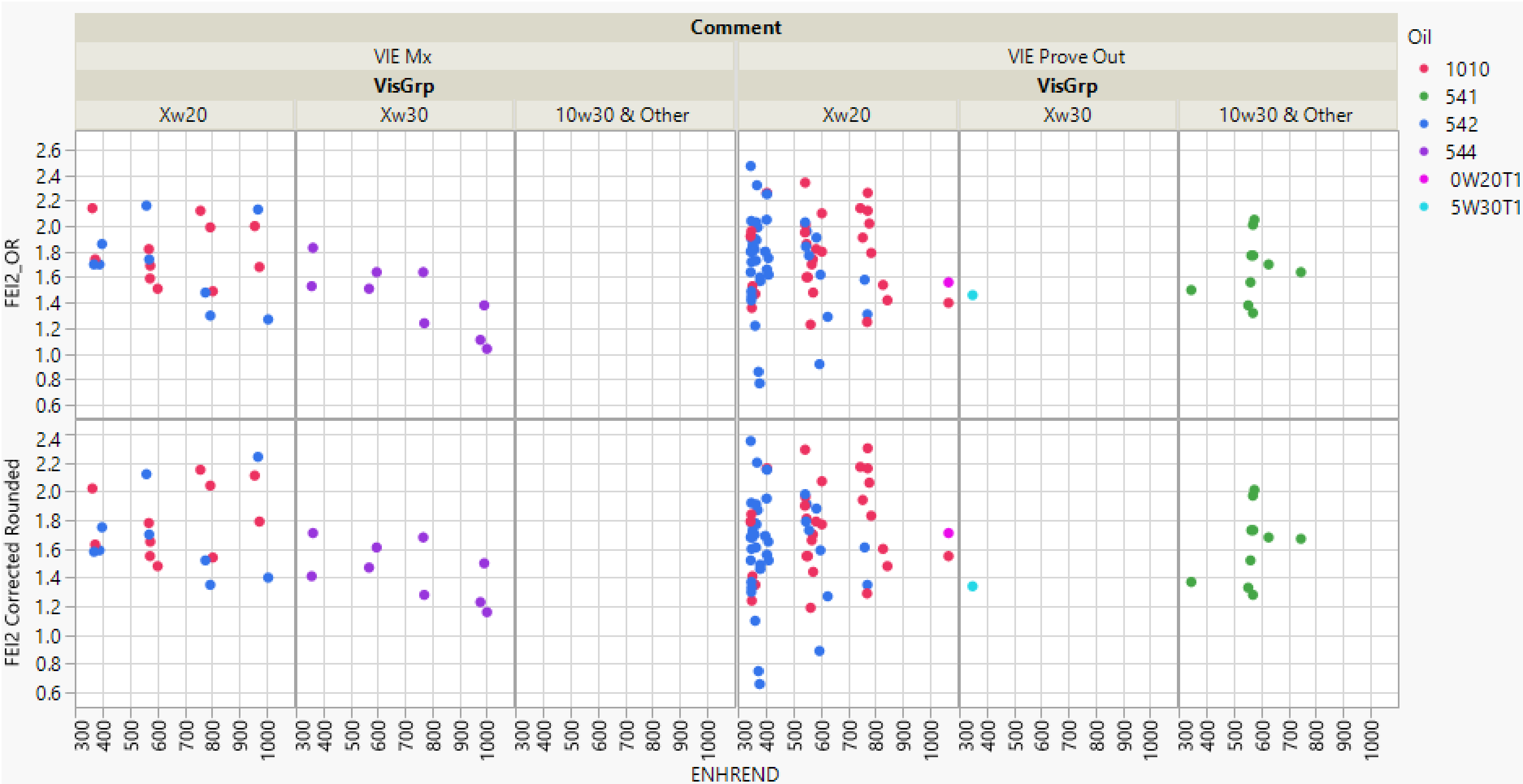
Oil Ranking highest to lowest: Xw20, Xw30, 10w30&Other

VIE FEI1



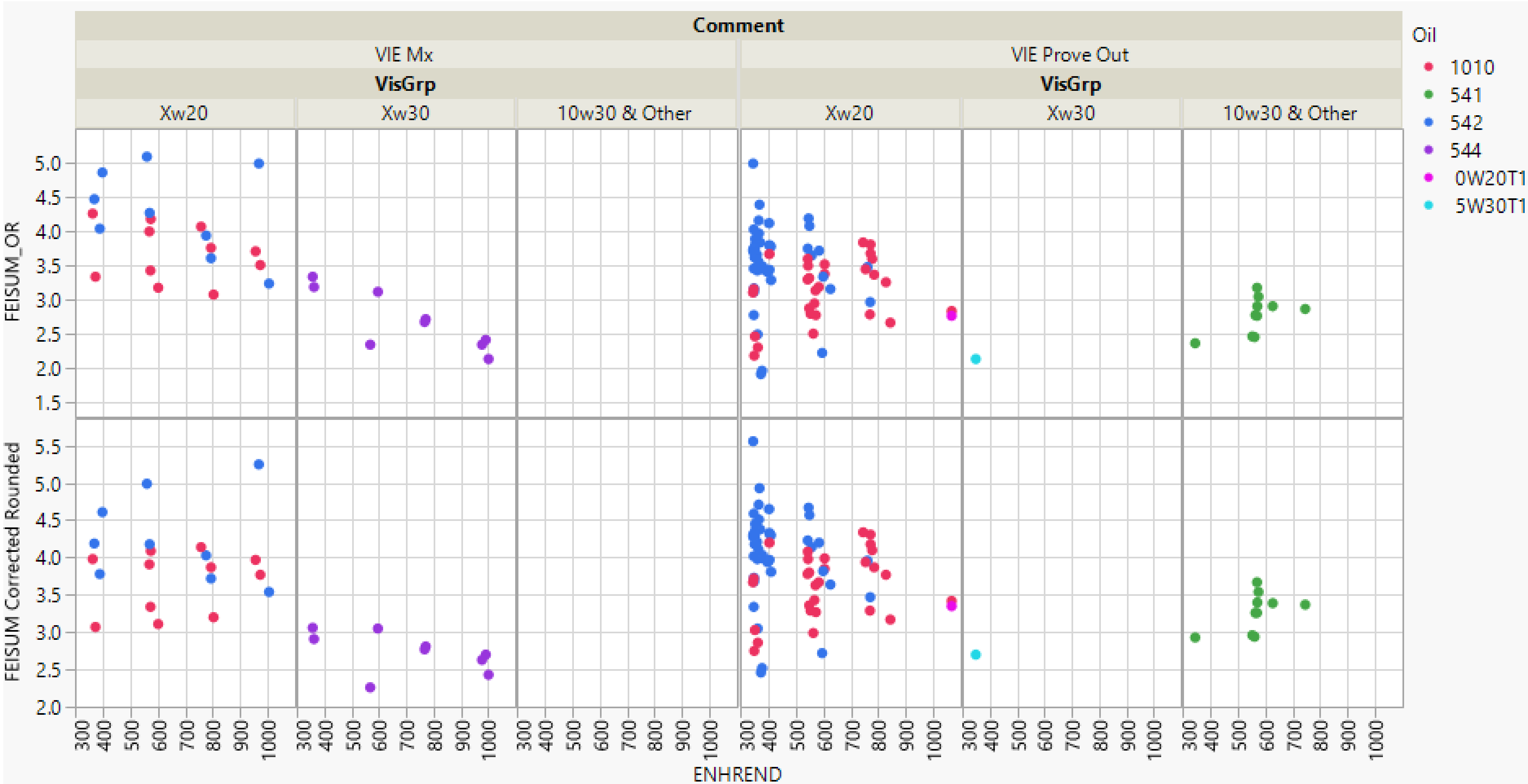
Oil Ranking highest to lowest: Xw20, 10w30&Other, Xw30

VIE FEI2



Oil Ranking highest to lowest: Xw20, 10w30&Other, Xw30

VIE FEISUM



Oil Ranking highest to lowest: Xw20, 10w30&Other, Xw30

Summary

- Oil Ranking:
  - VID: Xw20, Xw30, 10w30&Other VIE: Xw20, 10w30&Other, Xw30

Viscosity Group	Average FEI1	Average FEI2	Average FEISUM
Xw20	1.40	0.93	2.32
Xw30	1.08	0.72	1.80
10w30 & Other	0.90	0.67	1.58

Viscosity Group	Average FEI1	Average FEI2	Average FEISUM
Xw20	2.20	1.69	3.89
Xw30	1.29	1.44	2.73
10w30 & Other	1.64	1.63	3.27

    - VID rankings line up with ranking in GF-5 limits:

	GF5 FEI2 Limit	GF5 FEISUM Limit
Xw20	1.2	2.6
Xw30	0.9	1.9
10w30 and all other Viscosity Grades not listed above	0.6	1.5

  - The data suggest that Xw30 and 10w30&Other flip flop in their performance in the VID and VIE.

Severity Difference

Approach 1

Potential VID limits in VIE

Row	Math	Description	542-2 (0W-20)		1010-1 (5W-20)		544 (5W-30)		10W-30	
			FEI2	FEISUM	FEI2	FEISUM	FEI2	FEISUM	FEI2	FEISUM
R1		VID Target	0.80	2.29	1.10	2.44				
R2		VID Limit	1.2	2.6	1.2	2.6	0.9	1.9	0.6	1.5
R3		VIE Avg	1.73	4.29	1.82	3.72	1.41	2.71		
R4	R4 - R3	Severity Difference (542-2)	0.93	2.00						
R5	R4 - R3	Severity Difference (1010-1)			0.72	1.28				
R6	(R5 + R6) / 2	Average Severity Difference	0.83	1.64	0.83	1.64				
R7	*	Ratio of VID Limit - XW-20 as Basis	1.00	1.00	1.00	1.00	0.75	0.73	0.50	0.58
R8	R6 × R7	Ratio Applied to Average Severity Difference	0.8	1.6	0.8	1.6	0.6	1.2	0.4	0.9
R9	R2 + R8	VID Limit in VIE	2.0	4.2	2.0	4.2	1.5	3.1	1.0	2.4

* Ratio is VID Limit (FEIX) for Viscosity Grade in question divided by like FEIX VID Limit for XW-20.

- Method disregards FEISUM ranking difference.
- Method assumes that the severity differences realized in other grades are proportional to the VID limits for the two grades considered using XW-20 as the basis.
  - For example, for 5W-30 FEI2:

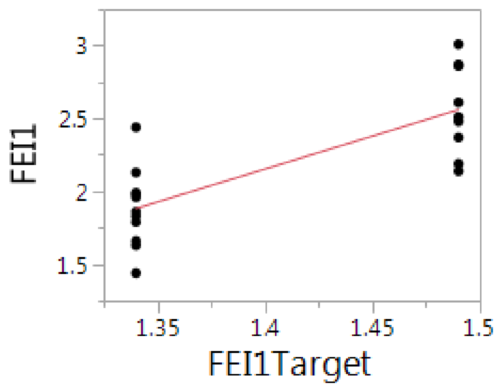
$$FEI2_{VIE.5W-30} = FEI2_{VID.5W-30} + \left(\frac{FEI2_{VID.5W-30}}{FEI2_{VID.XW-20}}\right)\Delta_{FEI2}$$

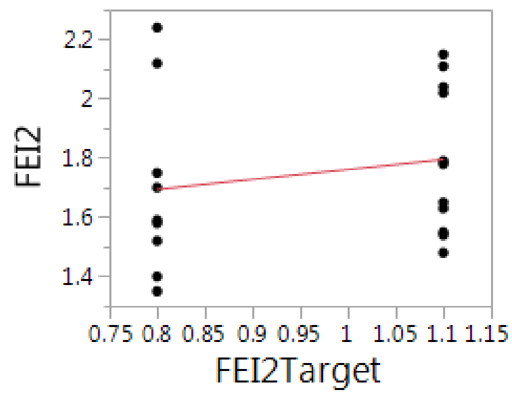
$$1.5 = 0.9 + \left(\frac{0.9}{1.2}\right)0.83$$

Means Method (Linear Equation)

Approach 2

Regress VIE FEI on VID Target using 542-2 and 1010-1





Summary of Fit

RSquare	0.607105
RSquare Adj	0.585277
Root Mean Square Error	0.285717
Mean of Response	2.1875
Observations (or Sum Wgts)	20

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2.2705568	2.27056	27.8137
Error	18	1.4694182	0.08163	**Prob > F**
C. Total	19	3.7399750		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-4.167576	1.206703	-3.45	0.0028*
FEI1Target	4.5151515	0.856136	5.27	<.0001*

Summary of Fit

RSquare	0.035431
RSquare Adj	-0.01816
Root Mean Square Error	0.273891
Mean of Response	1.7495
Observations (or Sum Wgts)	20

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.0496001	0.049600	0.6612
Error	18	1.3502949	0.075016	**Prob > F**
C. Total	19	1.3998950		0.4268

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.4275084	0.400696	3.56	0.0022*
FEI2Target	0.33367	0.41035	0.81	0.4268

Using the Regression Equation, estimate the VID Equivalent Limit in VIE

- Since 542-2 and 1010-1 both fall in the SN+RC category of xW-20, we can only use the regression equation to estimate the limit for xW-20
- SN+RC Limits for xW-20:
  - FEI2=1.2
  - FEISUM=2.6
  - FEI1=(2.6-1.2)=1.4
- Using the FEI1 and FEI2 regression equations the equivalent limits are:
  - FEI1=2.2 (-4.2+4.5*1.4)
  - FEI2=1.8 (1.4+0.3*1.2)
  - FEISUM=(2.2+1.8)=4.0

Estimate the Equivalent limits of xW-30 and 10W-30/Others using the difference of the VID limits from xW-20 limit

Category	VID Limits		Difference from xW-20 Limit		Equivalent Limits in VIE	
SN+RC	**FEI2**	**FEISUM**	**FEI2**	**FEISUM**	**FEI2**	**FEISUM**
xW-20	1.2	2.6			1.8	4.0
xW-30	0.9	1.9	0.3	0.7	1.5	3.3
10W-30 & all others	0.6	1.5	0.6	1.1	1.2	2.9

Probability of Pass

Approach 3

Viscosity Groupings
Probability of Pass Methodology

- An approach to equate the VID and VIE is it maintain the same probability of passing within each of the tests
- The GF-5 pass limits are given in D4485 as can be summarized as follows:

	GF5 FEI2 Limit	GF5 FEISUM Limit
Xw20	1.2	2.6
Xw30	0.9	1.9
10w30 and all other Viscosity Grades not listed above	0.6	1.5

- The goal of this approach is to determine limits in the VIE that provide the same probability of passing in each one of these viscosity grade groupings

Viscosity Groupings
Probability of Pass Methodology

- Step 1: Calculate VID means and standard deviations for the viscosity grade groups

- Step 2: For each viscosity grade group calculate the probability of passing the corresponding GF-5 limit

- Step 3: Calculate VIE means and standard deviations for the viscosity grade groups

- Step 4: Determine the VIE FEI test result necessary in order to achieve the same probability of passing as the VID. This value becomes the VIE equivalent limit

Step 1: Calculate VID means and standard deviations for the viscosity grade groups

- Using the VID ltms.csv file on the TMC site, 584 tests were identified with validity codes AC AG AO OC OO from the beginning of the VID until 5/5/16
- Each test was assigned a viscosity group: Xw20, Xw30, or 10w30&Other
- Estimated means and standard deviation were calculated:

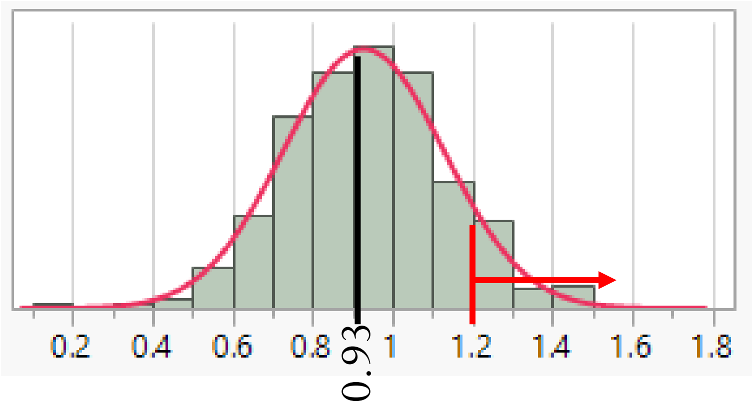
VisGrp	Parameter	Estimated Mean	Estimated Standard Deviation
10w30 & Other	FEI2	0.67	0.13
10w30 & Other	FEISUM	1.58	0.22
Xw20	FEI2	0.93	0.2
Xw20	FEISUM	2.34	0.27
Xw30	FEI2	0.7	0.31
Xw30	FEISUM	1.77	0.44

Step 2: For each viscosity grade group calculate the probability of passing the corresponding GF-5 limit

- Using the estimated means and standard deviations, the probability of obtaining test results greater than the GF-5 pass limits were calculated

Viscosity Group	Parameter	Estimated Mean	Estimated Standard Deviation	GF-5 Limit	Probability of Passing GF-5 Limit Assuming Estimated Mean and SD
10w30 & Other	FEI2	0.67	0.13	0.6	0.7049
10w30 & Other	FEISUM	1.58	0.22	1.5	0.6419
Xw20	FEI2	0.93	0.2	1.2	0.0885
Xw20	FEISUM	2.34	0.27	2.6	0.1678
Xw30	FEI2	0.7	0.31	0.9	0.2594
Xw30	FEISUM	1.77	0.44	1.9	0.3838

For example, consider Xw20:
The probability of obtaining a passing GF-5 result, given the FEI2 pass limit of 1.2, is 0.0885 (8.85%)



Step 3: Calculate VIE means and standard deviations for the viscosity grade groups

- Data used:
  - 29 precision matrix VIE tests deemed acceptable by the surveillance panel for inclusion in statistical analyses of the matrix
  - 10 541-1 VIE prove out data test results which have EOT engine hours < 1000
    - The inclusion of 541-1 results is to obtain 10w30&Other VID to VIE equivalency
- Each of the 39 tests was assigned a viscosity group: Xw20, Xw30, or 10w30&Other
- Estimated means and standard deviation were calculated:

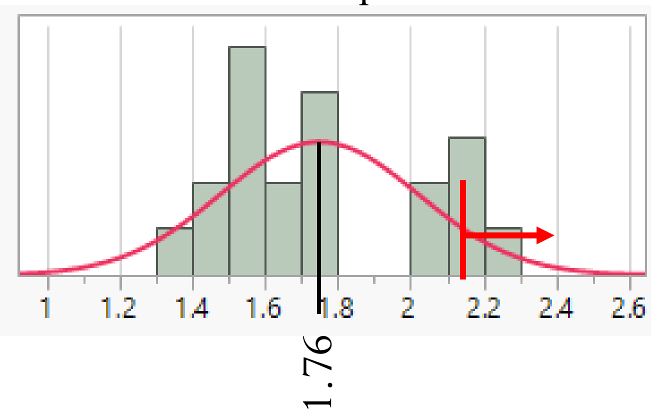
Viscosity Group	Oils	Parameter	Estimated Mean	Estimated Standard Deviation
10w30 & Other	541-1	FEI2	1.69	0.25
10w30 & Other	541-1	FEISUM	3.37	0.26
Xw20	542-2 & 1010-1	FEI2	1.76	0.27
Xw20	542-2 & 1010-1	FEISUM	3.96	0.57
Xw30	544	FEI2	1.4	0.2
Xw30	544	FEISUM	2.71	0.27

Step 4: Determine the VIE FEI test result necessary in order to achieve the same probability of pass as the VID. This value becomes the VIE equivalent limit

- Using the VIE estimated means and standard deviations we can determine the value at which the probability of being greater than this number is the same probability calculated for the VID. Hence, the VIE equivalent limit.

Viscosity Group	Oils	Parameter	Estimated Mean	Estimated Standard Deviation	VIE Equivalent Limt
10w30 & Other	541-1	FEI2	1.69	0.25	1.56
10w30 & Other	541-1	FEISUM	3.37	0.26	3.28
Xw20	542-2 & 1010-1	FEI2	1.76	0.27	2.12
Xw20	542-2 & 1010-1	FEISUM	3.96	0.57	4.51
Xw30	544	FEI2	1.4	0.2	1.53
Xw30	544	FEISUM	2.71	0.27	2.79

For example, consider Xw20:
The probability of obtaining a passing FEI2 GF-5 result in the VID was calculated to be 0.0885.
The FEI2 needed in the VIE to achieve the same estimated pass rate is 2.12



Mean Difference

Approach 4

Viscosity Groupings
Mean Difference Methodology

- An approach to equate the VID and VIE is to offset the VID limits by an amount equal to the difference in average viscosity group performance between the VID and VIE
- The GF-5 pass limits are given in D4485 as can be summarized as follows:

	GF5 FEI2 Limit	GF5 FEISUM Limit
Xw20	1.2	2.6
Xw30	0.9	1.9
10w30 and all other Viscosity Grades not listed above	0.6	1.5

- We can use the same estimated means calculated for the Probability of Pass approach.

Viscosity Groupings
Mean Difference Methodology

- Data Utilized (Same as Probability of Pass approach):
  - VID ltms.csv file on the TMC site: 584 tests were identified with validity codes AC AG AO OC OO from the beginning of the VID until 5/5/16
  - 29 precision matrix VIE tests deemed acceptable by the surveillance panel for inclusion in statistical analyses of the matrix
  - 10 541-1 VIE prove out data test results which have EOT engine hours < 1000
    - The inclusion of 541-1 results is to obtain 10w30&Other VID to VIE equivalency

- Oils were assigned one of the 3 viscosity groupings (Xw20, Xw30, or 10w30&Other)

- Estimated means were calculated in the same manor as the Probability of Pass approach

Viscosity Groupings
Mean Difference Methodology

Viscosity Group	GF5 FEI2 Limit	GF5 FEISUM Limit	VID FEI2 Estimated Mean	VID FEISUM Estimated Mean	VIE FEI2 Estimated Mean	VIE FEISUM Estimated Mean	FEI2 Difference in Means	FEISUM Difference in Means	VIE FEI2 Equivalent Limit	VIE FEISUM Equivalent Limit
Xw20	1.2	2.6	0.93	2.34	1.76	3.96	0.83	1.62	2.03	4.22
Xw30	0.9	1.9	0.7	1.77	1.4	2.71	0.7	0.94	1.6	2.84
10w30 and all other viscosity grades not listed above	0.6	1.5	0.67	1.58	1.69	3.37	1.02	1.79	1.62	3.29

Assign tests a viscosity group → Calculate VID and VIE means → Calculate difference in means → Add difference to GF5 limit

Example: Xw20 FEI2

- Each test in the available data was assigned a viscosity group
- Estimated means were generated for each viscosity group in the VID and VIE:
  - VID FEI2 Estimated Mean = 0.93; VIE FEI2 Estimated Mean = 1.76
- The difference in these means was calculated:
  - FEI2 Difference in Means = 1.76 – 0.93 = 0.83
- The difference was added to the GF5 FEI2 Limit to obtain the VIE equivalent limit:
  - VIE FEI2 Equivalent Limit = (GF5 FEI2 Limit) + (FEI2 Difference in Means)

    = 1.2 + 0.83 = 2.03

Proportional Change

Approach 5

Viscosity Groupings
Proportional Change Methodology

- An approach to equate the VID and VIE is to offset the VID limits by an amount equal to the proportional change in average viscosity group performance between the VID and VIE
- The GF-5 pass limits are given in D4485 as can be summarized as follows:

	GF5 FEI2 Limit	GF5 FEISUM Limit
Xw20	1.2	2.6
Xw30	0.9	1.9
10w30 and all other Viscosity Grades not listed above	0.6	1.5

- We can use the same estimated means calculated for the Probability of Pass approach.

Viscosity Groupings
Proportional Change Methodology

- Data Utilized (Same as Probability of Pass approach):
  - VID ltms.csv file on the TMC site: 584 tests were identified with validity codes AC AG AO OC OO from the beginning of the VID until 5/5/16
  - 29 precision matrix VIE tests deemed acceptable by the surveillance panel for inclusion in statistical analyses of the matrix
  - 10 541-1 VIE prove out data test results which have EOT engine hours < 1000
    - The inclusion of 541-1 results is to obtain 10w30&Other VID to VIE equivalency

- Oils were assigned one of the 3 viscosity groupings (Xw20, Xw30, or 10w30&Other)

- Estimated means were calculated in the same manor as the Probability of Pass approach

Viscosity Groupings
Proportional Change Methodology

Viscosity Group	GF5 FEI2 Limit	GF5 FEISUM Limit	VID FEI2 Estimated Mean	VID FEISUM Estimated Mean	VIE FEI2 Estimated Mean	VIE FEISUM Estimated Mean	FEI2 Proportional Change in Means	FEISUM Proportional Change in Means	VIE FEI2 Equivalent Limit	VIE FEISUM Equivalent Limit
Xw20	1.2	2.6	0.93	2.34	1.76	3.96	1.8925	1.6923	2.27	4.40
Xw30	0.9	1.9	0.7	1.77	1.4	2.71	2.0000	1.5311	1.80	2.91
10w30 and all other viscosity grades not listed above	0.6	1.5	0.67	1.58	1.69	3.37	2.5224	2.1329	1.51	3.20

Assign tests a viscosity group → Calculate VID and VIE means → Calculate proportional change in means → Multiple GF5 limit by proportional change

Example: Xw20 FEI2

- Each test in the available data was assigned a viscosity group
- Estimated means were generated for each viscosity group in the VID and VIE:
  - VID FEI2 Estimated Mean = 0.93; VIE FEI2 Estimated Mean = 1.76
- The proportional change in these means was calculated:
  - FEI2 Proportional Change in Means = 1.76/0.93 = 1.8925
- The GF5 FEI2 Limit was then multiplied by the proportional change to obtain an estimate for the VIE equivalent limit:
  - VIE FEI2 Equivalent Limit = (GF5 FEI2 Limit)*(FEI2 Proportional Chg in Means)

= 1.2*1.8925 = 2.27

VIF Precision Matrix Analysis

Statistics Group

July 26, 2016

Statistics Group

- Arthur Andrews, ExxonMobil
- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Kevin O'Malley, Lubrizol
- Martin Chadwick, Intertek
- Richard Grundza, TMC
- Lisa Dingwell, Afton
- Todd Dvorak, Afton
- Travis Kostan, SwRI

Executive Summary

- Precision Matrix (PM) Analysis Highlights:
  - This analysis includes the results of 14 valid precision matrix tests which reflects surveillance panel decision to limit engine life
  - Within the shortened engine hours, data support the use of no transformation
  - Oils discriminate for both FEI1 and FEI2
    - FEI1: 542-2 > (543 & 1011)
    - FEI2: 543 > (542-2 & 1011)
  - On average, there is no significant difference between the labs
  - Engine differences within labs:
    - FEI1: no significant difference between the engines
    - FEI2: G58 < G96; no significant difference in Lab A engines
    - An engine-based LTMS system is recommended
  - No compelling rationale to change current 80/20 baseline weighting for FEI1 and 10/90 baseline weighting for FEI2

Executive Summary

- Precision Matrix (PM) Analysis Highlights (continued):
  - Engine hour corrections:
    - FEI1 = FEI1_OR + 0.000359*(ENHREND – 686)
    - FEI2 = FEI2_OR + 0.000258*(ENHREND – 686)
  - Estimated within engine test precision
    - FEI1 = 0.17; FEI2 = 0.21
  - Estimated test precision across labs and engines
    - FEI1 = 0.17; FEI2 = 0.31
  - LTMS Oil Targets:

FEIAdjusted	LSMean		Standard Deviation		RMSE	
Oil	FEI1	FEI2	FEI1	FEI2	FEI1	FEI2
542-2 (n=5)	2.23	1.44	0.18	0.12	0.17	0.21
1011 (n=3)	1.43	1.35	0.16	0.52	0.17	0.21
543 (n=6)	1.77	2.12	0.17	0.30	0.17	0.21

  - The calculated engine hours corrections and LTMS oils targets would benefit from data from additional engines while ensuring a total of at least 6 test results to estimate each oil's targets. (Is 542-2 going to be a reference oil in the VIF?)

Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Review BL Shift Within Each Engine
- Analyze PM Data
  - FEI1
  - FEI2

Agenda

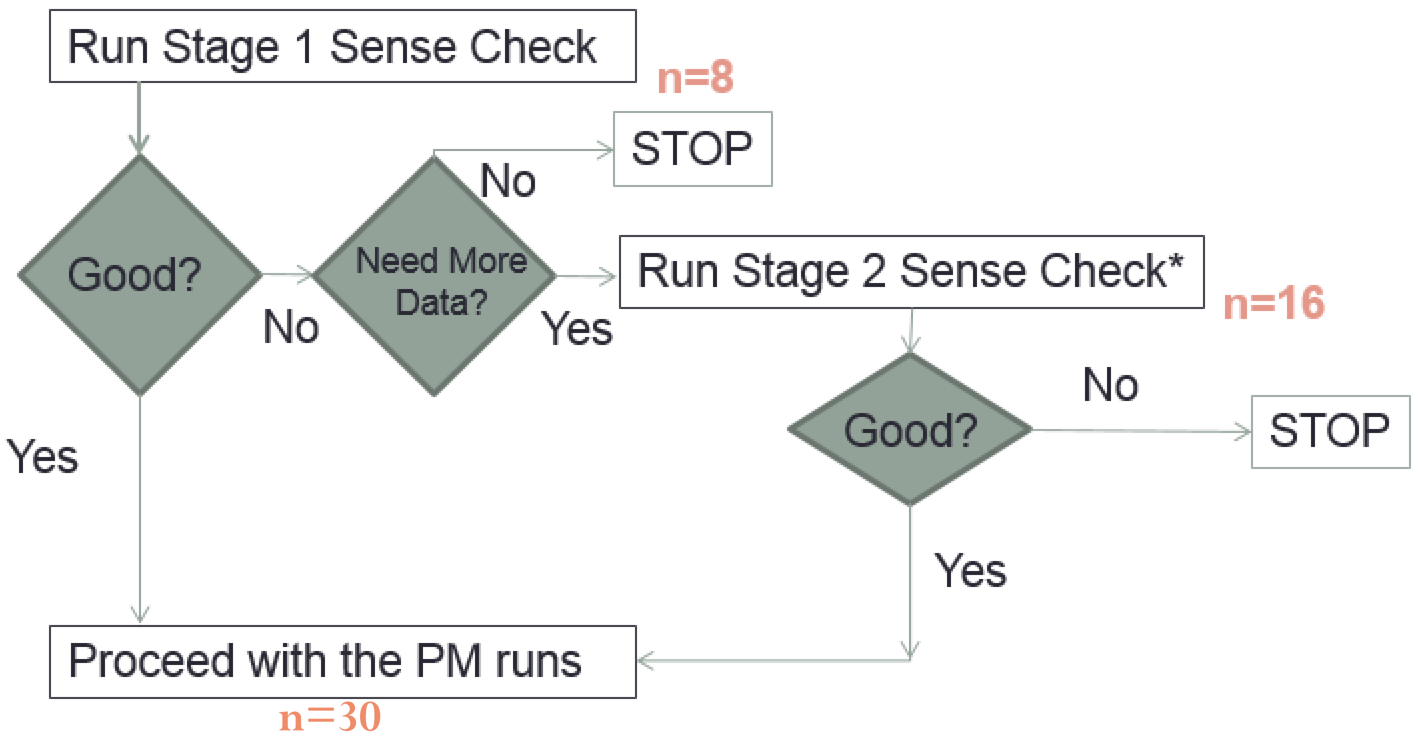
- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Review BL Shift Within Each Engine
- Analyze PM Data
  - FEI1
  - FEI2

Review PM Data for Analysis

- Precision Matrix data summary:
  - 2 Labs {A, G}
  - 3 Reference Oils {1011, 542-2, 543}
  - 4 Engines {58 & 96 at Lab G; 122 & 144 at Lab A}
  - 30 tests were conducted

Review PM Data for Analysis

- Precision matrix tests were conducted in a stage gate process



*Stage 2 Sense Check can be re-designed based on the outcome of Stage 1 Sense Check

Review PM Data for Analysis

- Precision Matrix (PM):

Run Order	EOT Engine Hours	SwRI #1		SwRI #2		IAR #1		IAR #2	
1	350	Stage 1 Sense Check	543 112952-VIF	Stage 2 Sense Check	1011 112953-VIF	Stage 1 Sense Check	542-2 112957-VIF	Stage 2 Sense Check	1011 112955-VIF Baseline Shift
2	550		542-2 112951-VIF		542-2 116037-VIF		543 112958-VIF		543 113824-VIF
3	750		542-2 113818-VIF		1011 112954-VIF		543 113823-VIF		1011 112956-VIF
4	950		543 113819-VIF		543 113820-VIF		542-2 113822-VIF EBP Calibration Shift; 542-2 113231-VIF		542-2 116030-VIF
5	1150	1011 117508-VIF		543 113821-VIF Worn Throttle Controller; 543 117512-VIF		1011 116832-VIF		542-2 116031-VIF Baseline Shift	
6	1350	543 117626-VIF		1011 117509-VIF		543 113825-VIF		1011 117495-VIF	
7	1550	542-2 116038-VIF		542-2 117511-VIF		1011 117496-VIF		543 117494-VIF	
8	1750	1011 117510-VIF				542-2 117493-VIF			

Test Reported | Under Review | Invalid

- Table is from Frank Faber's 6-21-16 matrix update
- Testkeys 112955 and 116031 were invalidated; 28 tests considered in the analysis

Review PM Data for Analysis

- Precision Matrix (PM):
  - On 7-19-16 the surveillance panel passed a motion to limit the VIF engine life to 4 full length tests with the 4th test starting no later than 900 engine hours (see Appendix B for supporting documentation)
  - Analyses presented reflect this motion with 14 tests fitting these criteria

Run Order	EOT Engine Hours	SwRI #1		SwRI #2		IAR #1		IAR #2	
1	350	Stage 1 Sense Check	543 112952-VIF	Stage 2 Sense Check	1011 112953-VIF	Stage 1 Sense Check	542-2 112957-VIF	Stage 2 Sense Check	1011 112955-VIF Baseline Shift
2	550		542-2 112951-VIF		542-2 116037-VIF		543 112958-VIF		543 113824-VIF
3	750		542-2 113818-VIF		1011 112954-VIF		543 113823-VIF		1011 112956-VIF
4	950		543 113819-VIF		543 113820-VIF		542-2 113822-VIF EBP Calibration Shift 542-2 113231-VIF		542-2 116030-VIF
5	1150	1011 117508-VIF		543 113821-VIF Worn Throttle Controller 543 117512-VIF		1011 116832-VIF		542-2 116031-VIF Baseline Shift	
6	1350	543 117626-VIF		1011 117509-VIF		543 113825-VIF		1011 117495-VIF	
7	1550	542-2 116038-VIF		542-2 117511-VIF		1011 117496-VIF		543 117494-VIF	
8	1750	1011 117510-VIF				542-2 117493-VIF			

Excluded From Analysis (runs 5–8)

Test Reported | Under Review | Invalid

Review PM Data for Analysis

- Average engine hour age[1]:
  - PM Average EngHrs = 686

LTMSLAB	ENGNO	Average ENHREND	Max ENHREND
A	122	673	972
A	144	678	995
G	58	604	820
G	96	798	1023

[1] *For reference:VID Ln(EngHrs) = 7.37 ($e^{7.37}$ = 1598 hours)*
VIE ENHREND = 675 Hours

Agenda

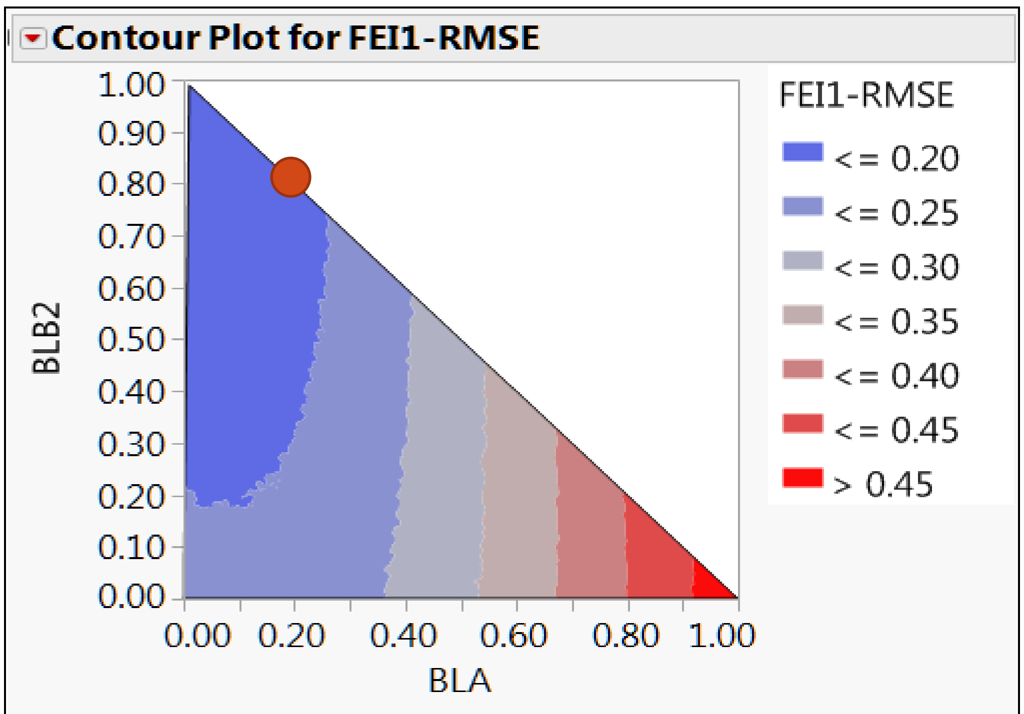
- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Review BL Shift Within Each Engine
- Analyze PM Data
  - FEI1
  - FEI2

Evaluating Baseline Weight Scenarios

- Excel Program developed to evaluate 10,000 different weight combinations of BLB1, BLB2, and BLA
- Excel based prediction model for precision (RMSE) included Lab, Eng(Lab), Oil, and Ln(EngHr) factors
- All BL weight combinations summed to a value of 1.0
- For those runs that included a BLB3, BL weights were applied to BLB2 & BLB3 in lieu of BLB1 & BLB2
- Results are shown on the following slides

Evaluating Baseline Weight Scenarios

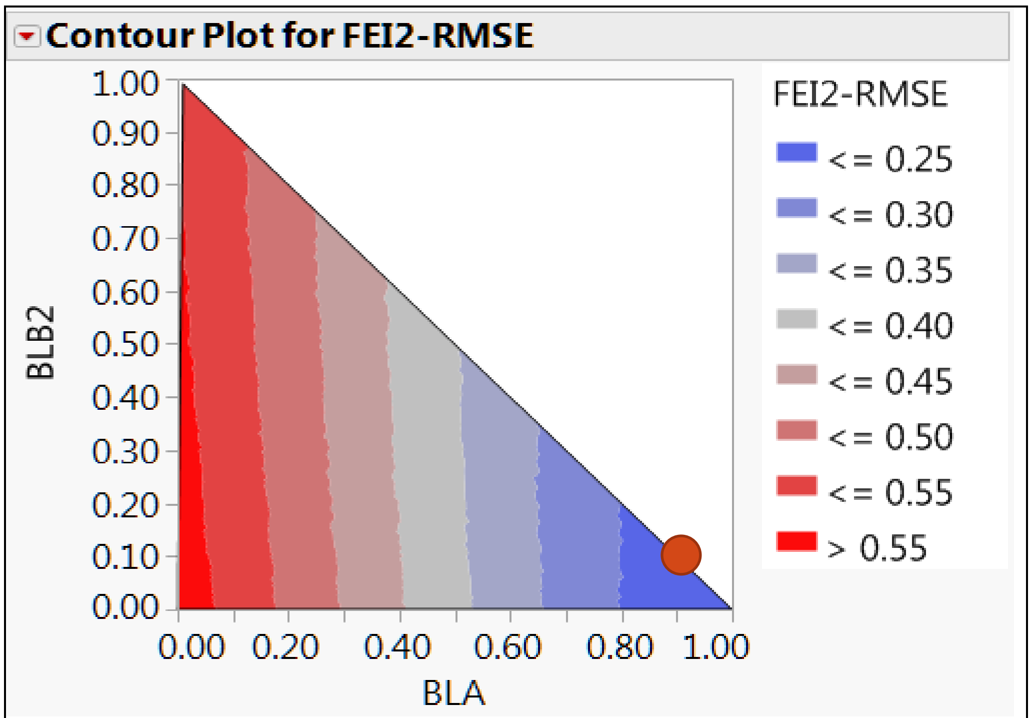
- Plot of RMSE vs. baseline weight combinations for FEI1 shown below
  - RMSE of weights can be interpreted from plot- if BL weights sum to 1.0
  - VID FEI1 Baseline weights of 80% & 20% shown in red circle
  - A BL2 weight of 1.0 provides improvement to test precision



Baseline Weights	FEI1 RMSE
80/20 BLB2/BLA Weights	0.1804
100/0 BLB2/BLA Weights	0.1390

Evaluating Baseline Weight Scenarios

- Plot of RMSE vs. baseline weight combinations for FEI2 shown below
  - RMSE of weights can be interpreted from plot- if BL weights sum to 1.0
  - VID FEI2 Baseline weights of 10% & 90% shown in red circle
  - BLA weight of 1.0 provides some improvement to precision



Baseline Weights	FEI2 RMSE
10/90 BLB2/BLA Weights	0.1950
0/100 BLB2/BLA Weights	0.2211

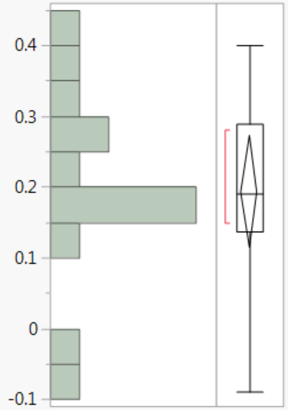
Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Review BL Shift Within Each Engine
- Analyze PM Data
  - FEI1
  - FEI2

BLB2 and BLA Shift

- BLB2/3 Shift Range (-0.09, 0.4)
- BLA Shift Range (-0.47, 1.18)

BLSFDT12



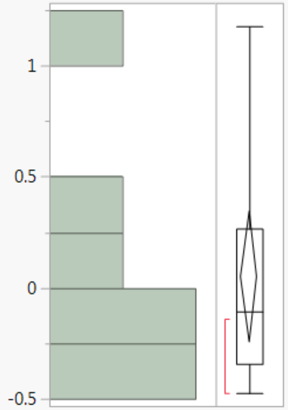
Quantiles

100.0%	maximum	0.4
99.5%		0.4
97.5%		0.4
90.0%		0.375
75.0%	quartile	0.29
50.0%	median	0.19
25.0%	quartile	0.1375
10.0%		-0.06
2.5%		-0.09
0.5%		-0.09
0.0%	minimum	-0.09

Summary Statistics

Mean	0.1928571
Std Dev	0.1369126
Std Err Mean	0.0365914
Upper 95% Mean	0.2719081
Lower 95% Mean	0.1138062
N	14

BLSFDT2A



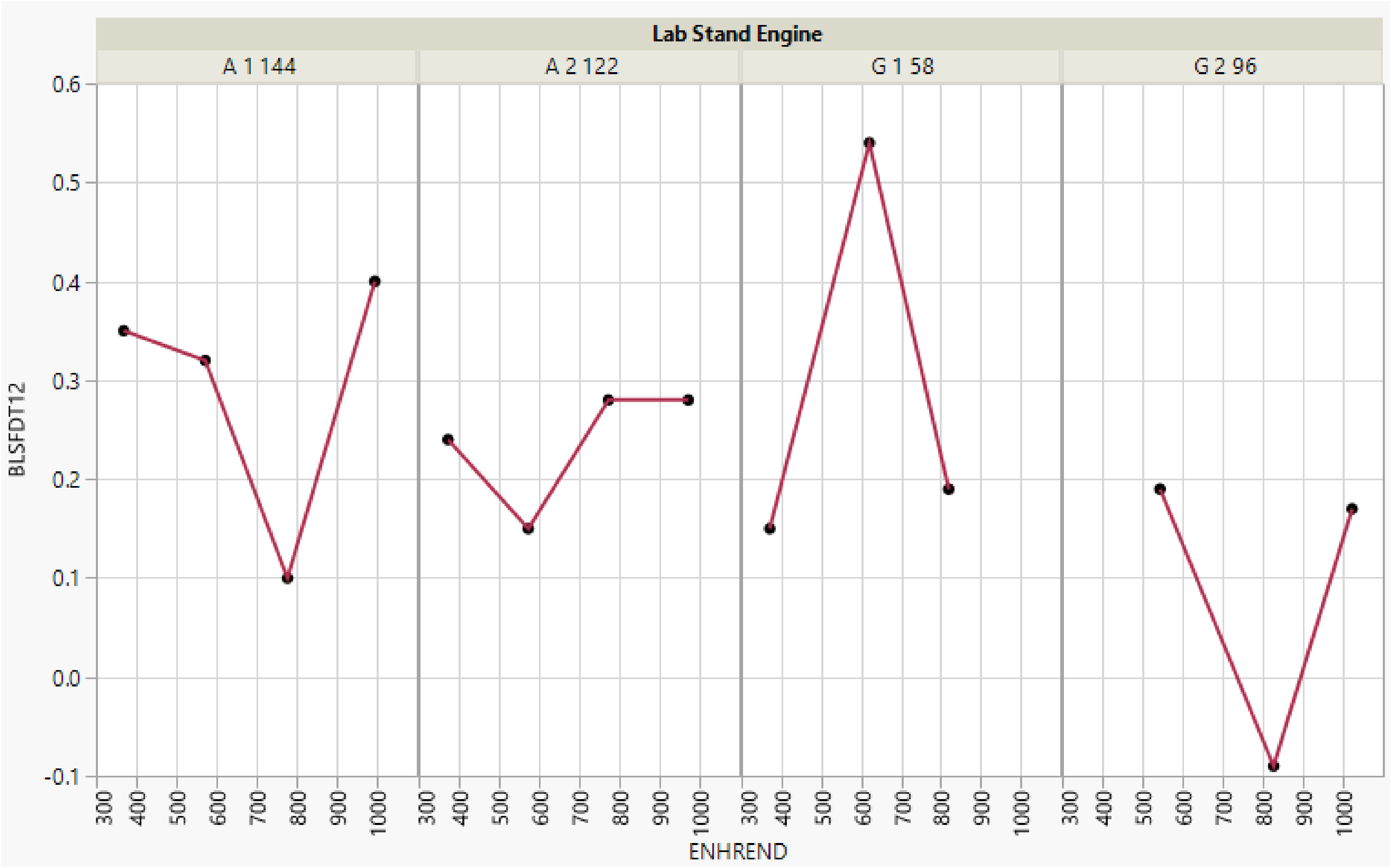
Quantiles

100.0%	maximum	1.18
99.5%		1.18
97.5%		1.18
90.0%		1.115
75.0%	quartile	0.2675
50.0%	median	-0.105
25.0%	quartile	-0.345
10.0%		-0.455
2.5%		-0.47
0.5%		-0.47
0.0%	minimum	-0.47

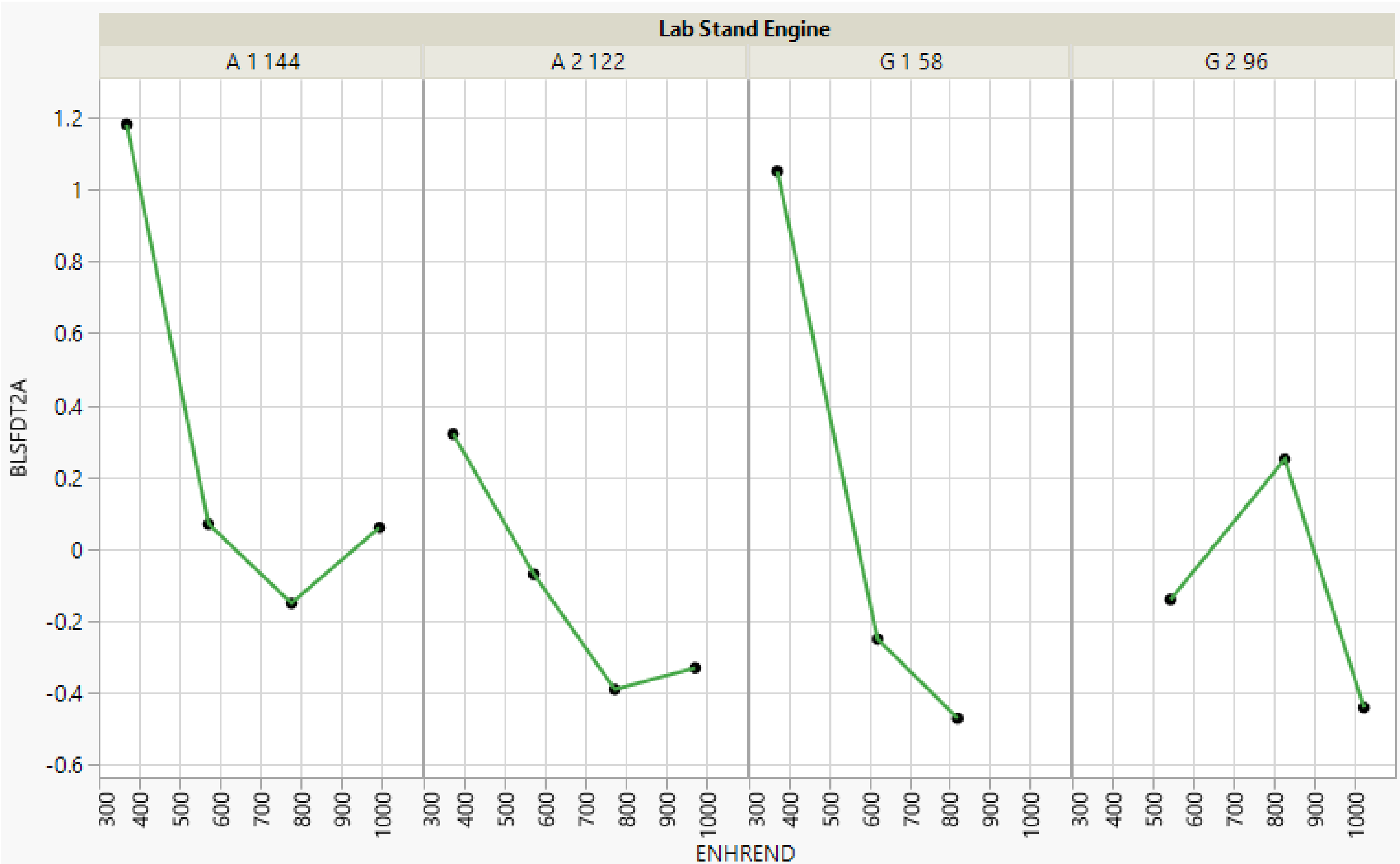
Summary Statistics

Mean	0.0492857
Std Dev	0.5128572
Std Err Mean	0.1370669
Upper 95% Mean	0.3454007
Lower 95% Mean	-0.246829
N	14

BLB2 Shift Within Each Engine



BLA Shift Within Each Engine

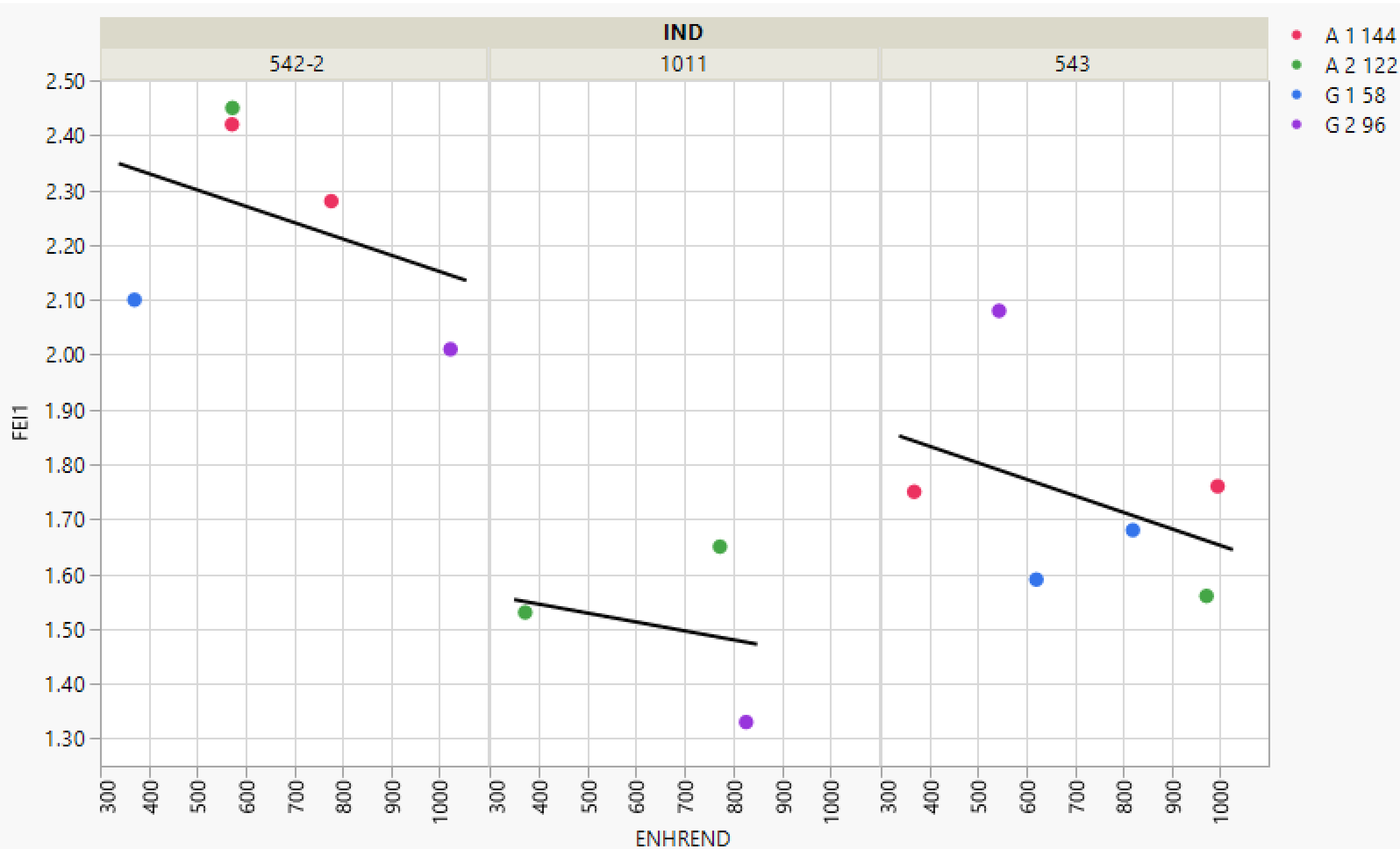


Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Review BL Shift Within Each Engine
- Analyze PM Data
  - FEI1
  - FEI2

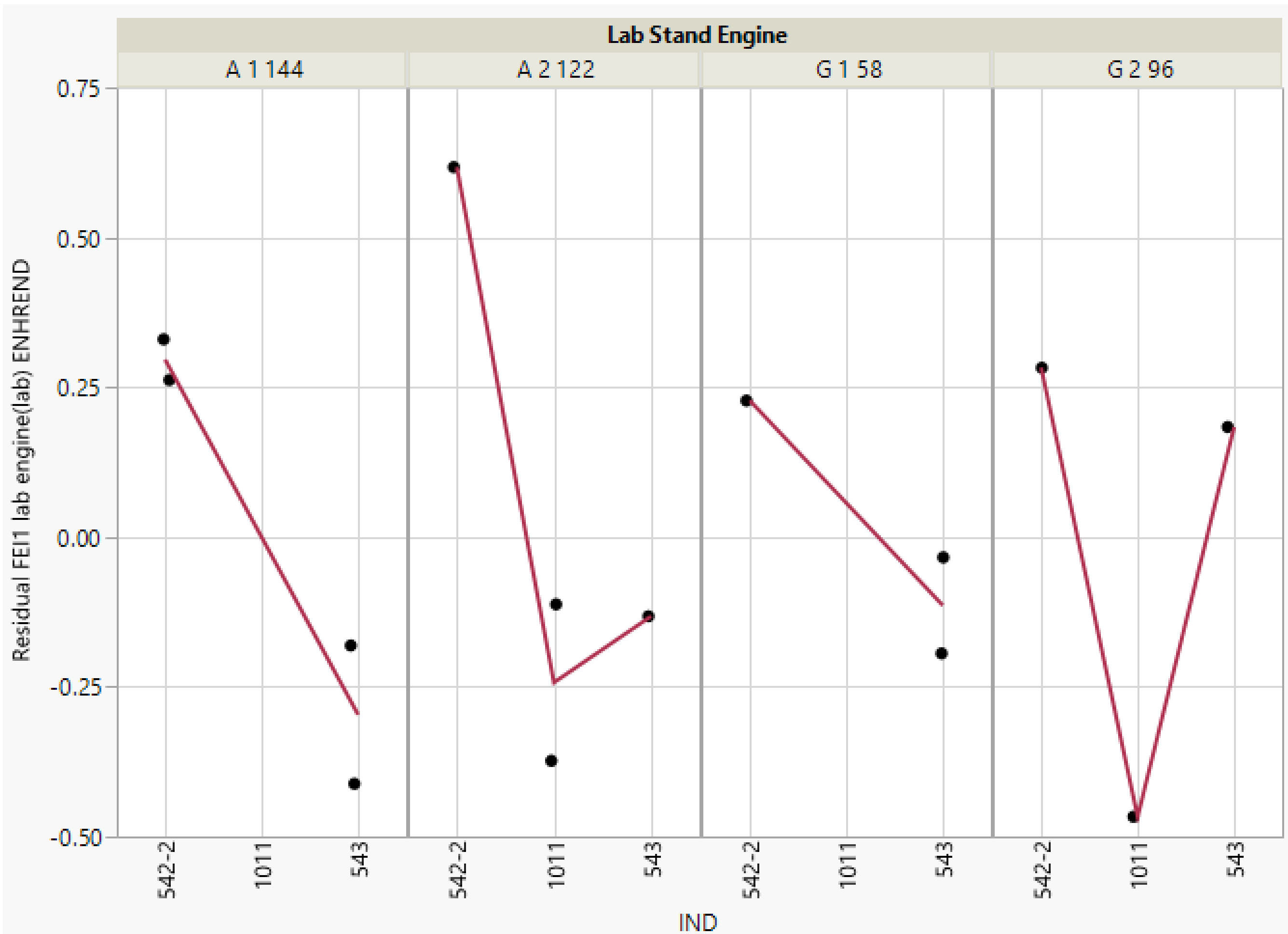
Analyzing PM Data – FEI1

- Plot of FEI1 (unadjusted results are shown)



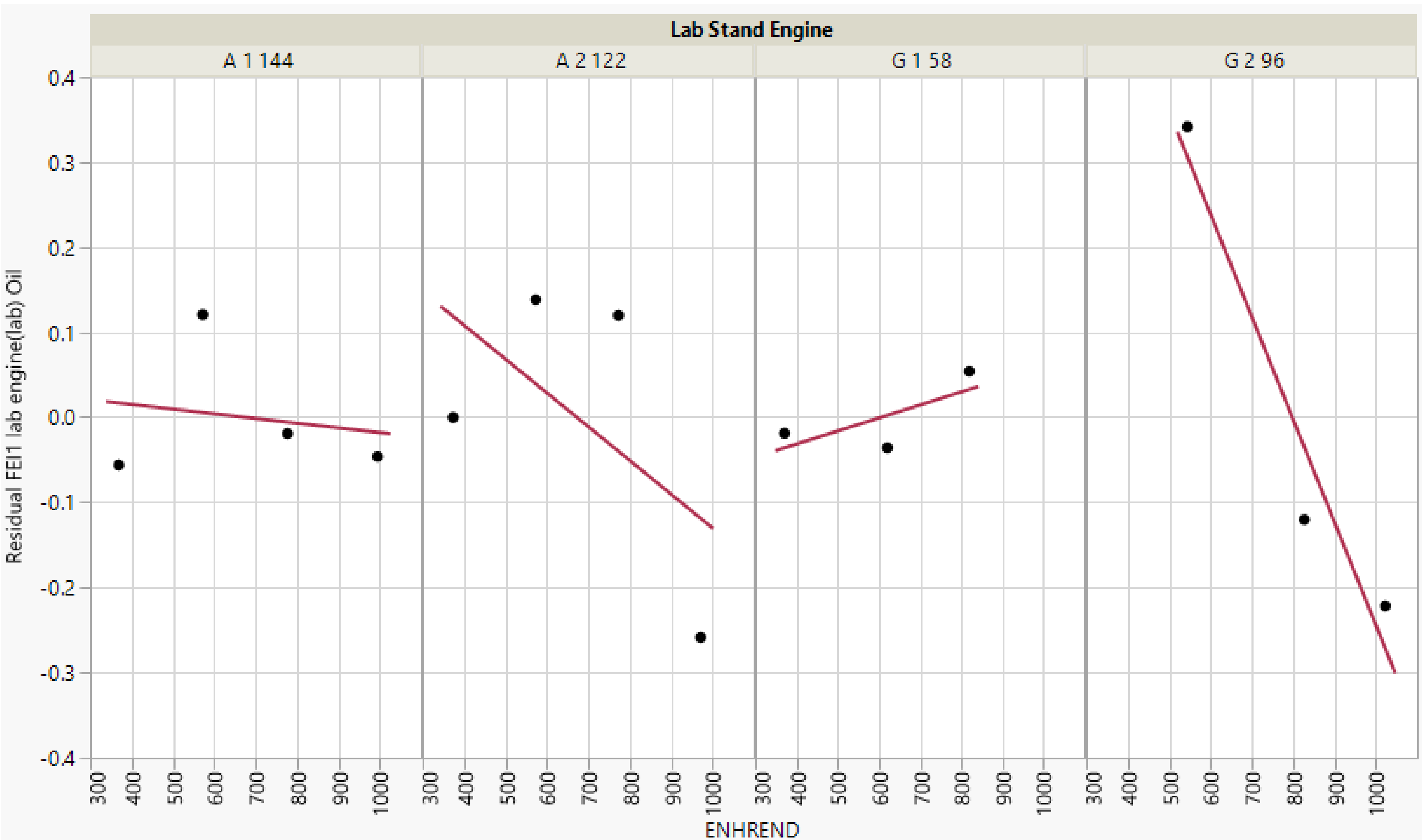
Analyzing PM Data – FEI1

- The consistency of oil discrimination across engines is difficult to judge given the amount of data
- Residuals are from a model containing lab, engine(lab), and ENHREND



Analyzing PM Data – FEI1

- Data suggest use of no transformation for ENHREND is reasonable within the shortened engine life
- Residuals are from a model containing lab, engine(lab), and IND



Analyzing PM Data - FEI1

- Overall ANOVA Summary of FEI1 data:
  - Analysis indicates differences in the oils
  - FEI1 Engine Hours Adjustment:
    - FEI = FEI1_OR + 0.000359*(ENHREND – 686)
    - We acknowledge that the ENHREND term is not statistically significant (using a 0.05 p-value threshold), but calculate a correction knowing that from the n=28 analysis there is significant evidence of an hours effect

Summary of Fit

RSquare	0.858981
RSquare Adj	0.738108
Root Mean Square Error	0.180447
Mean of Response	1.870714
Observations (or Sum Wgts)	14

Parameter Estimates

Term	Estimate	Prob>|t|
Intercept	2.0565749	<.0001*
LTMSLAB[A]	0.0631568	0.2410
LTMSLAB[A]:ENGNO[122]	0.0144398	0.8487
LTMSLAB[G]:ENGNO[58]	-0.099576	0.2677
IND[542-2]	0.4236423	0.0006*
IND[1011]	-0.381137	0.0050*
ENHREND	-0.000359	0.1671

Effect Tests

Source	DF	Prob > F
LTMSLAB	1	0.2410
ENGNO[LTMSLAB]	2	0.5174
IND	2	0.0020*
ENHREND	1	0.1671

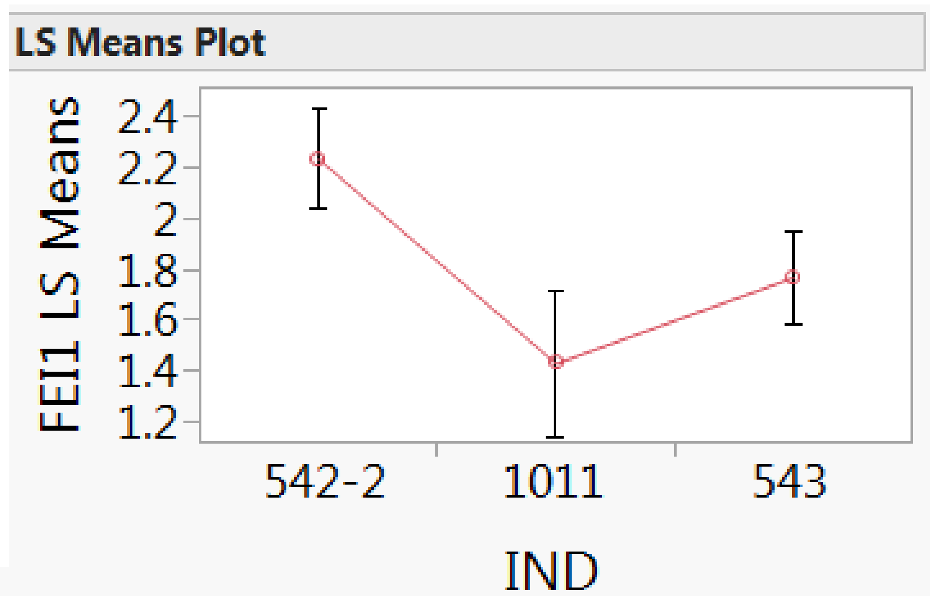
Analyzing PM Data - FEI1

- On average, oils significantly differ: 542-2 > (543 & 1011)

Least Squares Means Table

Level	Least Sq Mean
542-2	2.2339220
1011	1.4291425
543	1.7677748

Level	- Level	Difference	p-Value
542-2	1011	0.8047795	0.0027*
542-2	543	0.4661472	0.0102*
543	1011	0.3386323	0.1387



Level		Least Sq Mean
542-2	A	2.2339220
543	B	1.7677748
1011	B	1.4291425

Levels not connected by same letter are significantly different.

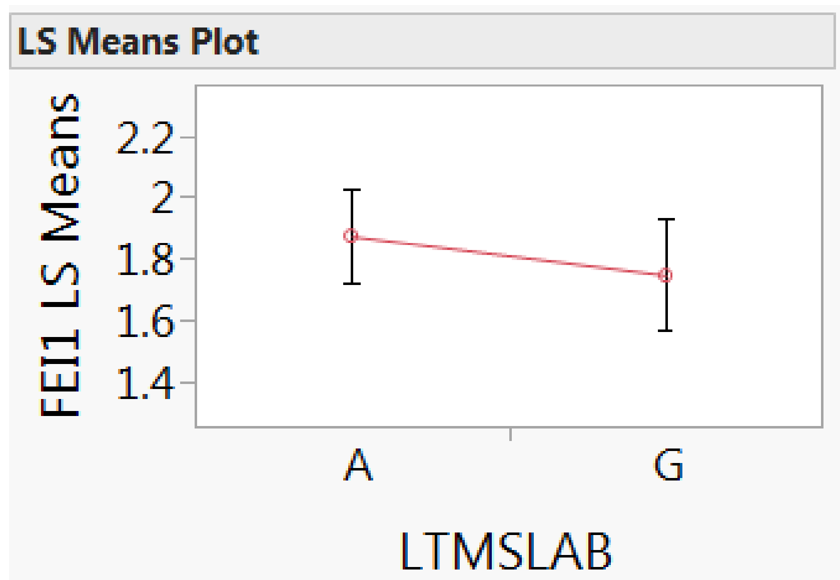
Analyzing PM Data - FEI1

- On average, Labs A and G do not significantly differ in their FEI1 results

Least Squares Means Table

Level	Least Sq Mean
A	1.8734366
G	1.7471229

Level	- Level	Difference	p-Value
A	G	0.1263137	0.2410

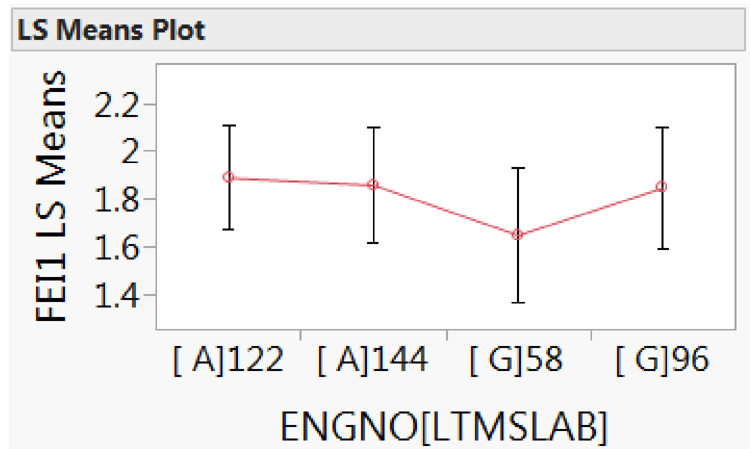


Analyzing PM Data - FEI1

- On average, engines do not significantly differ within each of the 2 labs

Parameter Estimates

Term	Estimate	Prob>|t|
Intercept	2.0565749	<.0001*
LTMSLAB[A]	0.0631568	0.2410
LTMSLAB[A]:ENGNO[122]	0.0144398	0.8487
LTMSLAB[G]:ENGNO[58]	-0.099576	0.2677
IND[542-2]	0.4236423	0.0006*
IND[1011]	-0.381137	0.0050*
ENHREND	-0.000359	0.1671



Least Squares Means Table

Level	Least Sq Mean
[A]122	1.8878764
[A]144	1.8589968
[G]58	1.6475466
[G]96	1.8466992

FEI1 Precision

Model: FEI1 vs. Oil, Lab, Engine(Lab)		Model: FEI1 vs. Oil
Model RMSE	**Repeatability**	**Reproducibility**
• s = 0.17 • VIE Precision Matrix s=0.29 • VID Precision Matrix s=0.14 • VID current data s=0.12	• s = 0.17 • r = 0.47	• s = 0.17 • R = 0.47

Note: VIF estimates are calculated on engine hour corrected results rounded to 2 decimal places

FEI1 Precision

Based upon the Seq. VIE and VID pooled standard deviations (s_r) and ASTM's repeatability (r), there is no significant difference between an FEI1 result[1] of 1.53 – 2.00 for the VIF and 1.61 – 2.00 for the VID.

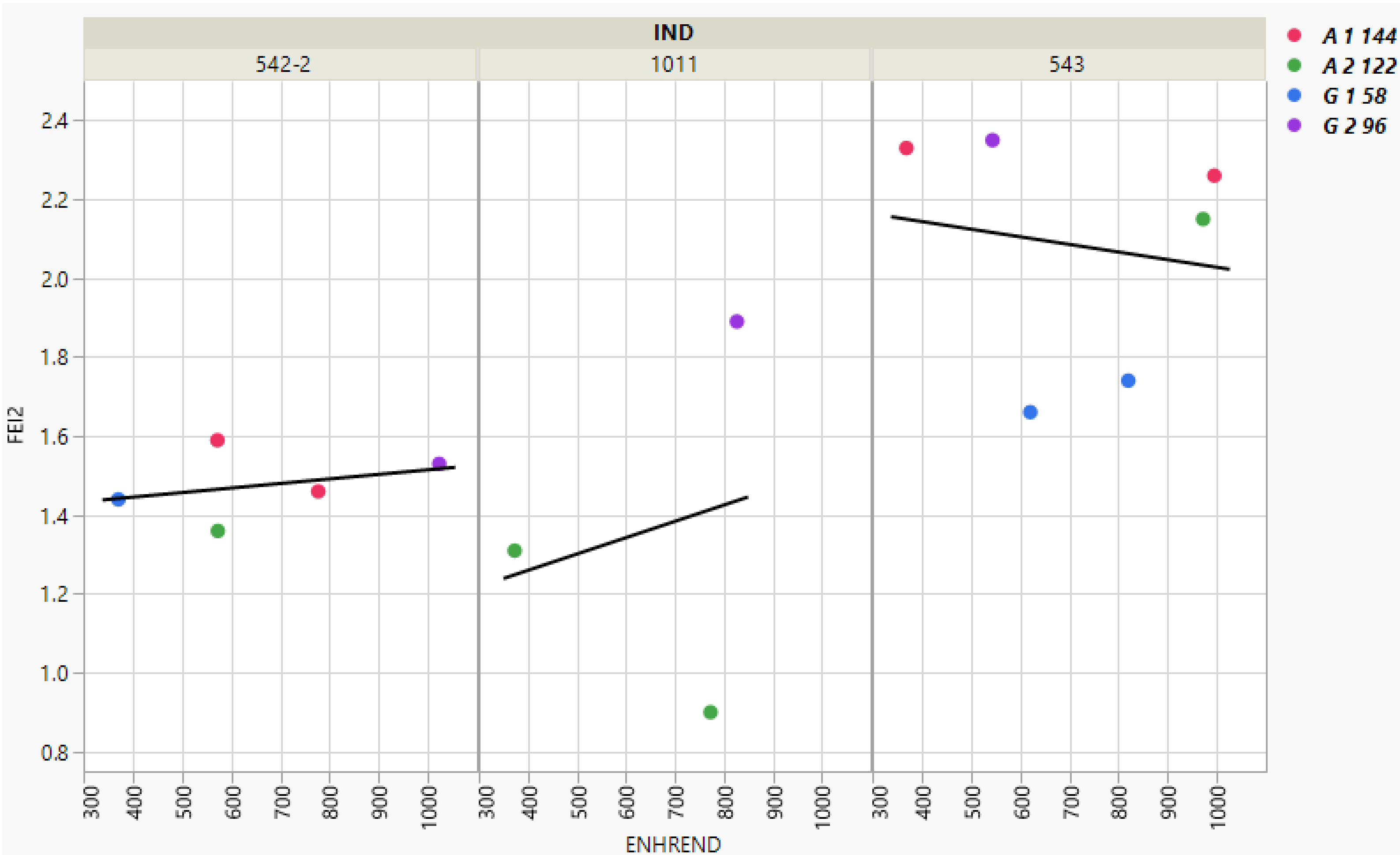
Note 1: An FEI1 of 2.0 was arbitrarily selected in the calculations as the upper pass/fail limit.

Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Review BL Shift Within Each Engine
- Analyze PM Data
  - FEI1
  - FEI2

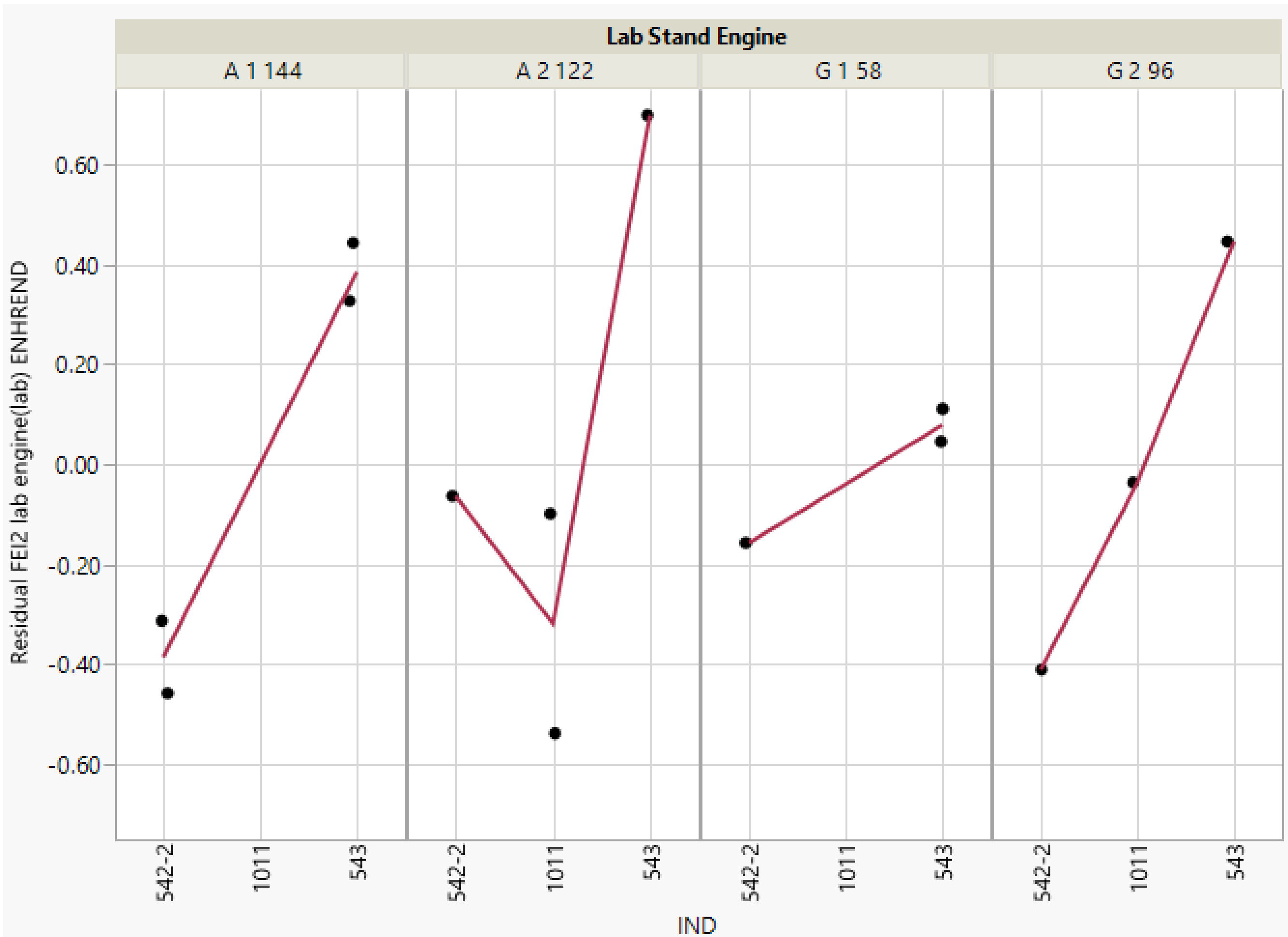
Analyzing PM Data - FEI2

- Plot of FEI2 (unadjusted results are shown)



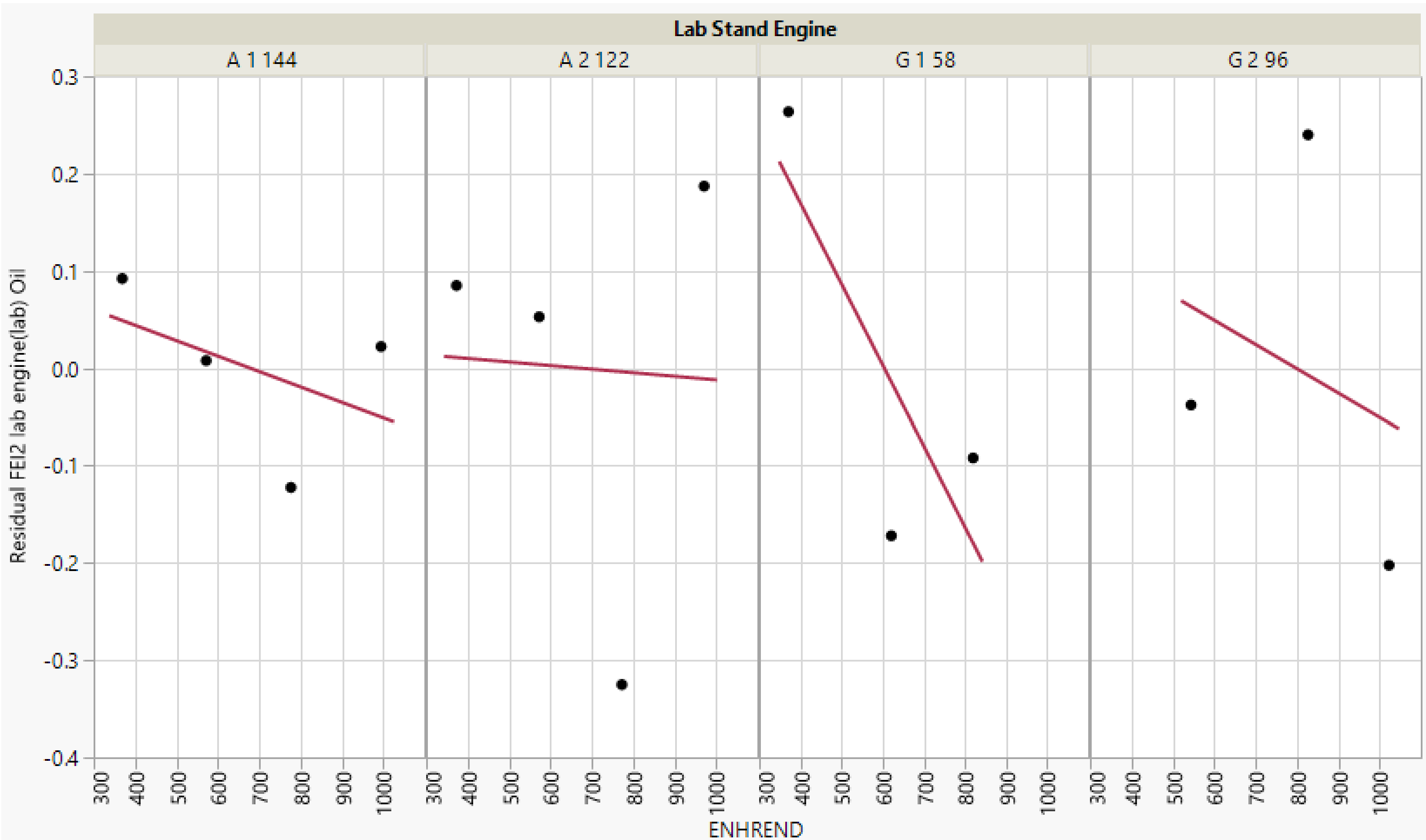
Analyzing PM Data - FEI2

- The consistency of oil discrimination across engines is difficult to judge given the amount of data
- Residuals are from a model containing lab, engine(lab), and ENHREND



Analyzing PM Data - FEI2

- Data suggest use of no transformation for ENHREND is reasonable within the shortened engine life
- Residuals are from a model containing lab, engine(lab), and IND



Analyzing PM Data - FEI2

- Overall ANOVA Summary of FEI2 data:
  - FEI2 Engine Hours Adjustment:
    - FEI2 = FEI2_OR + 0.000258*(ENHREND – 686)
    - We acknowledge that the ENHREND term is not statistically significant (using a 0.05 p-value threshold), but calculate a correction knowing that from the n=28 analysis there is significant evidence of an hours effect

Summary of Fit

RSquare	0.860122
RSquare Adj	0.740226
Root Mean Square Error	0.221111
Mean of Response	1.712143
Observations (or Sum Wgts)	14

Parameter Estimates

Term	Estimate	Prob>|t|
Intercept	1.8137831	<.0001*
LTMSLAB[A]	-0.006145	0.9218
LTMSLAB[A]:ENGNO[122]	-0.131621	0.1843
LTMSLAB[G]:ENGNO[58]	-0.308961	0.0186*
IND[542-2]	-0.192046	0.0668
IND[1011]	-0.290901	0.0403*
ENHREND	-0.000258	0.3964

Effect Tests

Source	DF	Prob > F
LTMSLAB	1	0.9218
ENGNO[LTMSLAB]	2	0.0243*
IND	2	0.0030*
ENHREND	1	0.3964

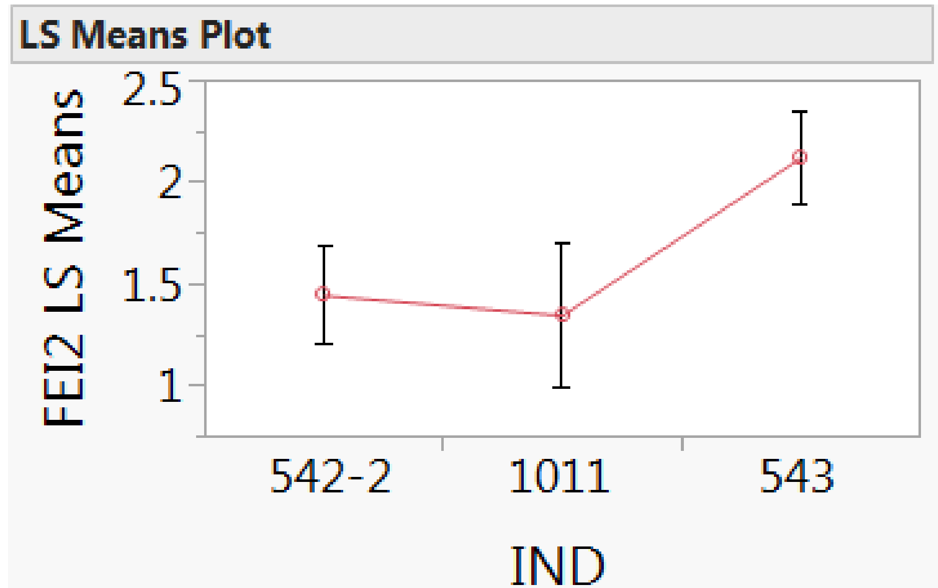
Analyzing PM Data - FEI2

- On average, oils significantly differ: 543 > (542-2 & 1011)

Least Squares Means Table

Level	Least Sq Mean
542-2	1.4449215
1011	1.3460664
543	2.1199139

Level	- Level	Difference	p-Value
543	1011	0.7738475	0.0110*
543	542-2	0.6749924	0.0042*
542-2	1011	0.0988551	0.8575



Level		Least Sq Mean
543	A	2.1199139
542-2	B	1.4449215
1011	B	1.3460664

Levels not connected by same letter are significantly different.

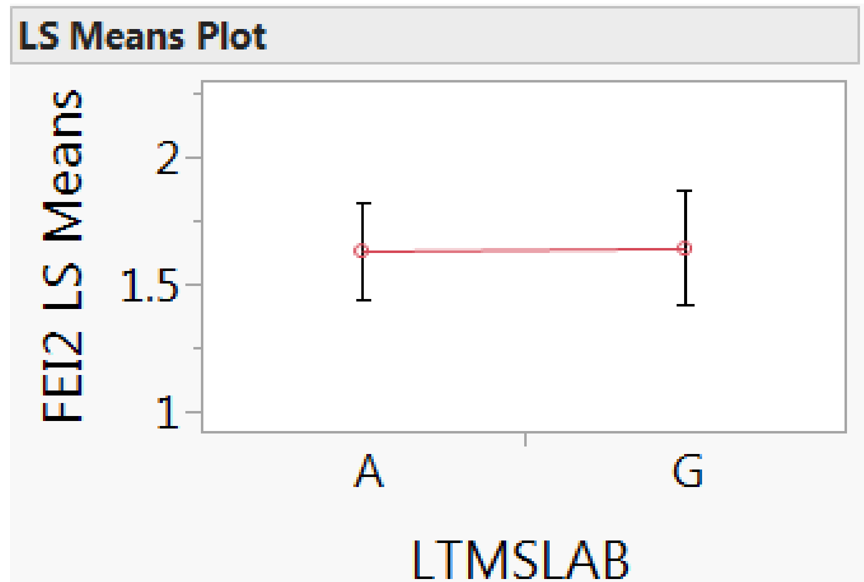
Analyzing PM Data - FEI2

- On average, Labs A and G do not significantly differ in their FEI2 results

Least Squares Means Table

Level	Least Sq Mean
A	1.6308223
G	1.6431122

Level	- Level	Difference	p-Value
G	A	0.0122899	0.9218

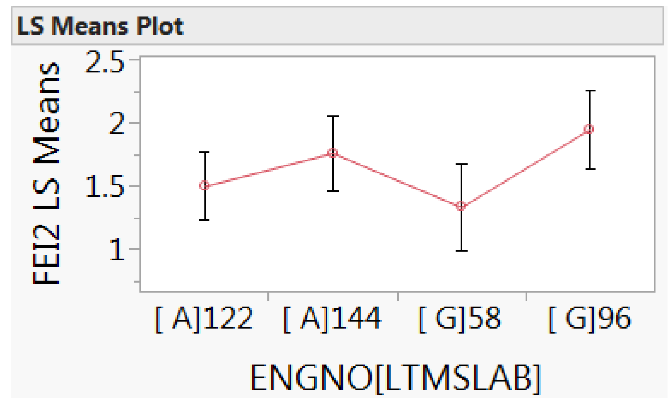


Analyzing PM Data - FEI2

- On average, Lab G engines significantly differ from one another with engine 58 producing lower FEI2, on average, compared to engine 96.
- This supports an engine based LTMS system

Parameter Estimates

Term	Estimate	Prob>|t|
Intercept	1.8137831	<.0001*
LTMSLAB[A]	-0.006145	0.9218
LTMSLAB[A]:ENGNO[122]	-0.131621	0.1843
LTMSLAB[G]:ENGNO[58]	-0.308961	0.0186*
IND[542-2]	-0.192046	0.0668
IND[1011]	-0.290901	0.0403*
ENHREND	-0.000258	0.3964



Least Squares Means Table

Level	Least Sq Mean
[A]122	1.4992018
[A]144	1.7624429
[G]58	1.3341516
[G]96	1.9520728

FEI2 Precision

Model: FEI2 vs. Oil, Lab, Engine(Lab)

Model RMSE	Repeatability
• s = 0.21 • VIE Precision Matrix s=0.12 • VID Precision Matrix s=0.14 • VID current data s=0.12	• s = 0.21 • r = 0.58

Model: FEI2 vs. Oil

Reproducibility
• s = 0.31 • R = 0.86

Note: VIF estimates are calculated on engine hour corrected results rounded to 2 decimal places

FEI2 Precision

Based upon the Seq. VIE and VID pooled standard deviations (s_r) and ASTM's repeatability (r), there is no significant difference between an FEI2 result[1] of 0.92 – 1.50 for the VIF and 1.06 – 1.50 for the VID.

Note 1: An FEI2 of 1.5 was arbitrarily selected in the calculations as the upper pass/fail limit.

Comparing VIF Precision and Oil Discrimination with other Tests

Sequence VID FEI1

Oil		Target (LTMS)		
540	(GF5A)	1.32	Method Standard Deviation	0.13
541	(GF5D)	0.87	**Full span of results (st devs)**	4.77
542	(GF5X)	1.49		
1010		1.34		

Sequence VID FEI2

Oil		Target (LTMS)		
540	(GF5A)	1.04	Method Standard Deviation	0.14
541	(GF5D)	0.71	**Full span of results (st devs)**	2.79
542	(GF5X)	0.8		
1010		1.1		

Sequence VIF FEI1

Oil	LS Mean (Regression)		
542-2	2.23	Regression RMSE	0.17
1011	1.43	**Full span of results (st devs)**	4.71
543	1.77		

Sequence VIF FEI2

Oil	LS Mean (Regression)		
542-2	1.44	Regression RMSE	0.21
1011	1.35	**Full span of results (st devs)**	3.67
543	2.12		

<u>Comments</u>

- A method of measuring test precision and oil discrimination is to divide the (FEI difference of best and worst performing reference oils) by the (test precision)
- The result is the # *of standard deviations that separate good and bad oil performance*
- Comparing the standard deviation alone is not necessarily meaningful; what if the standard deviation is larger, but oils span a larger FEI range?
- Granted, this approach is influenced by choice of reference oils
- Engine tests typically show reference oil discrimination of about 1-3 standard deviations (see next slide)

Comparing VIE Precision and Oil Discrimination with other Tests

- Sequence IIIG ln(PVIS): oils separated by 2.0 standard deviations
- Sequence IIIG WPD: oils separated by 2.3 standard deviations
- Sequence IVA wear: oils separated by 1.2 standard deviations
- Sequence VID FEI2: oils separated by 2.9 standard deviations

Seq IIIG

PERCENT VISCOSITY INCREASE
Unit of Measure: LN(PVIS)

Reference Oil	Mean	Standard Deviation
434	4.7269	0.3859
435	5.1838	0.3096
435-2	5.1838	0.3096
438	4.5706	0.1768

Seq IIIG

WEIGHTED PISTON DEPOSITS
Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
434	4.80	0.96
435	3.59	0.58
435-2	3.59	0.58
438	3.20	0.33

Seq IVA

AVERAGE CAMSHAFT WEAR
Unit of Measure: micrometers

Reference Oil	Mean	Standard Deviation
1006-2	102.18	13.54
1007	84.76	15.40

Seq VID

FUEL ECONOMY IMPROVEMENT at 100 Hours
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
540 (GF5A)	1.04	0.14
541 (GF5D)	0.71	0.14
542 (GF5X)	0.80	0.14
1010	1.10	0.18

LTMS Targets (FEIAdj)

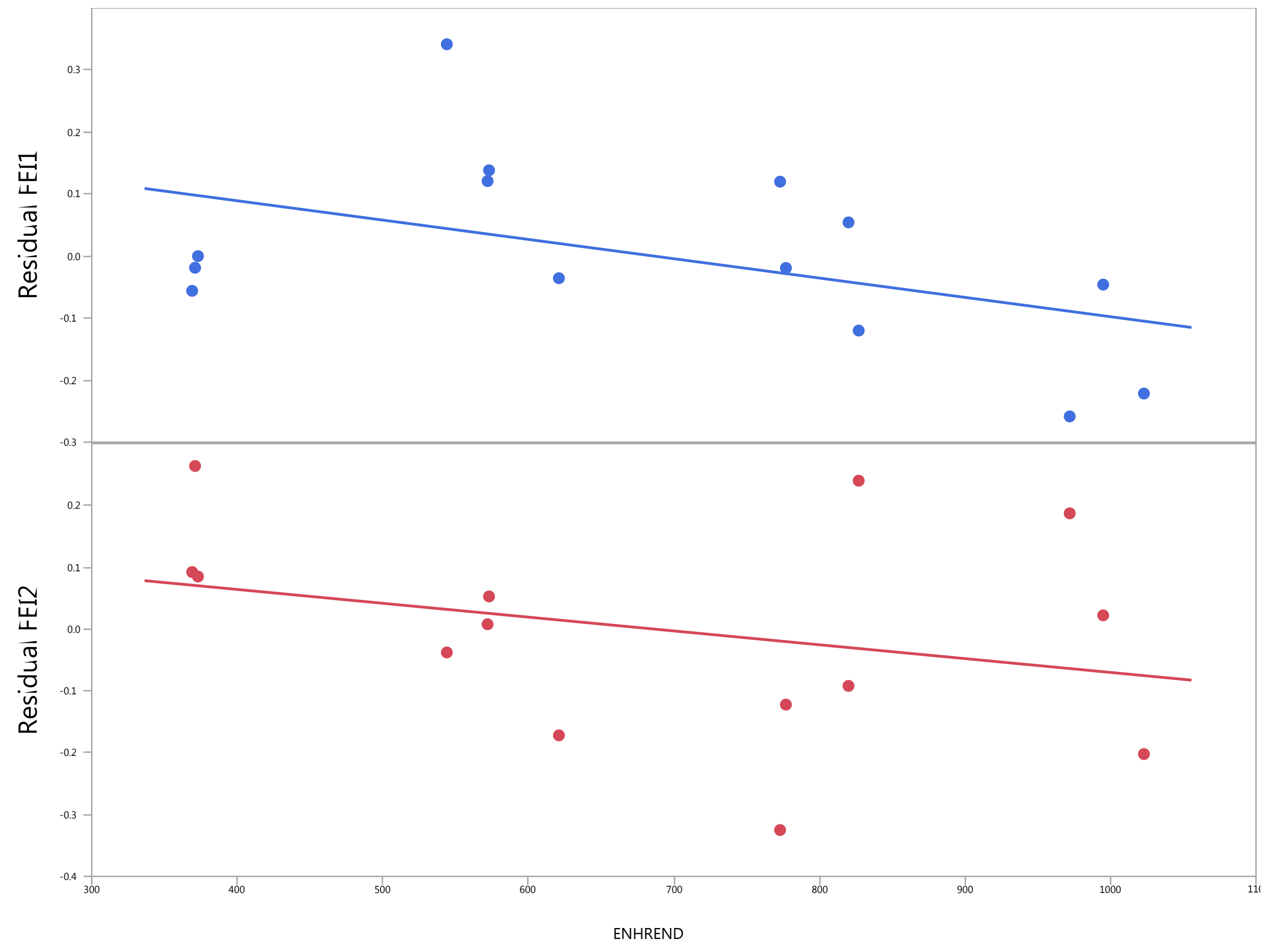
FEIAdjusted	LSMean		Standard Deviation		RMSE	
Oil	FEI1	FEI2	FEI1	FEI2	FEI1	FEI2
542-2 (n=5)	2.23	1.44	0.18	0.12	0.17	0.21
1011 (n=3)	1.43	1.35	0.16	0.52	0.17	0.21
543 (n=6)	1.77	2.12	0.17	0.30	0.17	0.21

Note: A guideline for establishing oil targets is to have at least 6 test results to estimate an oil's targets. This is true for 1 of the 3 oils.

Appendix A

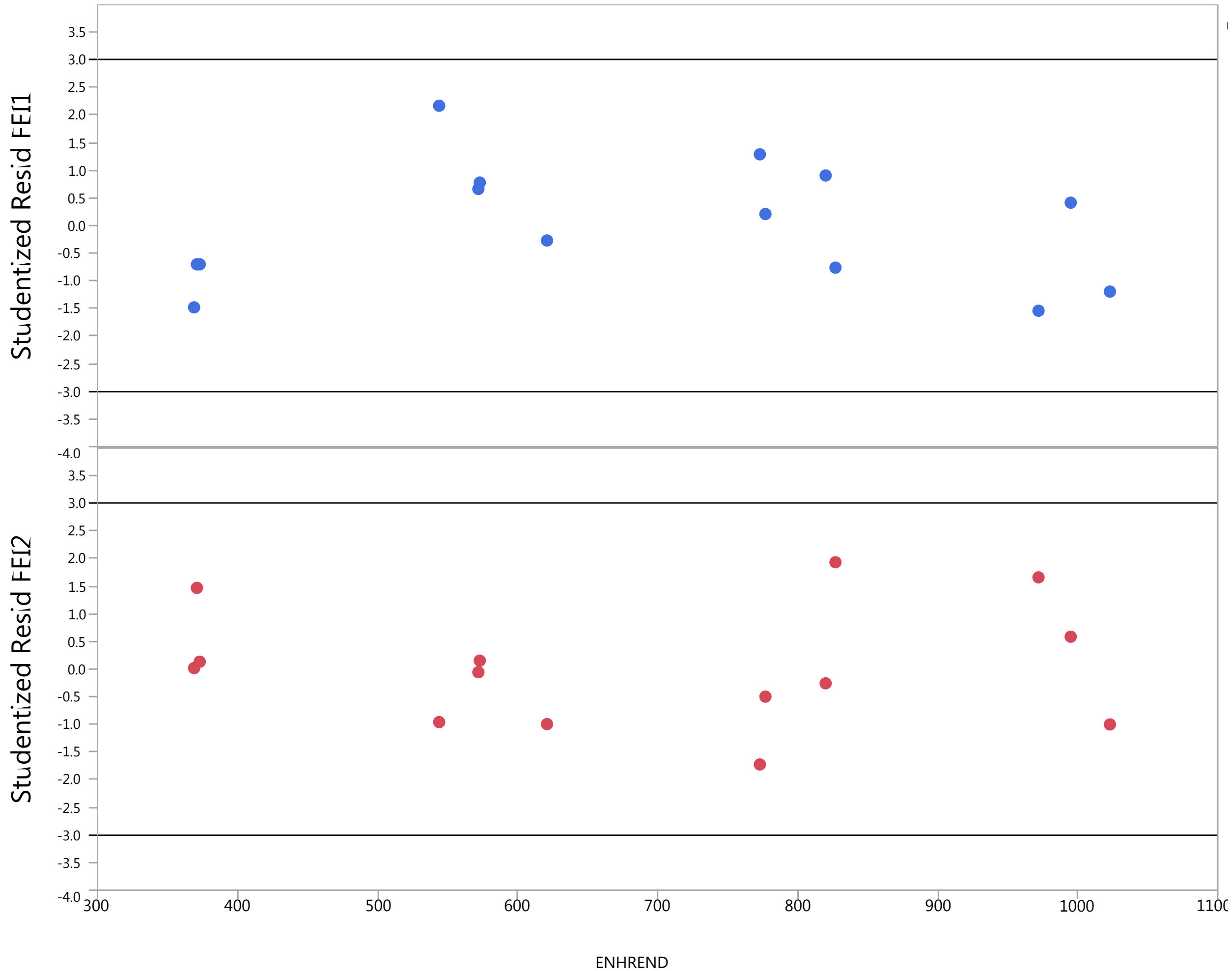
Residual Diagnostics for Models

Residual by Engine Hour



Residual plot (model without ENHREND term) suggests a linear trend.

Studentized Residuals vs. Engine Hours



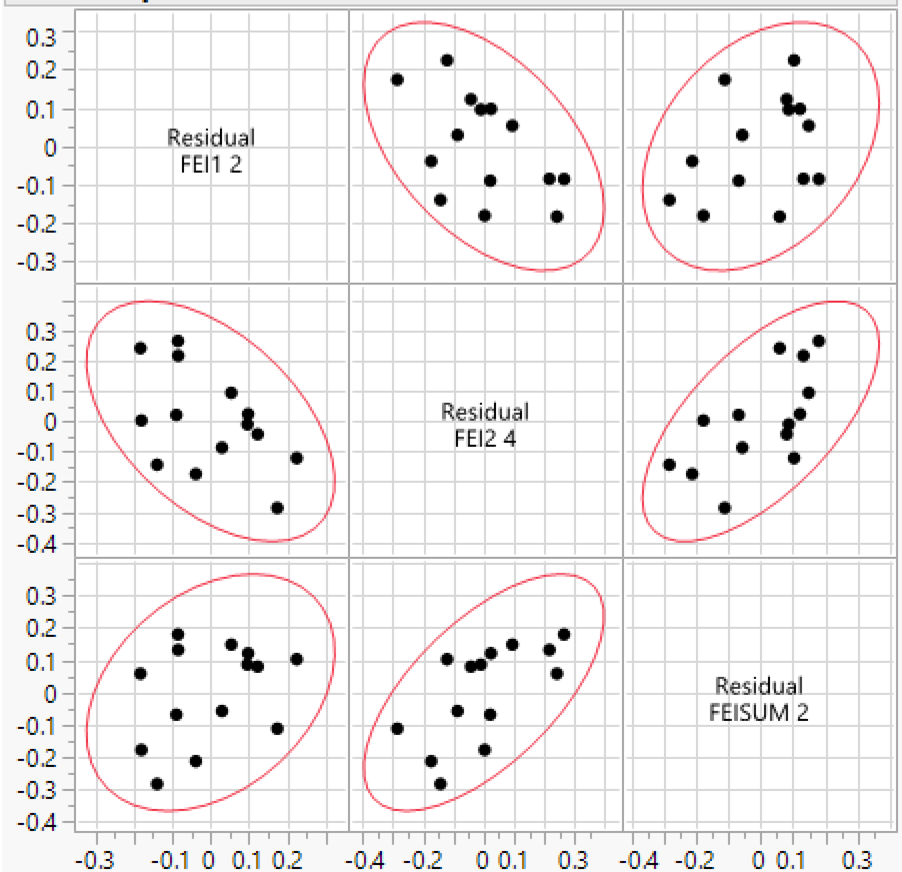
FEI1 and FEI2 models contain lab, engine(lab), IND, and ENHREND

Parameter Correlation

Correlations

	Residual FEI1 2	Residual FEI2 4	Residual FEISUM 2
Residual FEI1 2	1.0000	-0.4986	0.3439
Residual FEI2 4	-0.4986	1.0000	0.6425
Residual FEISUM 2	0.3439	0.6425	1.0000

Scatterplot Matrix



Models contain lab, engine(lab), IND, and ENHREND

Appendix B
VIF Engine Life Determination n=28

Slides are a subset from presentation issued by the Industry Statistician's Group:

VIE-F Engine Life Analysis_7_19_16.pdf

Executive Summary

- Statistical analyses based on the 28 valid VIF matrix tests indicate that the effect of engine hours in FEI1 is not the same for all oils tested. This complicates the estimation of an engine hours correction that is applicable to all oils

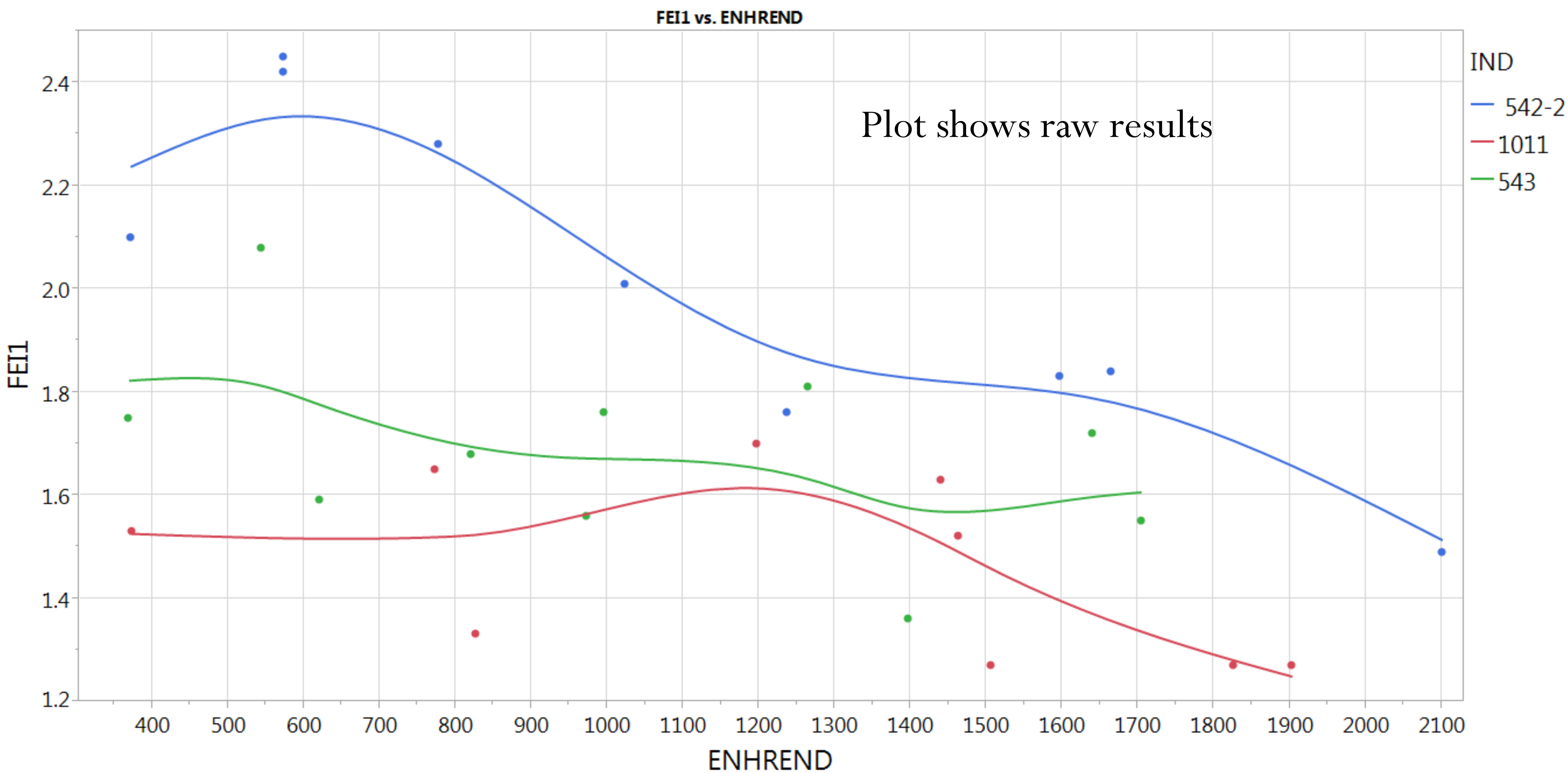
- The panel may find that this rapid decrease in oil separation as engine hours increases requires limiting the VIF engine life

- Multiple statistical approaches have been taken to aid in the determination of engine life

- Based on the results of these various approaches, which follow similar logic used in the VIE engine life determination, a VIF engine life of 4 to 5 tests is reasonable

Assess Engine Life Based on Oil Discrimination

- FEI1 oil discrimination over the engine life
  - Less oil discrimination occurs at higher hours



Assess Engine Life Based on Oil Discrimination

- Overall ANOVA Summary of FEI1 data:
  - Analysis indicates that the engine hours effect in FEI1 is not consistent across the oils tested

Summary of Fit

RSquare	0.841812
RSquare Adj	0.775207
Root Mean Square Error	0.15371
Mean of Response	1.721786
Observations (or Sum Wgts)	28

Analysis of Variance

Parameter Estimates

Term	Estimate	Prob>|t|	VIF
Intercept	1.9908417	<.0001*	.
IND[542-2]	0.3070791	<.0001*	1.4689633
IND[1011]	-0.263521	<.0001*	1.5751954
LTMSLAB[A]	0.0360773	0.2456	1.0689289
LTMSLAB[A]:ENGNO[122]	0.0333984	0.4443	1.1576671
LTMSLAB[G]:ENGNO[58]	-0.113188	0.0221*	1.1077156
ENHREND	-0.000235	0.0012*	1.1346756
(ENHREND-1126.5)*IND[542-2]	-0.000224	0.0125*	1.3256859
(ENHREND-1126.5)*IND[1011]	0.0001796	0.0671	1.4722341

Effect Tests

Source	Prob > F
IND	<.0001*
LTMSLAB	0.2456
ENGNO[LTMSLAB]	0.0603
ENHREND	0.0012*
ENHREND*IND	0.0333*

Assess Engine Life Based on Oil Discrimination

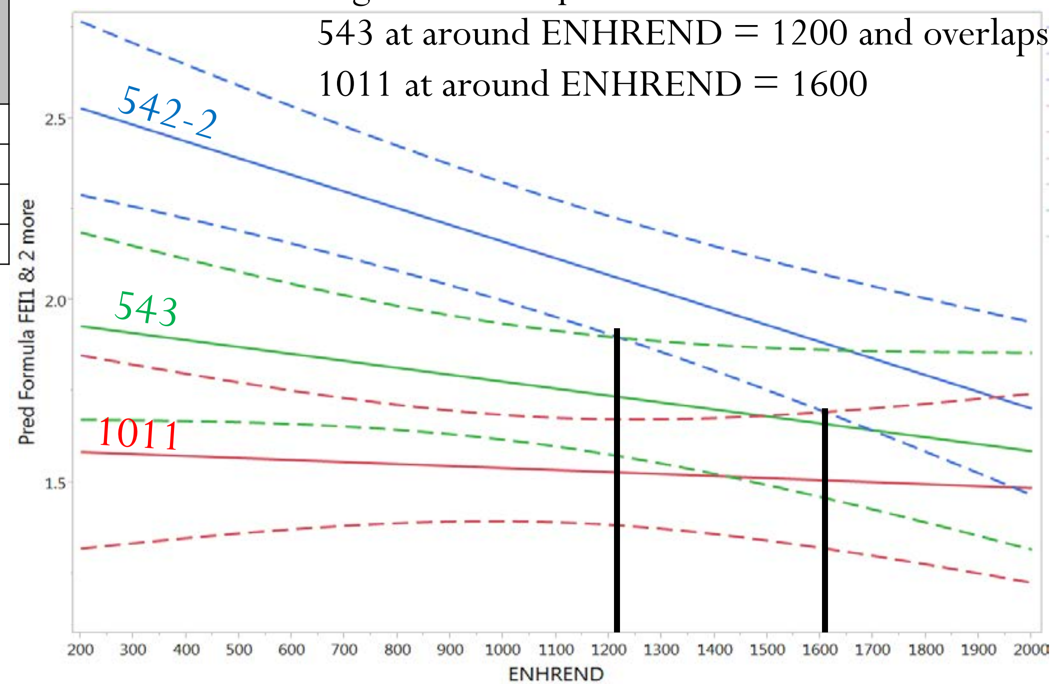
- FEI1 oil discrimination over the engine life
  - Using the prediction model we can obtain estimates for when oil discrimination is lost within each engine.
  - These estimates can be used to gauge VIF engine life.

Lab-Engine	Predicted Hours at which 542-2 no longer discriminates from all other oils	Predicted Hours at which 542-2 no longer discriminates from any other oil
A 144	≈ 1300	≈ 1650
A 122	≈ 1200	≈ 1600
G 58	≈ 1300	≈ 1700
G 96	≈ 1150	≈ 1600

Refer to Appendix D.1 for plots of other stands

Example: Using A 122

Notice how the 95% confidence interval for 542-2 begins to overlap the 95% confidence interval for 543 at around ENHREND = 1200 and overlaps 1011 at around ENHREND = 1600



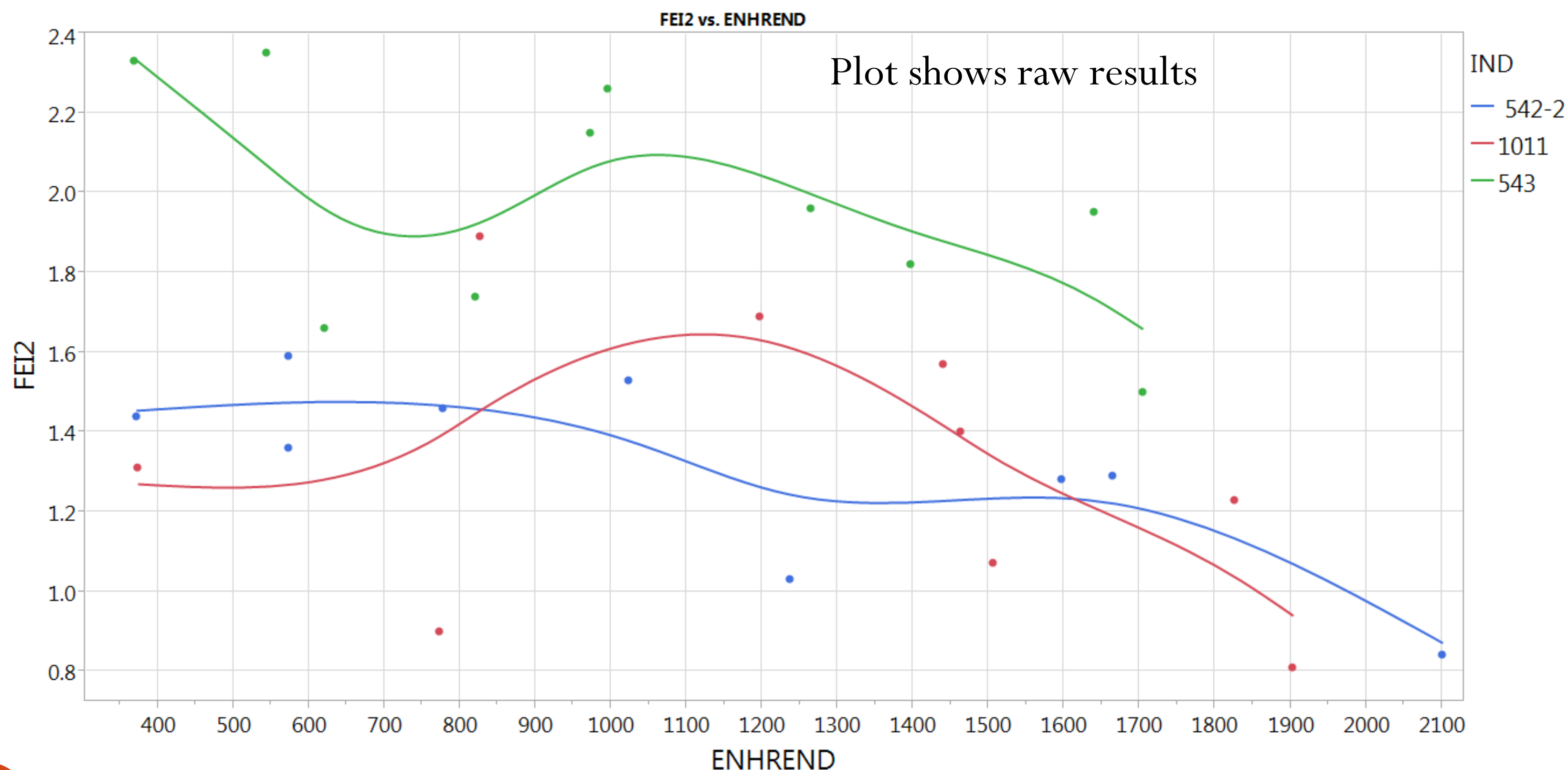
Assess Engine Life Based on Oil Discrimination

- FEI1 oil discrimination over the engine life
  - Another approach to determine VIF engine life would be to track the p-value of the oil*ENHREND term using various subsets of the valid matrix data. The significance of this term represents the point at which the same engine hour correction should no longer be used for all oils.

Data used	Number of test results	Overall p-value of oil*ENHREND term	Range of p-values by oil of oil*ENHREND term
ENHREND < 1100	14	.8321	.5872 to .9833
ENHREND < 1300	17	.2591	.1489 to .8258
ENHREND < 1450	19	.0648	.0228 to .2633
ENHREND < 1600	22	.0402	.0163 to .3575
ENHREND < 1800	25	.0392	.0147 to .8215
All Valid Tests	28	.0333	.0125 to .6322

Assess Engine Life Based on Oil Discrimination

- FEI2 oil discrimination over the engine life
  - 543 discrimination from 542-2 and 1011 is consistent throughout the engine life



Assess Engine Life Based on Oil Discrimination

- Overall ANOVA Summary of FEI2 data:
  - Analysis indicates that the engine hours effect in FEI2 is consistent across the oils tested

Summary of Fit

Root Mean Square Error	0.178313
Mean of Response	1.550357
Observations (or Sum Wgts)	28

Analysis of Variance

Parameter Estimates

Term	Estimate	Prob>|t|	VIF
Intercept	1.8080271	<.0001*	.
IND[542-2]	-0.194258	0.0009*	1.4689633
IND[1011]	-0.214514	0.0005*	1.5751954
LTMSLAB[A]	0.0228922	0.5201	1.0689289
LTMSLAB[A]:ENGNO[122]	-0.076093	0.1414	1.1576671
LTMSLAB[G]:ENGNO[58]	-0.279961	<.0001*	1.1077156
ENHREND	-0.000227	0.0051*	1.1346756
(ENHREND-1126.5)*IND[542-2]	-0.000021	0.8261	1.3256859
(ENHREND-1126.5)*IND[1011]	0.0001242	0.2616	1.4722341

Effect Tests

Source	Prob > F
IND	<.0001*
LTMSLAB	0.5201
ENGNO[LTMSLAB]	<.0001*
ENHREND	0.0051*
ENHREND*IND	0.4947

Assess Engine Life Based on Oil Discrimination

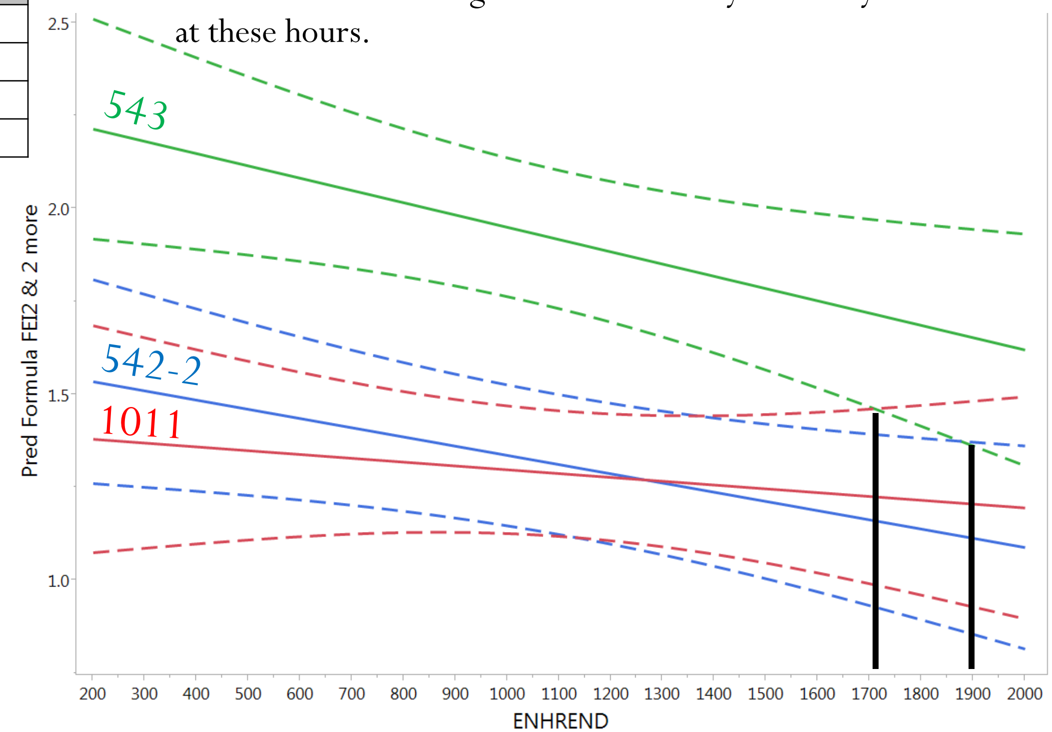
- FEI2 oil discrimination over the engine life
  - Using the prediction model we can obtain estimates for when oil discrimination is lost within each engine.
  - These estimates can be used to gauge VIF engine life based on FEI2.

Lab-Engine	Predicted Hours at which 543 no longer discriminates from all other oils	Predicted Hours at which 543 no longer discriminates from any oil
A 144	≈ 1750	≈ 1900
A 122	≈ 1700	≈ 1900
G 58	≈ 1800	≈ 1950
G 96	≈ 1700	≈ 1825

Refer to Appendix D.1 for plots of other stands

<u>Example: Using A 122</u>

Notice how the 95% confidence interval for 543 begins to overlap the 95% confidence interval for 1011 at around ENHREND = 1700 and overlaps 542-2 at around ENHREND = 1900. This loss of discrimination at higher hours is mostly driven by a lack of data at these hours.



Assess Engine Life Based on Oil Discrimination

- FEI2 oil discrimination over the engine life
  - Another approach to determine VIF engine life would be to track the p-value of the oil*ENHREND term using various subsets of the valid matrix data. The significance of this term represents the point at which the same engine hour correction should no longer be used for all oils.

Data used	Number of test results	Overall p-value of oil*ENHREND term	Range of p-values by oil of oil*ENHREND term
ENHREND < 1100	14	.1799	.1210 to .9242
ENHREND < 1300	17	.2870	.1293 to .6012
ENHREND < 1450	19	.5187	.3320 to .9908
ENHREND < 1600	22	.2498	.1325 to .7137
ENHREND < 1800	25	.1763	.0725 to .4185
All Valid Tests	28	.4947	.2616 to .8261

Diminishing Oil Discrimination in VIF

FEI1	EngHr	542-2	1011	543	542-2-1011	# of Sd	543-1011	# of Sd
	350	2.41	1.51	1.84	0.90	5.31	0.33	1.97
	550	2.33	1.50	1.81	0.83	4.90	0.31	1.84
	750	2.25	1.49	1.78	0.76	4.49	0.29	1.71
	950	2.17	1.48	1.75	0.69	4.07	0.27	1.58
	1150	2.09	1.47	1.71	0.62	3.66	0.25	1.45
	1350	2.01	1.46	1.68	0.55	3.25	0.22	1.32
	1550	1.93	1.45	1.65	0.48	2.84	0.20	1.19
	1750	1.85	1.44	1.62	0.41	2.43	0.18	1.06
	1950	1.77	1.43	1.59	0.34	2.01	0.16	0.93
	2150	1.69	1.42	1.55	0.27	1.60	0.14	0.80
	2350	1.61	1.41	1.52	0.20	1.19	0.11	0.67
FEI2	EngHr	542-2	1011	543	543-542-2	# of Sd	543-1011	# of Sd
	350	1.56	1.42	2.23	0.67	3.71	0.81	4.50
	550	1.52	1.40	2.17	0.65	3.62	0.77	4.27
	750	1.47	1.38	2.11	0.64	3.53	0.73	4.05
	950	1.43	1.36	2.05	0.62	3.44	0.69	3.83
	1150	1.38	1.34	1.99	0.60	3.35	0.65	3.61
	1350	1.34	1.32	1.93	0.59	3.26	0.61	3.39
	1550	1.30	1.30	1.87	0.57	3.18	0.57	3.16
	1750	1.25	1.28	1.81	0.56	3.09	0.53	2.94
	1950	1.21	1.26	1.75	0.54	3.00	0.49	2.72
	2150	1.16	1.24	1.69	0.52	2.91	0.45	2.50
	2350	1.12	1.22	1.63	0.51	2.82	0.41	2.27

n=28	FEI1	FEI2
RMSE	0.17	0.18
LSMeans		
542-2	2.03	1.35
1011	1.49	1.36
543	1.67	1.97
Effect Size		
%	0.54	0.62
SD	3.18	3.44
Model: Oil, Lab, Engine(Lab), Enghr		

Test discriminates FEI1 approximately 3 standard deviations up to around the 5th test.

Benchmarking: Oil Discrimination in Various GF-5 PCMO Tests

- Sequence IIIG ln(PVIS): oils separated by 2.0 standard deviations
- Sequence IIIG WPD: oils separated by 2.3 standard deviations
- Sequence IVA wear: oils separated by 1.2 standard deviations
- Sequence VID FEI2: oils separated by 2.9 standard deviations

Seq IIIG

PERCENT VISCOSITY INCREASE
Unit of Measure: LN(PVIS)

Reference Oil	Mean	Standard Deviation
434	4.7269	0.3859
435	5.1838	0.3096
435-2	5.1838	0.3096
438	4.5706	0.1768

Seq IIIG

WEIGHTED PISTON DEPOSITS
Unit of Measure: Merits

Reference Oil	Mean	Standard Deviation
434	4.80	0.96
435	3.59	0.58
435-2	3.59	0.58
438	3.20	0.33

Seq IVA

AVERAGE CAMSHAFT WEAR
Unit of Measure: micrometers

Reference Oil	Mean	Standard Deviation
1006-2	102.18	13.54
1007	84.76	15.40

Seq VID

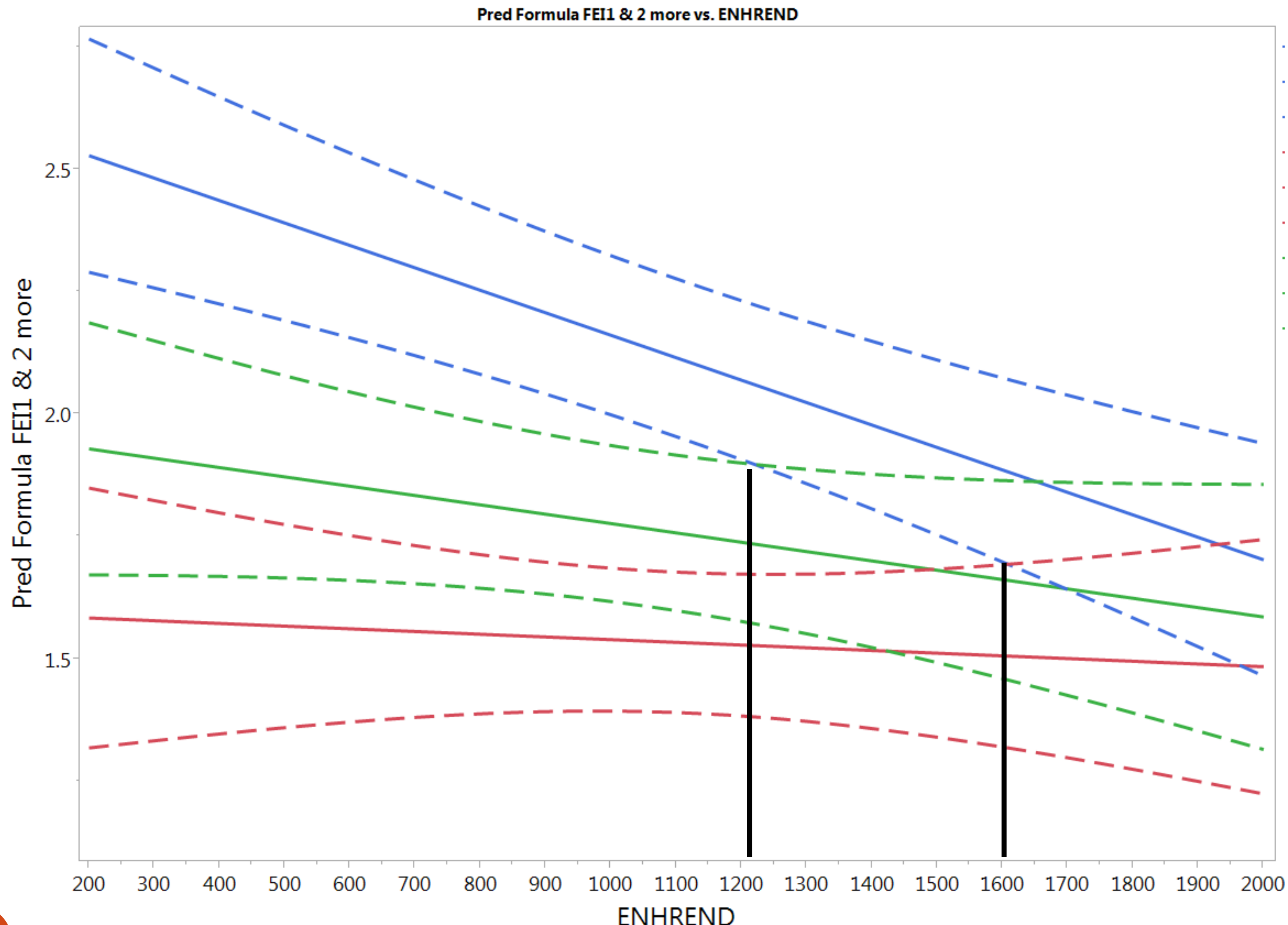
FUEL ECONOMY IMPROVEMENT at 100 Hours
Unit of Measure: Percent

Reference Oil	Mean	Standard Deviation
540 (GF5A)	1.04	0.14
541 (GF5D)	0.71	0.14
542 (GF5X)	0.80	0.14
1010	1.10	0.18

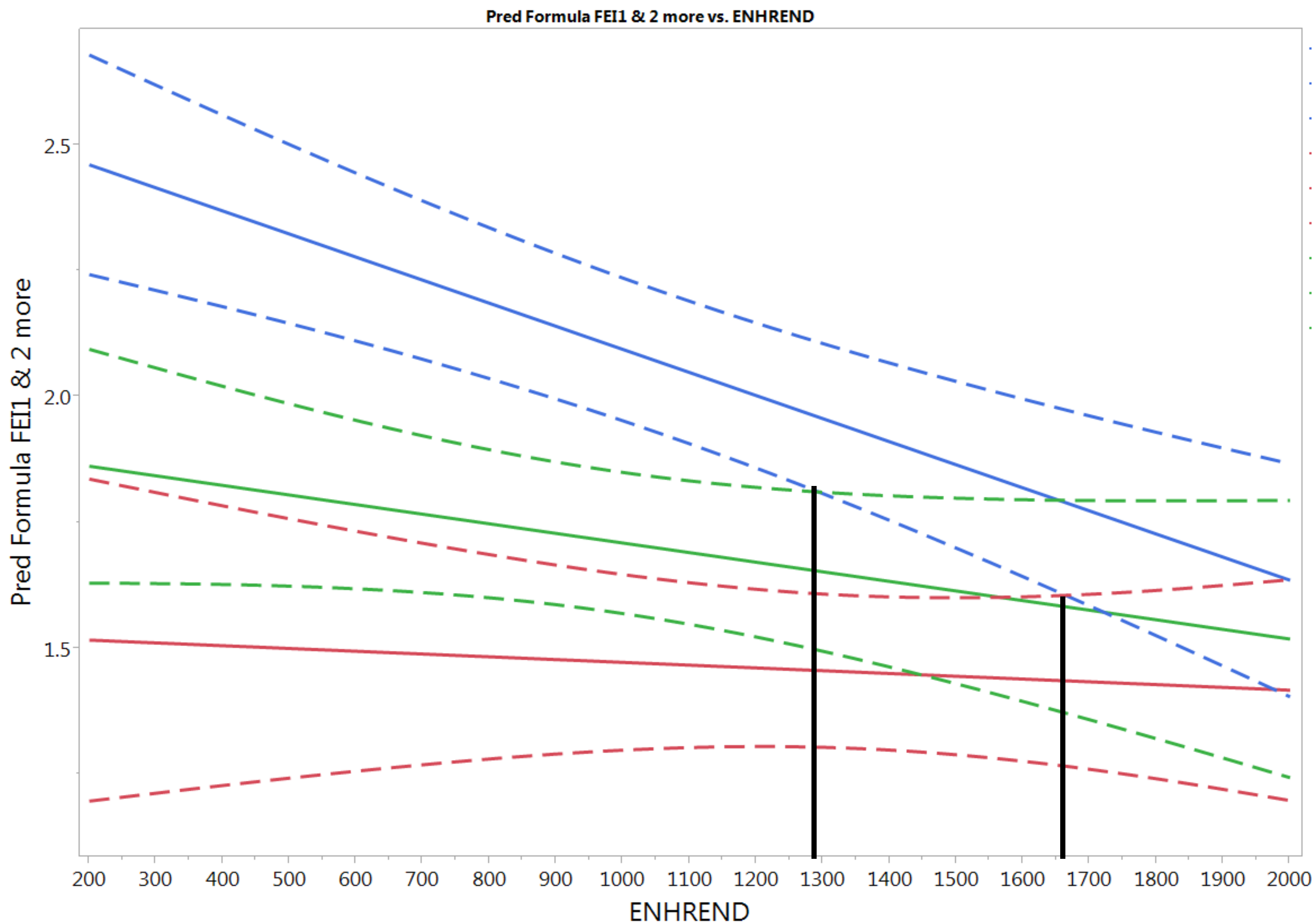
Appendix C.1

Additional Engine Plots

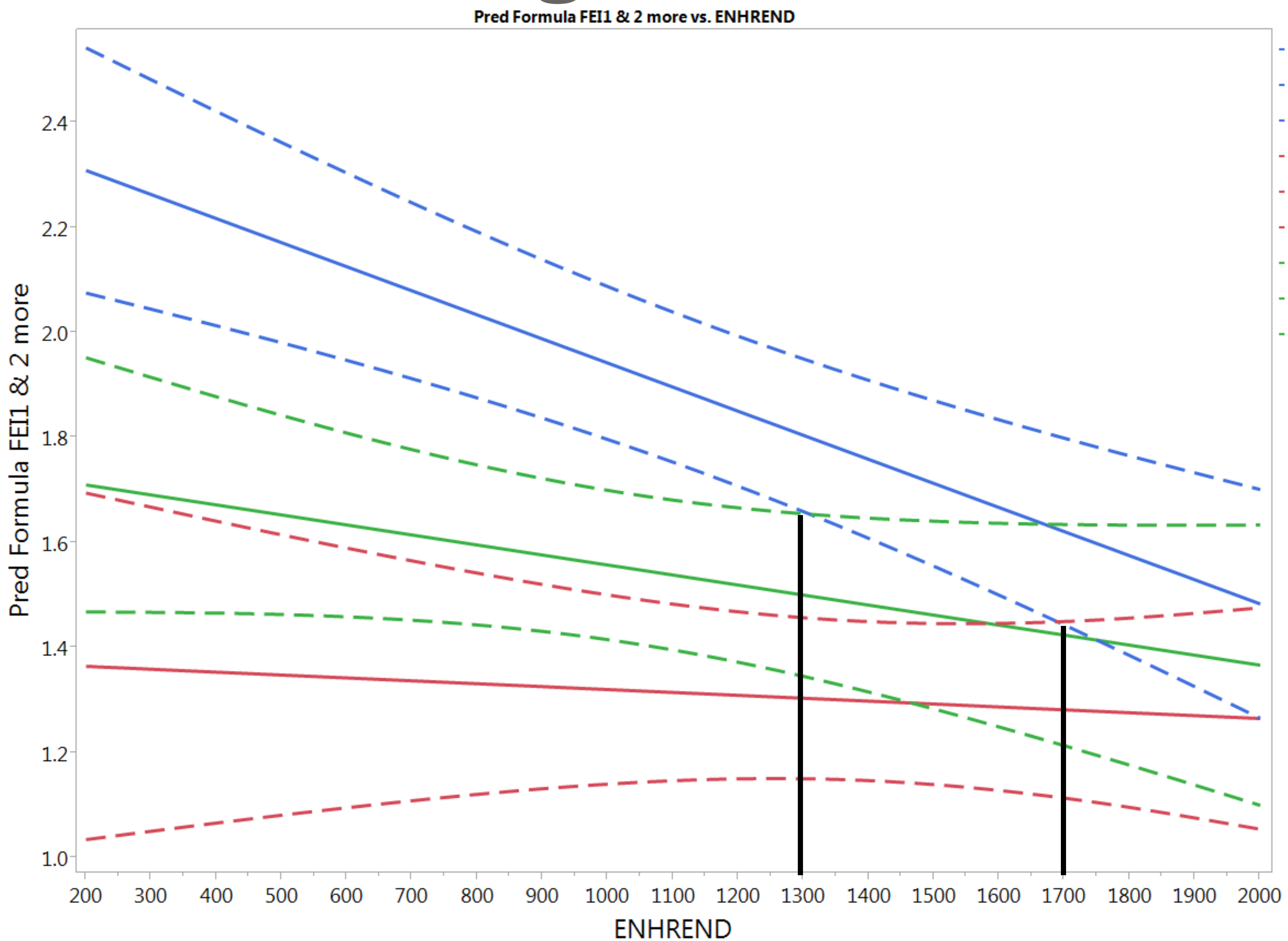
VIF Lab A Eng. 122 FEI1



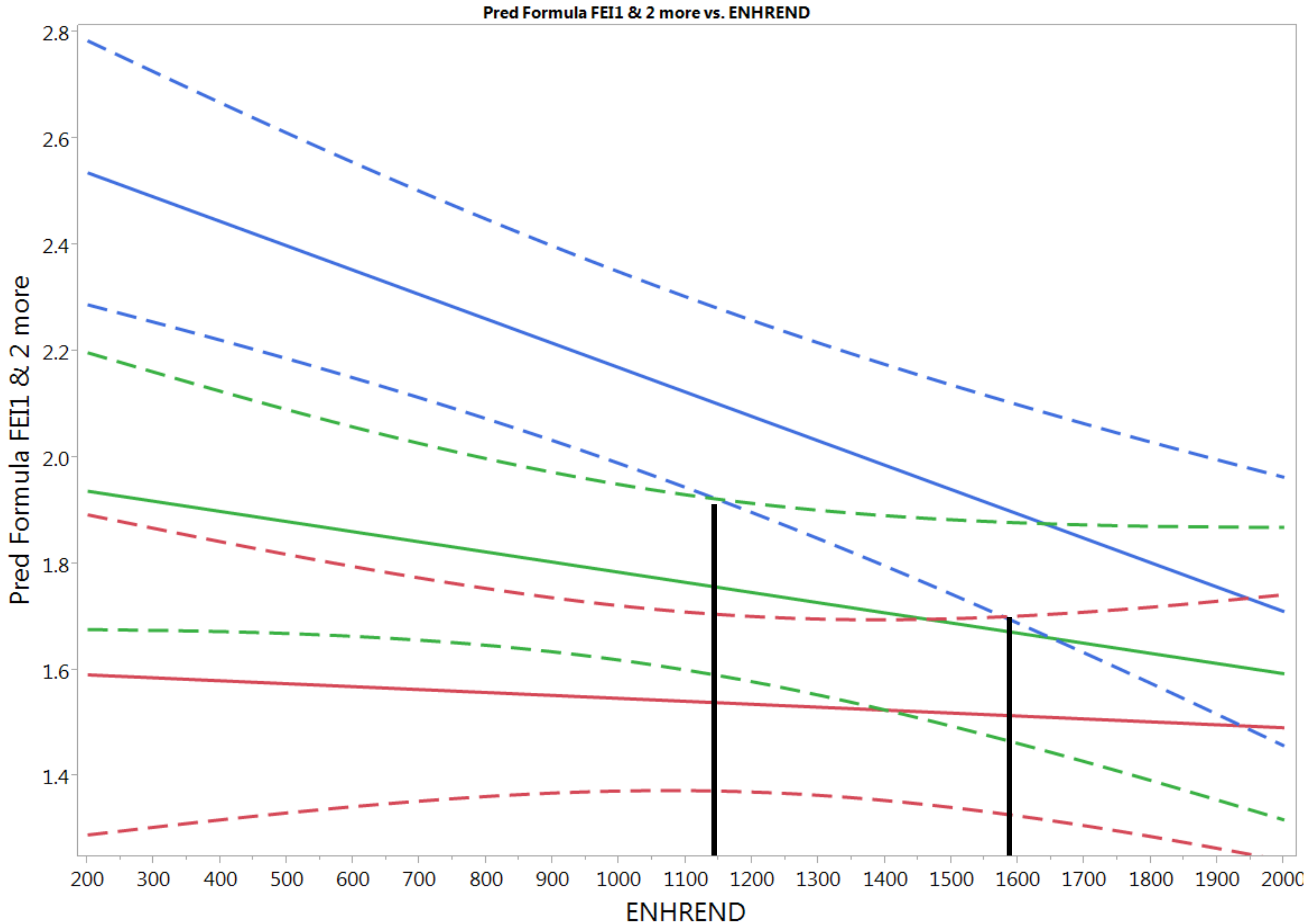
VIF Lab A Eng. 144 FEI1



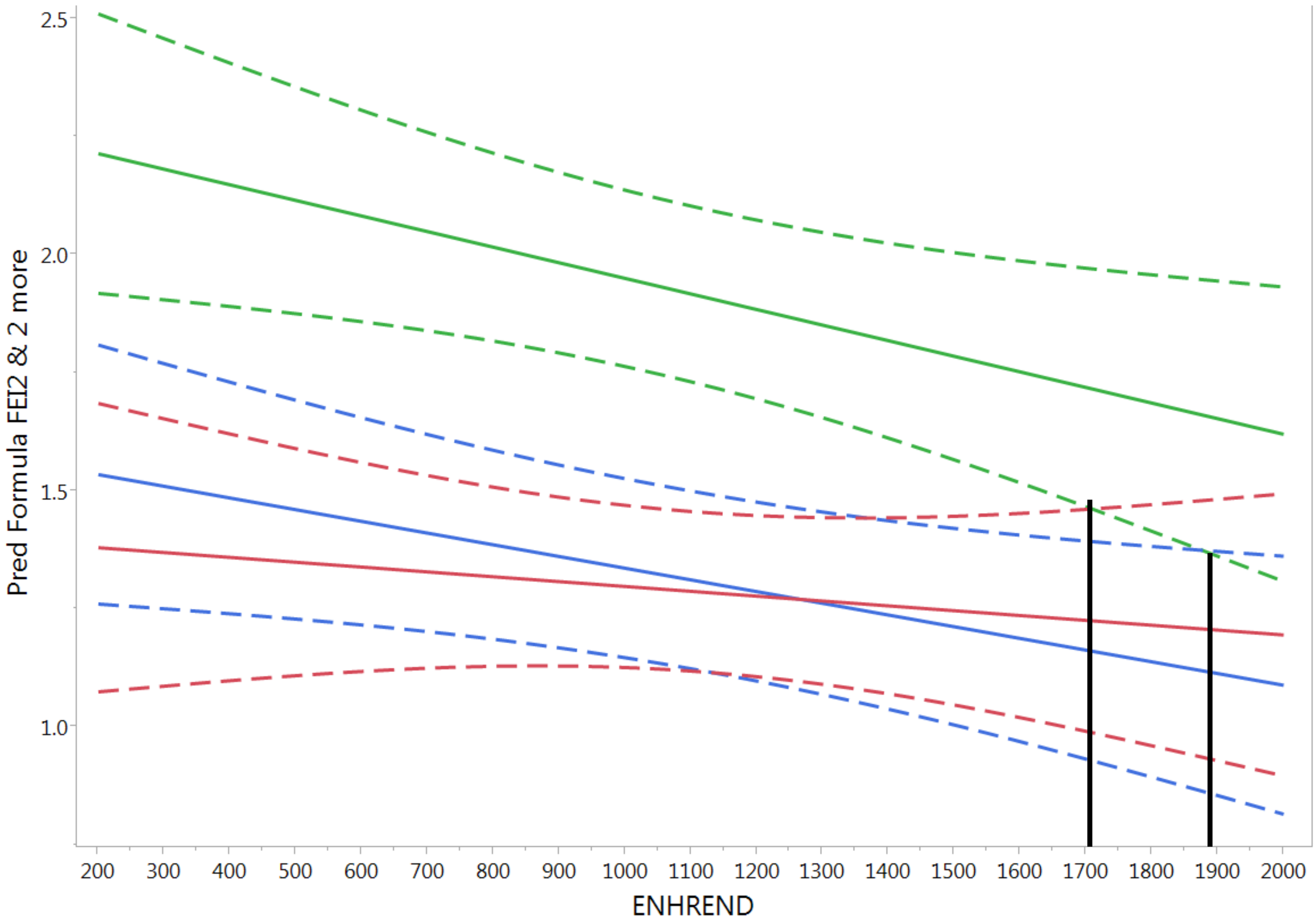
VIF Lab G Eng. 58 FEI1



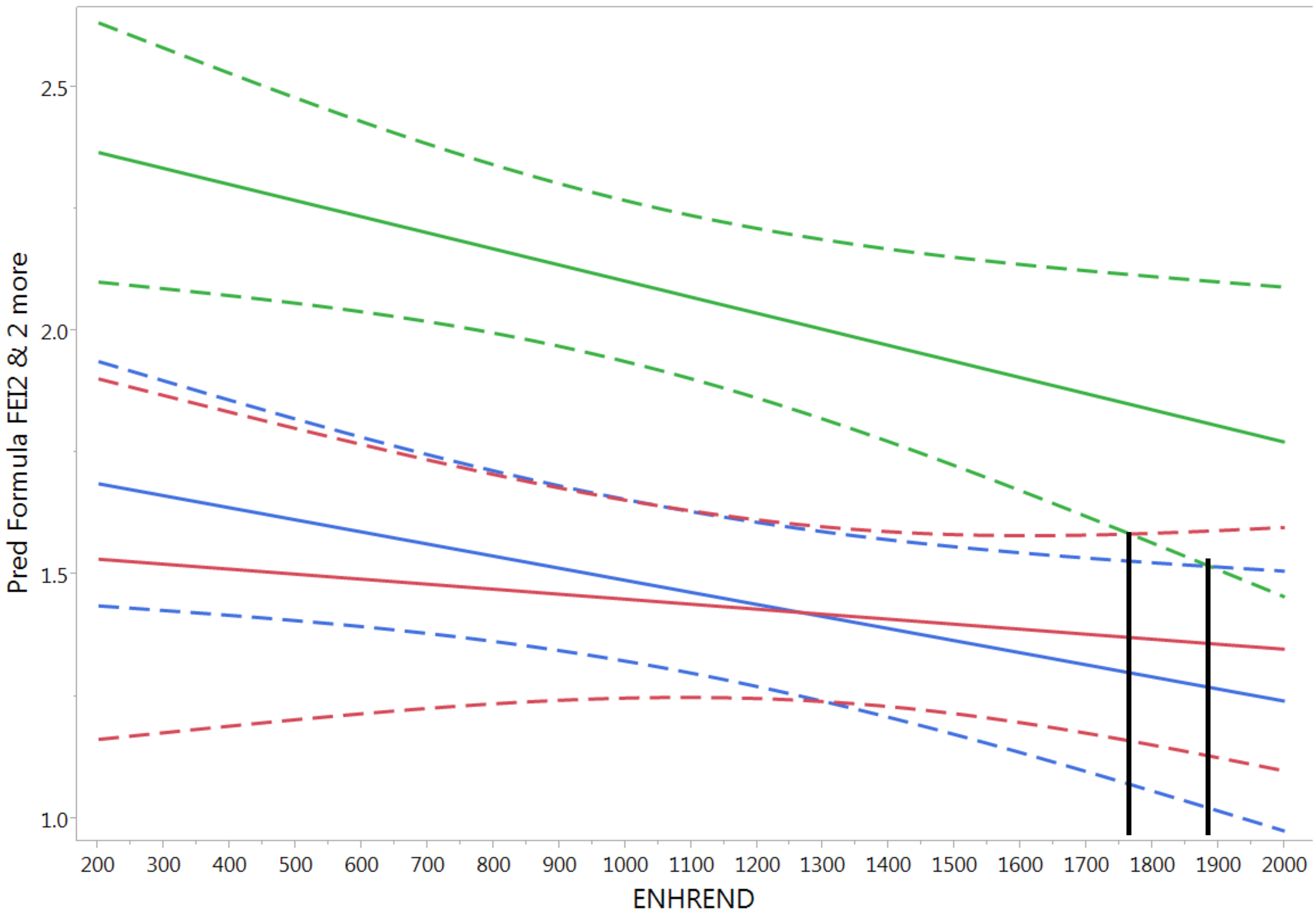
VIF Lab G Eng. 96 FEI1



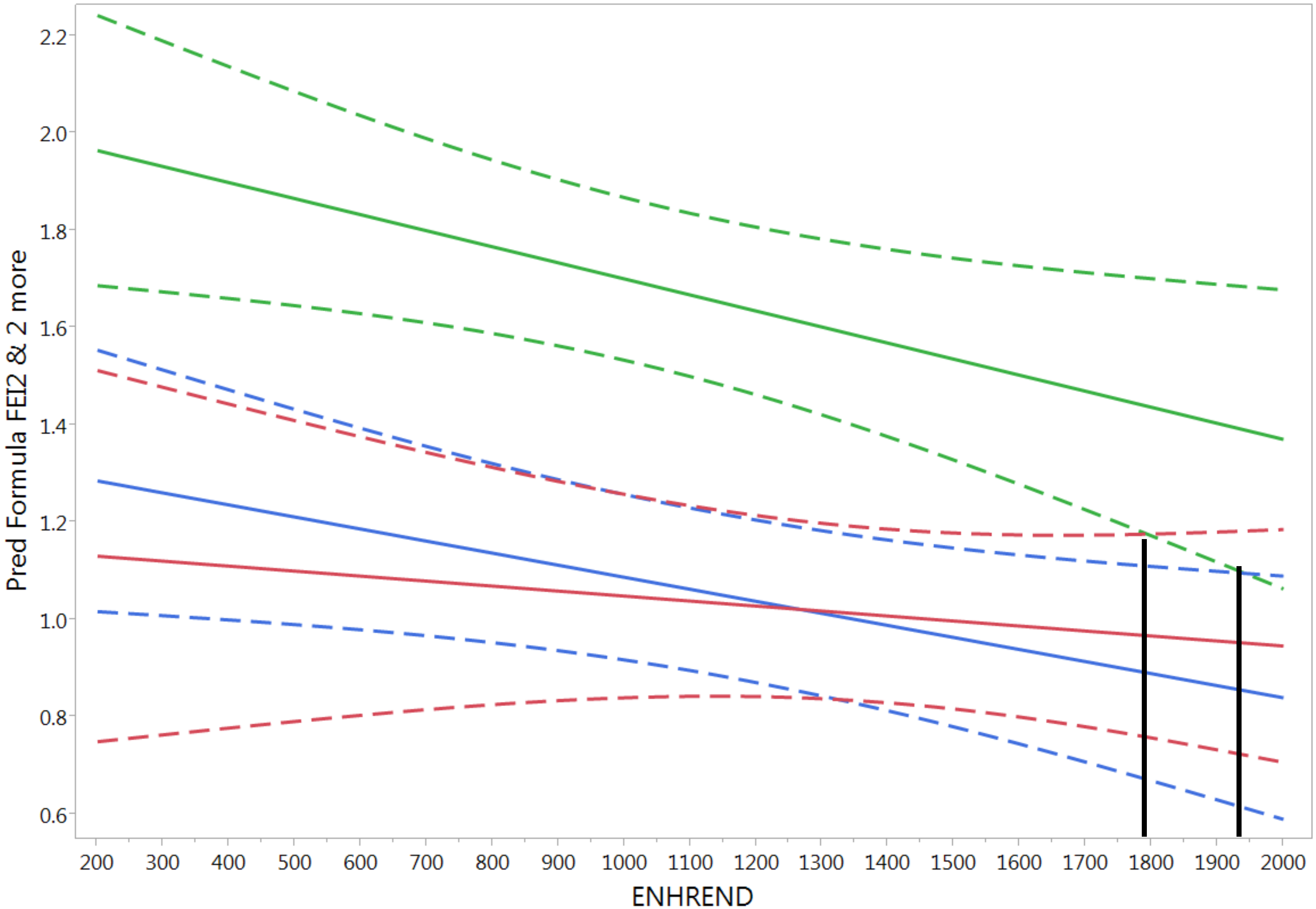
VIF Lab A Eng. 122 FEI2



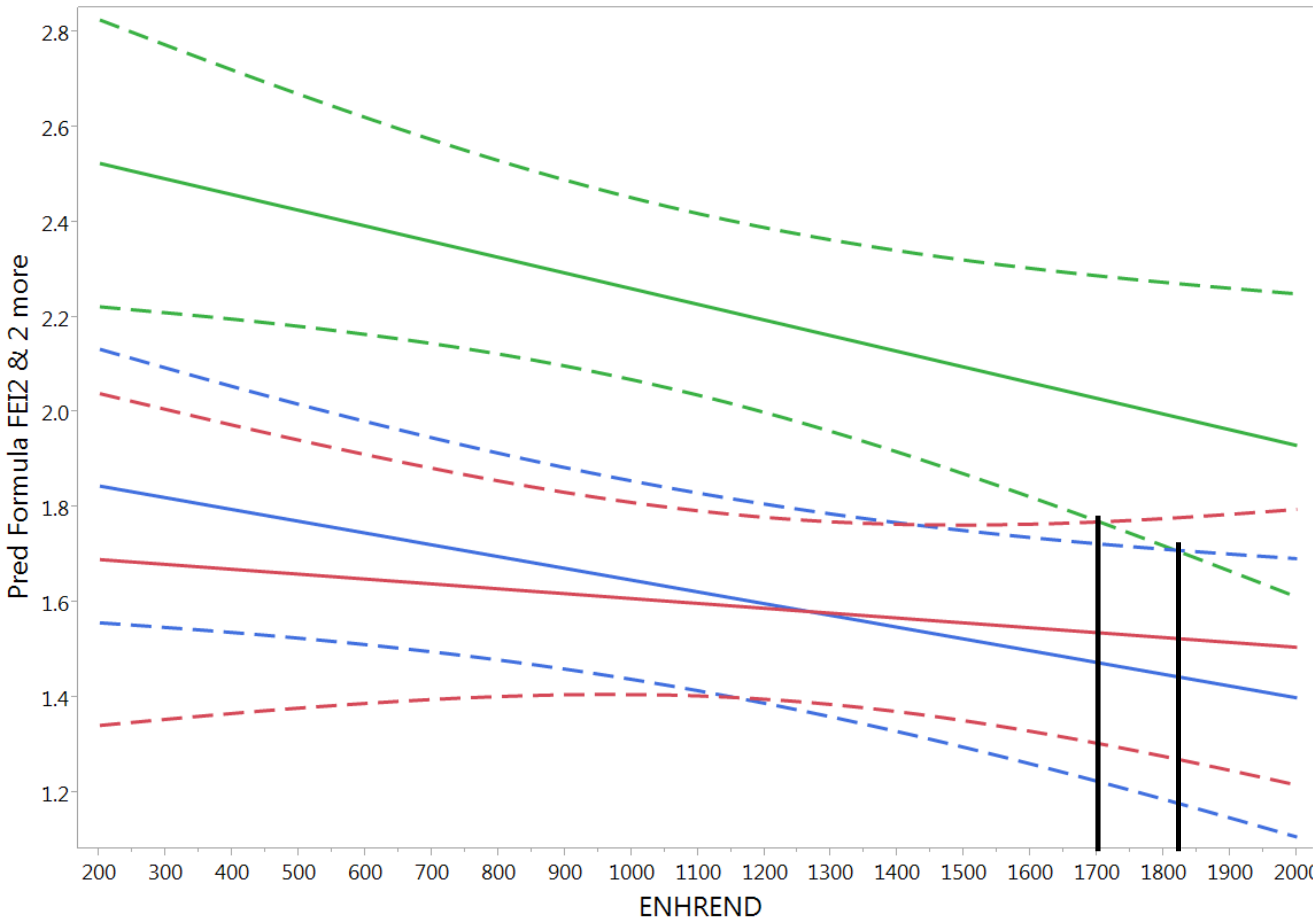
VIF Lab A Eng. 144 FEI2



VIF Lab G Eng. 58 FEI2



VIF Lab G Eng. 96 FEI2



Appendix D
VIF Analysis Summary with Alternate BL Weights

FEI1 BLB2 *(or BLB3)* = 1.0

FEI2 BLA= 1.0

Analyzing FEI1 PM Data with BLB2 Weight = 1.0

- Overall ANOVA Summary of FEI1 data:
  - Analysis indicates differences in the oils
  - FEI1 Engine Hours Adjustment:
    - FEI = FEI1_OR + 0.000708*(ENHREND – 686)

Response FEI1

Whole Model

Summary of Fit

RSquare	0.924236
RSquare Adj	0.859295
Root Mean Square Error	0.139078
Mean of Response	1.890714
Observations (or Sum Wgts)	14

Analysis of Variance

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.3199753	0.127082	18.26	<.0001*
ENHREND	-0.000708	0.000179	-3.95	0.0056*
RefOil[RO1011]	-0.358945	0.072854	-4.93	0.0017*
RefOil[RO542-2]	0.4078602	0.055707	7.32	0.0002*
LTMSLAB[A]	0.0620845	0.038001	1.63	0.1463
LTMSLAB[A]:ENGNO[122]	-0.036092	0.056213	-0.64	0.5413
LTMSLAB[G]:ENGNO[58]	-0.09367	0.063736	-1.47	0.1851

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
ENHREND	1	1	0.3012170	15.5728	0.0056*
RefOil	2	2	1.0395386	26.8718	0.0005*
LTMSLAB	1	1	0.0516292	2.6692	0.1463
ENGNO[LTMSLAB]	2	2	0.0570316	1.4743	0.2922

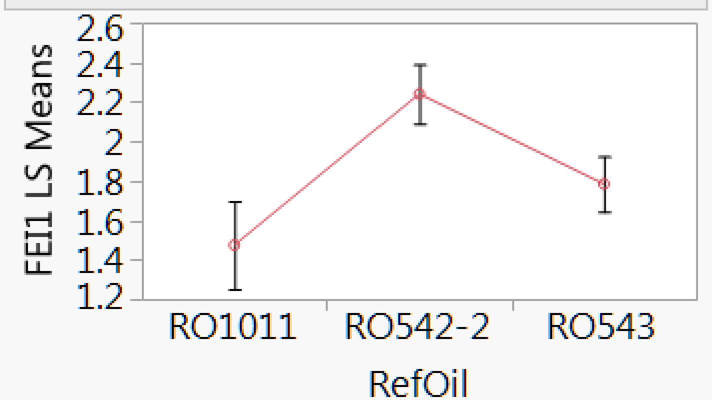
Analyzing FEI1 PM Data with BLB2 Weight = 1.0

- On average, oils significantly differ: 542-2 > (543 & 1011)

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
RO1011	1.4751167	0.09441688	1.52333
RO542-2	2.2419214	0.06365731	2.27800
RO543	1.7851457	0.05953637	1.75167

LS Means Plot



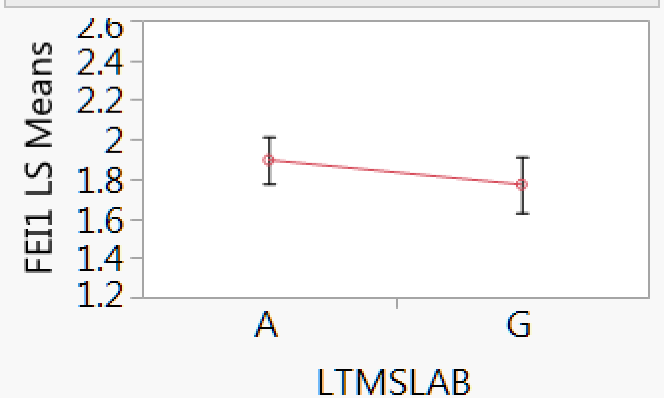
Analyzing FEI1 PM Data with BLB2 Weight = 1.0

- On average, Labs A and G do not significantly differ in their FEI1 results

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	1.8961457	0.05010581	1.94875
G	1.7719768	0.05999141	1.81333

LS Means Plot



Analyzing FEI1 PM Data with BLB2 Weight = 1.0

- On average, engines do not significantly differ within each of the 2 labs

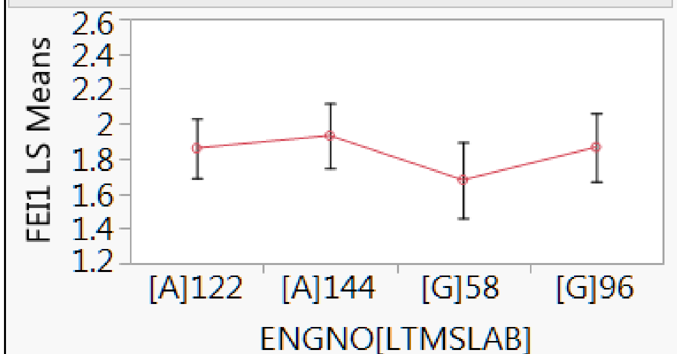
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.3199753	0.127082	18.26	<.0001*
ENHREND	-0.000708	0.000179	-3.95	0.0056*
RefOil[RO1011]	-0.358945	0.072854	-4.93	0.0017*
RefOil[RO542-2]	0.4078602	0.055707	7.32	0.0002*
LTMSLAB[A]	0.0620845	0.038001	1.63	0.1463
LTMSLAB[A]:ENGNO[122]	-0.036092	0.056213	-0.64	0.5413
LTMSLAB[G]:ENGNO[58]	-0.09367	0.063736	-1.47	0.1851

Least Squares Means Table

Level	Least Sq Mean	Std Error
[A]122	1.8600533	0.07182189
[A]144	1.9322382	0.07862992
[G]58	1.6783069	0.09205698
[G]96	1.8656467	0.08275315

LS Means Plot



Analyzing FEI2 PM Data with BLA Weight = 1.0

- Overall ANOVA Summary of FEI2 data:
  - Analysis indicates differences in the oils
  - FEI2 Engine Hours Adjustment:
    - FEI = FEI2_OR + 0.000086*(ENHREND – 686)
    - We acknowledge that the ENHREND term is not statistically significant (*using a 0.05 p-value threshold*)

Response FEI2

Whole Model

Actual by Predicted Plot

Summary of Fit

RSquare	0.888125
RSquare Adj	0.792232
Root Mean Square Error	0.195649
Mean of Response	1.700714
Observations (or Sum Wgts)	14

Analysis of Variance

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.6825482	0.178774	9.41	<.0001*
ENHREND	-0.000086	0.000252	-0.34	0.7434
RefOil[RO1011]	-0.303194	0.102488	-2.96	0.0212*
RefOil[RO542-2]	-0.185384	0.078367	-2.37	0.0499*
LTMSLAB[A]	-0.007398	0.053458	-0.14	0.8938
LTMSLAB[A]:ENGNO[122]	-0.106539	0.079079	-1.35	0.2199
LTMSLAB[G]:ENGNO[58]	-0.311964	0.089662	-3.48	0.0103*

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
ENHREND	1	1	0.0044392	0.1160	0.7434
RefOil	2	2	1.4846073	19.3921	0.0014*
LTMSLAB	1	1	0.0007330	0.0191	0.8938
ENGNO[LTMSLAB]	2	2	0.6055905	7.9103	0.0160*

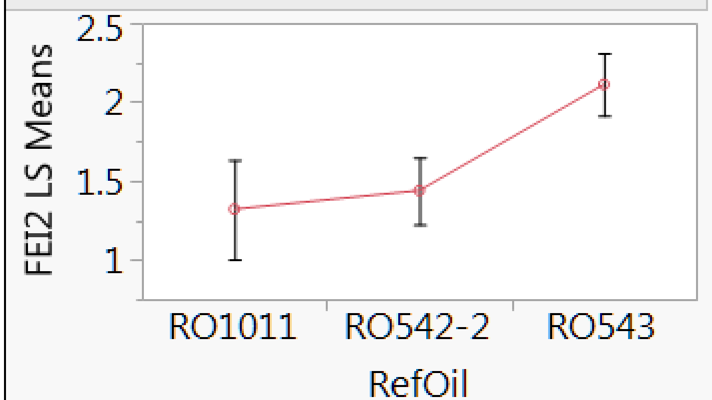
Analyzing FEI2 PM Data with BLA Weight = 1.0

- On average, oils significantly differ: 543 > (542-2 & 1011)

Least Squares Means Table

Level	Sq Mean	Std Error	Mean
RO1011	1.3203651	0.13282233	1.35333
RO542-2	1.4381757	0.08955086	1.46000
RO543	2.1121370	0.08375367	2.07500

LS Means Plot



Analyzing FEI2 PM Data with BLA Weight = 1.0

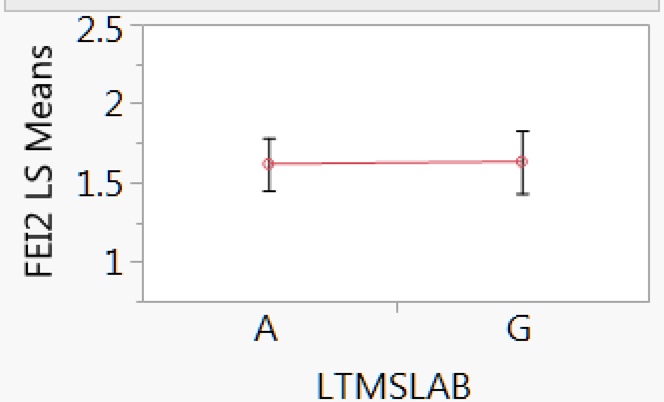
- On average, Labs A and G do not significantly differ in their FEI1 results

LTMSLAB

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	1.6161616	0.07048709	1.65500
G	1.6309569	0.08439380	1.76167

LS Means Plot



Analyzing FEI2 PM Data with BLA Weight = 1.0

- On average, engines 58 and 96 are significantly different within lab G

LTMSLAB[A]:ENGNO[122]	-0.106539	0.079079	-1.35	0.2199
LTMSLAB[G]:ENGNO[58]	-0.311964	0.089662	-3.48	0.0103*

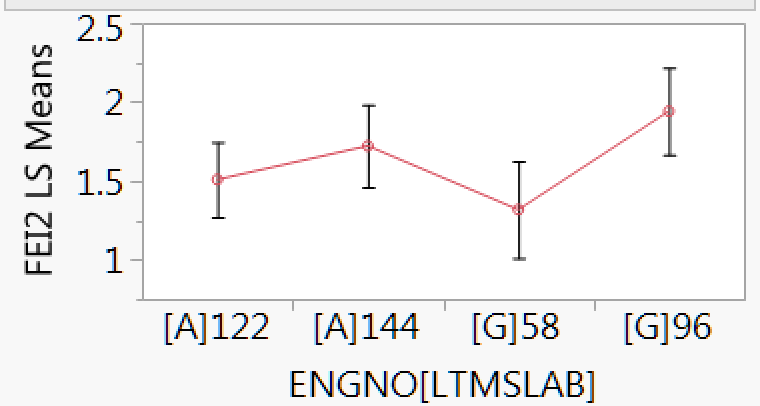
ENGNO[LTMSLAB]

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error
[A]122	1.5096231	0.10103650
[A]144	1.7227001	0.11061380
[G]58	1.3189924	0.12950251
[G]96	1.9429214	0.11641421

LS Means Plot



ADDENDUM K1

TEMPLATE CHECKLIST

Purpose

The Checklist for Comparing Tests to the Template is used to assess progress in new engine test development against the Code Acceptance Criteria and Action Plans. The checklist is updated periodically during the course of test development and is provided to, and discussed with, the appropriate ASTM test development task force.

The rating scale for comparing test development to the Template is as follows:
A - Completed
B - In Progress
C - Planned
D - No Action

Summary: Precision Matrix has been completed and data has been analyzed and discussed in industry groups. The test shows oil discrimination and good precision.

A. **Precision and Discrimination** – PM analysis complete, need d_p from MAD Survey
B. **Severity and Precision Control Charting** – Will be included in the next TMC LTMS update.
C. **Interpretation of Multiple Tests** – SP agreed to use MTAC
D1. **Reference Oils –** 1010-1, 542-2, and 544 were chosen as matrix oils and reference oils.
D2. **Test Parts -** Engines are the critical parts. The plan is to supply ____ complete engines and have them preserved and stored by the end of ____.
D3. **Test Fuel** - SEQ VI-E W/ DCA (HF2003) will be used and supplied by Haltermann.. There are no special fuel requirements.
D4. **Test Procedure –**
D5. **Rating and Reporting Results –** FEI1, FEI2, and FEISUM are pass/fail parameters.
D. D6. **Calibration, Monitoring and Surveillance –** Will be included in the next TMC LTMS update.

Test Name <u>Sequence VIE</u>   Assessment Date <u>July 28, 2016</u>

Appendix K - Template for Acceptance of New Tests

Checklist for Comparing Tests to the Template

A. Precision and Discrimination

A.1 Precision

$E_p = d_p/Spp$, $E_p \geq 1.0$ for all pass/fail parameters
d_p = Smallest difference of practical importance
Spp = Pooled standard deviation at target level of performance

Parameter	dp	Spp	Ep	Ep≥1.0
FEI1		0.29		
FEI2		0.25		

Comments:

A.2 Discrimination

Oil 542-2 has a higher FEI1 than 1010-1.
Oil 542-2 has a higher FEI1 than 544.
Oil 1010-1 has a higher FEI1 than 544.

Oil 542-2 has a higher FEI2 than 544.
Oil 1010-1 has a higher FEI2 than 544.

Parameter: FEI1

			p-value for t-test of equal means (Tukey)		
Oil	Least-Square Mean	95% Confidence Interval for Mean	Vs 1010-1	Vs 542-2	vs 544
1010-1	1.90	1.71 to 2.10		0.00	0.00
542-2	2.56	2.34 to 2.79	0.00		0.00
544	1.30	1.08 to 1.52	0.00	0.00	

Parameter: FEI2

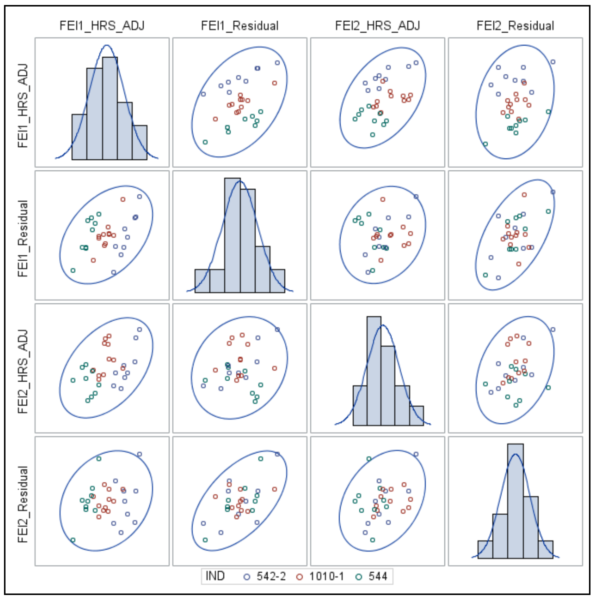
			p-value for t-test of equal means (Tukey)		
Oil	Least-Square Mean	95% Confidence Interval for Mean	Vs 1010-1	Vs 542-2	vs 544
1010-1	1.82	1.73 to 1.90		0.37	0.00
542-2	1.73	1.64 to 1.83	0.37		0.00
544	1.41	1.32 to 1.50	0.00	0.00	

Comments:

A.3 Parameter Redundancy

Parameter redundancy is concluded if a correlation coefficient is 0.85 or greater; and, none of the below listed parameters meet the 0.85 threshold.

Correlation Coefficients	FEI1_HRS_ADJ	FEI1_Residual	FEI2_HRS_ADJ	FEI2_Residual
FEI1_HRS_ADJ	1	0.41	0.44	0.23
FEI1_Residual	0.41	1	0.20	-0.57
FEI2_HRS_ADJ	0.44	0.20	1	0.34
FEI2_Residual	0.23	-0.57	0.34	1



B. Severity and Precision Control Charting

Requirements

B.1 Is an LTMS for reference oil tests in place which is consistent with the ACC Code Appendix A? __B___

B.2 Are appropriate data transforms applied to test results? __A___

Comments:

C. Interpretation of Multiple Tests

Requirements

C.1 Is a suitable system in place to handle repeat tests on a candidate oil? __A___

Type: MTAC Tiered Limits Other

C.2 Has a method for the determination and handling of outlier results been defined? __A___

A. **Comments:** SP agreed to use MTAC

RATING SCALE: A - Completed; B - In Progress; C - Planned; D - No Action

D. <u>Action Plan</u>

D.1 Reference Oils

Do the majority of reference oils represent current technology? __A___

Are the majority of reference oils of passing or borderline pass/fail performance? __A___

<u>Recommended Approaches</u>

D.1.1 Is reference oil supply and distribution handled through an independent organization? __A___

D.1.2 Is a quality control plan defined and in place? __A___

D.1.3 Is a turnover plan defined/in place to ensure uninterrupted supply of reference oil and an orderly transition to reblends? __A___

D.1.4 Is a process for introducing replacement reference oils defined and in place? __A___

D.1.5 Are oils blended in a homogeneous quantity to last 5 years? __A___

Comments: 1010-1, 544, 542-2 were chosen as matrix oils and reference oils. TMC and Seq VI SP handle all of the above.

D.2 Test Parts

Are all critical parts identified? __A___

Is a system defined/in place to maintain uniform hardware? __A___

Is there a system for engineering support and test parts supply? __A___

<u>Recommended Approaches</u>

D.2.1 Are critical parts distributed through a Central Parts Distributor (CPD)? __A___

D.2.2 Are critical parts serialized, and their use documented in test report? __A___

D.2.3 Are all parts used on a first in/first out basis? __A___

D.2.4 Are all rejected critical parts accounted for and returned to the CPD? __A___

RATING SCALE: A - Completed; B - In Progress; C - Planned; D - No Action

D.2.5 Does the CPD make status reports to the test surveillance body at least semi-annually? __A___

D.2.6 Is there a quality control and turnover plan in place for critical test parts, including identification and measurement of key part attributes, a system for parts quality accountability, a turnover plan in place for simultaneous industry-wide use of new parts or supply sources? __A___

D.2.7 Is the CPD active in industry surveillance panel/group, and in industry sponsored test matrices? __A___

D.3 Test Fuel

Recommended Approaches

D.3.1 Is the fuel specified and the supplier(s) identified? __A___

Is a process in place to monitor fuel stability over time? __A___

Are approval guidelines in place for fuel certification? __D___

D.3.2 If the test fuel is treated as a critical part of the test procedure: Is an approval plan and severity monitoring plan for each fuel batch in place? __D___

Is a quality control plan defined and in place to assure long term quality of the fuel? __A___

Is a turnover plan defined, in place and demonstrated to ensure uninterrupted supply of fuel? __A___

Comments: SEQ VI-E W/ DCA (HF2003) will be used and supplied by Haltermann.

RATING SCALE: A - Completed; B - In Progress; C - Planned; D - No Action

D.4 Test Procedure

Recommended Approaches

D.4.1 Is a technical report published documenting, per ASTM Flow Plan:

Test precision for reference oils?	__A__
Field correlation?	__D___
Test development history? To be completed after test acceptance.	__B*___
D.4.2 Are test preparation and operation clearly documented in a standard format, e.g., ASTM, CEC?	__A___
D.4.3 Are test stand configuration requirements documented and standardized?	__A___
D.4.4 Are milestones for precision improvements established?	__A___
D.4.5 Are routine engine builder workshops planned/conducted?	__D___

D.5 Rating and Reporting of Results

Recommended Approaches

D.5.1 Are the reported ratings from single raters (i.e. not averages from various raters)?	__D___
D.5.2 Is a suitable severity adjustment system in place?	__A___
D.5.3 Is each pass/fail parameter unique and have a significant purpose for judging engine oil performance?	__A___
D.5.4 Do all rate and report parameters judge operational validity, help in test interpretation or judge engine oil performance?	__D___
D.5.5 Are routine rater workshops conducted/planned?	__D___

RATING SCALE: A - Completed; B - In Progress; C - Planned; D - No Action

D.6 Calibration, Monitoring and Surveillance

Recommended Approaches

D.6.1 Is a process in place for independent monitoring of severity and precision with an action plan for maintaining calibration of all laboratories? __A___

D.6.2 Are stand, lab, and industry reference oil control charts of all pass/fail criteria parameters used to judge calibration status? __A___

D.6.3 Does the specified calibration test interval allow no more than 15 non-reference oil tests between successful calibration tests? __A___

D.6.4 Is an industry surveillance panel in place? __A___

RATING SCALE: A - Completed; B - In Progress; C - Planned; D - No Action