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COMMITTEE D02 ON PETROLEUM PRODUCTS, LIQUID FUELS, AND LUBRICANTS

Issued: May 19, 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 05.17.2016 Sequence VI Surveillance Panel call.

The meeting was called to order at 8:05 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.

2.0 Approval of minutes

2.1 Approval of the minutes of the 05.10.2016 meeting.

ftp://ftp.astmtmc.cmu.edu/docs/gas/sequencevi/minutes/VIMinutes201600510ConferenceCall.pdf

MOTION: Approve the minutes from the 05.10.2016 conference call.

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[Nathan Moles, Jason Bowden, second] Minutes were approved unanimously.

3.0 Action Item Review

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

There are 11 -001 and 144 -002 engines.

3.2 Labs reported VID engine inventory and expected depletion date of VID engines.

-Expected life of engines range from 2016 Q2 to 2018

Lab1: 0 engine

Lab2: 0 engine

Lab3: 0 engines

Lab4: 0 engine

There will be no further action on this, so 3.2 will be removed.

4.0 Old Business

4.1 List of items to be reviewed after the Precision Matrix

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

Discussion of reducing the new reference requirement to two oils, then a third oil run after a defined number of candidates.

Discussion of using FEI 2 and FEI Sum for references to match candidate pass/fail criteria.

Discussion of evaluating 80/20 ratio of BL before to after for FEI 1 and 10/90 for FEI 2.

Consider evaluating FEI 1 vs 100% BLB2 (or 3) and evaluating FEI 2 vs 100% BLA.

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.

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

Discussion of changing BLB1 to BLB2 delta acceptable limits.

Review impact of variable oil pressure of FEI (review prove out data to determine if it is stand or engine related)

4.2 Update from task force, to investigate alternative test procedure Sequence “VIF” that would improve 0W-16. – Dan Worcester/Satoshi Hirano

SwRI is running the 7th oil on one stand and the 6th oil on the second stand. IAR is also running the 7th oil on one stand and the 6th oil on the second stand. The matrix should complete mid-June.

4.3 Update from task force to investigate option to use short blocks to supplement engine inventory. –Adrian Alfonso/Bill Buscher This effort is on-going. The tag on the engine block can be used for the engine number. The final parts for the kits are being received and will then be packaged and shipped to lab.

5.0 New Business

5.1 Discussion on precision matrix analysis. –Stats Group

See Attachment 3 for the Analysis presentation. There was special thanks for all the support and effort of the Statistics Group. The Executive Summary includes: 6 labs, 3 reference oils (1010-1, 542-2, and 544), 9 engines and 53 tests run. The average engine hours was 1086 and this was used for engine hour equation comparison. For comparison the VID engine hours was 1598. The FEI 1 precision was worse than the current VID [0.26 vs 0.12]. Data review did not support a change to the weighting of 80/20 for FEI 1 and 10/90% for FEI 2. This is for comparison of FEI to BLB 2 and BL After. There is not enough data to support changing the BLB Delta shift. Current VID limits of [-0.2 to +0.4] will be retained. Slide 16 indicates that Lab A has a different response in that BLB to BLA does not flatten out as it did at other labs. This may be a break in effect. SwRI will aslo tear down the engine to check for burned valves that may have affected runs 10 and 11. A Ln and linear engine hour correction were compared. Both would use 1086 hours average, and the Ice Hockey Stick versions would set constant at 1650 hours for FEI 1 and 1800 hours for FEI 2. Andy Ritchie of Infineum commented they were in favor of the hockey stick version with the knee above a set number of hours. FEI 2 sigma is 0.32 vs 0.14 for VID. The oils are being ranked correctly. Lab G is showing different response when multiple criteria are added [lab*oil and oil*engine hours]. FEI 2 response is not as good as the VID. The Surveillance Panel will select the engine hour correction method. BLA shift will be reviewed further. There will be a review of operational validity.

ACTION: There will be a review to look at adjusting to 1600 hours as the VID is now.

5.2 Discussion on small group to be formed to review ALL of the data and operational parameters for all of the matrix tests. –Mike McMillan There will be a Task Force for operational validity. Dave Glaenzer has agreed to gather validity criteria for each lab. Rich Grundza will begin a data review of the tests in the Precision Matrix.

ACTION: Each lab will supply their test validity criteria.

5.3 Face to face meetings May 24th and 25th Lubrizol, Wickliffe Ohio.

-Confirm attendance list

-Remote access:

https://meetings.webex.com/collabs/meetings/join?uuid=M5N3FDHOYW6LAICWAKTC7NKSVO-20XT

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

Country	Access Type	Dial-In Number	Global Dialing Comment
Japan	Toll-Free	0066-33-830233	JAPAN C&W USERS
Japan	Toll-Free	0034-800-900316	JAPAN NTT USERS
Japan	Toll-Free	00531-11-3585	JAPAN KDD USERS

6.0 Next Meetings.

May 24th and 25th Lubrizol, Wickliffe Ohio

The meeting adjourned at 9:47 AM.

Sequence VI Surveillance Panel Conference Call Agenda
May 17 @ 9:00-10:00AM EST

<u>Call-in information is included below:</u>

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

1.0) Roll Call

Do we have any membership changes or additions?

2.0) Approval of minutes

2.1 Approve the minutes from the May 10, 2016 Sequence VI Surveillance Panel.
ftp://ftp.astmtmc.cmu.edu/docs/gas/sequencevi/minutes/VIMinutes20160510ConferenceCall.pdf

3.0) Action Item Review

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

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

-Expected life of engines range from 2016 Q3
Lab1: 0 engines
Lab2: 0 engines
Lab3: 0 engines
Lab4: 0 engines

4.) Old Business

4.1 List of items to be reviewed after the Precision Matrix

-Do we really need to run three RO tests to establish the new engine for LTMS?
-Discussion of reducing the new reference requirement to two oils, then a third oil run after a defined number of candidates.
-Discussion of using FEI 2 and FEI Sum for references to match candidate pass/fail criteria.

-Discussion of evaluating 80/20 ratio of BL before to after for FEI 1 and 10/90 for FEI 2. Consider evaluating FEI 1 vs 100% BLB2 (or 3) and evaluating FEI 2 vs 100% BLA.
-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.
-SP chair and test sponsor to investigate what is needed to establish VID equivalent limits for VIE
-Discussion of changing BLB1 to BLB2 delta acceptable limits.
-Review impact of variable oil pressure of FEI (review prove out data to determine if it is stand or engine related)

4.2 Update from task force, to investigate alternative test procedure Sequence “VIF” that would improve 0W-16. – Dan Worcester/Satoshi Hirano

4.3 Update from task force to investigate option to use short blocks to supplement engine inventory. –Adrian Alfonso/Bill Buscher

5.) New Business

5.1 Discussion on precision matrix analysis. –Stats Group

5.2 Discussion on small group to be formed to review ALL of the data and operational parameters for all of the matrix tests. –Mike McMillan

5.3 Face to face meetings May 24th and 25th Lubrizol, Wickliffe Ohio.
-Confirm attendance list
-Remote access:
https://meetings.webex.com/collabs/meetings/join?uuid=M5N3FDHOYW6LAICWAKTC7NKSVO-20XT

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6.) Next Meeting

May 24th and 25th Lubrizol, Wickliffe Ohio

7.) Meeting Adjourned

ASTM SEQUENCE VI

Name	Address	Phone/Fax/Email	Attendance
Adrian Alfonso **Voting Member**	Intertek	Phone: (210) 838-0431 adrian.alfonso@intertek.com	**ATTEND**
Jason Bowden **Voting Member**	OH Technologies	Phone: (440) 354-7007 jhbowden@ohtech.com	**ATTEND**
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David Glaenzer **Voting Member**	Afton	Phone: (804) 788-5214 Dave.Glaenzer@aftonchemical.com	**ATTEND**
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Dan Worcester **Voting Member**	Southwest	Phone: (210) 522-2405 dan.worcester@swri.org	**ATTEND**

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Chris Taylor	Chris.taylor@vpracingfuels.com	VP Racing Fuels	

VIE Precision Matrix Analysis

Industry Statistician Team

Date: 05-17-2016

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 this presentation
- Update Appendix K (update scheduled at next SP meeting in Wickliffe)

Executive Summary

- Precision Matrix (PM) Analysis Highlights:
  - No compelling rationale to change current 80/20 baseline weighting for FEI1 and 10/90 baseline weighting for FEI2
  - VIE Precision[1] with Ln(Engine Hours) Adjustment option:
    - FEI1 and FEI2 RMSE is 0.26 and 0.32, respectively
    - Reference oil LSMeans indicate that (3) FEI1 and (1) FEI2 pair-wise contrast(s) are significantly different
  - VIE Precision[1] with Ice Hockey Stick (Engine Hours) Adjustment option:
    - FEI1 and FEI2 RMSE is 0.255 and 0.295, respectively
    - Reference oil LSMeans indicate that (3) FEI1 and (2) FEI2 pair-wise contrast(s) are significantly different
  - Both the Sequence VID and VIE show oil discrimination of over 4 standard deviations for FEI1, which is a comparatively good amount of discrimination. The VIE FEI2 shows oil discrimination of 1 standard deviation, which is less discrimination than VID FEI2, and less than most GF-5 PCMO engine tests.

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

Executive Summary

- Precision Matrix (PM) Analysis Highlights (continued):
  - No Significant difference between test labs
  - No significant difference between engines within the same test lab; Lab G engines differ in FEI1 when additional significant interactions are included in the model (lab*oil & oil*engine hours)
  - FEI results suggest labs do not discriminate oils the same way, though sample size is small and inferences can be impacted by variation
  - FEI1 oil discrimination changes over the range of engine hours
  - Weak evidence that oil pressure differences between consecutive test runs on the same engine may be related to changes in FEI2 test results
  - Two unusual (studentized deleted) residuals resulted on Engine128 in Lab A

Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Evaluating Alternatives for Engine Hour Adjustment
- Analyzing PM Data
  - FEI1 – LnEngHr Model
  - FEI1 – Ice Hockey Stick Model
  - FEI2 – LnEngHr Model
  - FEI2 – Ice Hockey Stick Model
  - Comparing VIE Precision and Oil Discrimination with other Tests

Agenda

- **Review PM Data for Analysis**
- Evaluating Baseline Weighting Scenarios
- Evaluating Alternatives for Engine Hour Adjustment
- Analyzing PM Data
  - FEI1 – LnEngHr Model
  - FEI1 – Ice Hockey Stick Model
  - FEI2 – LnEngHr Model
  - FEI2 – Ice Hockey Stick Model
  - 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 with engine pairs
    - Lab A: 103 vs. 128
    - Lab C: 29 vs. 31
    - Lab G: 55 vs. 60
  - Data set total sample size: 53

Review PM Data for Analysis

- Precision Matrix (PM):
- On 5-10-16 the surveillance panel concluded 53 tests were valid (these are shown in green).
- Table is from Frank Faber's 5-11-16 matrix update email

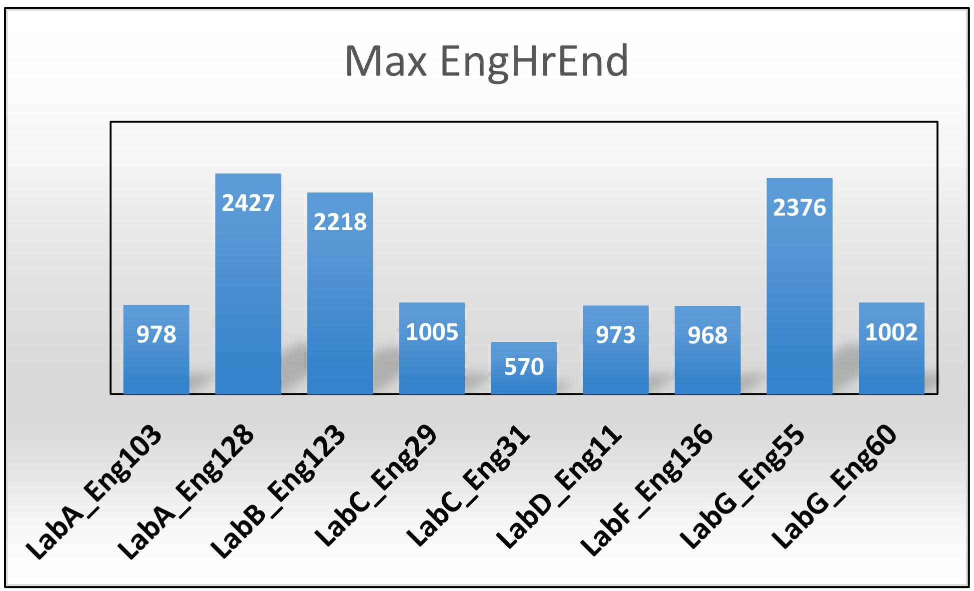
Step	Run Order	A 1	A 2	G 1	G 2	B	D	C	F	
	SOT Engine Hours	150	150	150	150	150	150	150	150	Eng. Hrs
1	1	544 113244-VIE	1010-1 110587-VIE	542-2 105705-VIE	544 113224-VIE	542-2 110003-VIE	542-2 110588-VIE	544 113298-VIE 544 116040-VIE (new engine)	1010-1 113223-VIE	350
1	2	544 113247-VIE	1010-1 110725-VIE	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
1	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
1	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
2	6	1010-1 110727-VIE	1010-1		542-2 113230-VIE	542-2 110004-VIE				1350
2	7	1010-1 113252-VIE	544		544 113226-VIE	542-2 113261-VIE				1550
2	8	542-2 113248-VIE	542-2		544 113227-VIE	1010-1 113265-VIE				1750
2	9	542-2 113249-VIE	542-2		1010-1 113238-VIE	1010-1 113266-VIE				1950
2	10	544 115022-VIE	1010-1		542-2 113232-VIE	544 116027-VIE				2150
2	11	1010-1 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

Test Reported

Invalid

Review PM Data for Analysis

- Precision Matrix data summary (continued):
  - Average engine hour age[1]:
    - PM Average EngHrs = 1086
    - PM Average Ln(EngHrs) Transform = 6.83 ($e^{6.83}$ = 925 hours)



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

Agenda

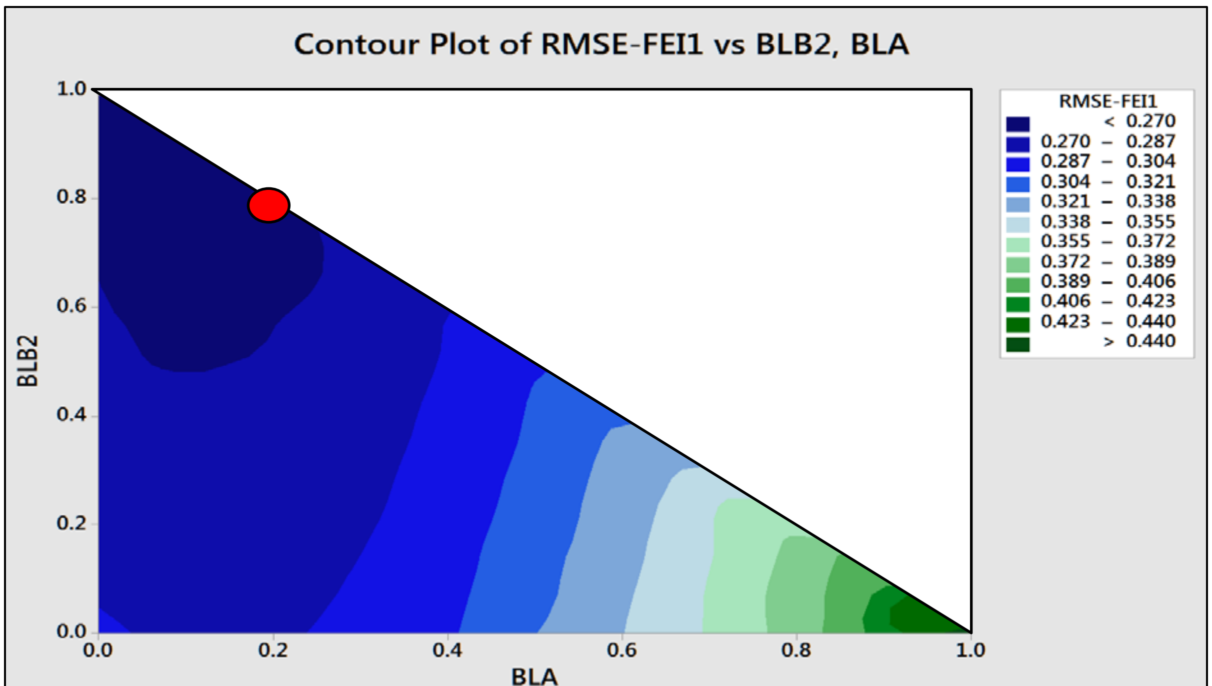
- Review PM Data for Analysis
- **Evaluating Baseline Weighting Scenarios**
- Evaluating Alternatives for Engine Hour Adjustment
- Analyzing PM Data
  - FEI1 – LnEngHr Model
  - FEI1 – Ice Hockey Stick Model
  - FEI2 – LnEngHr Model
  - FEI2 – Ice Hockey Stick Model
  - Comparing VIE Precision and Oil 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

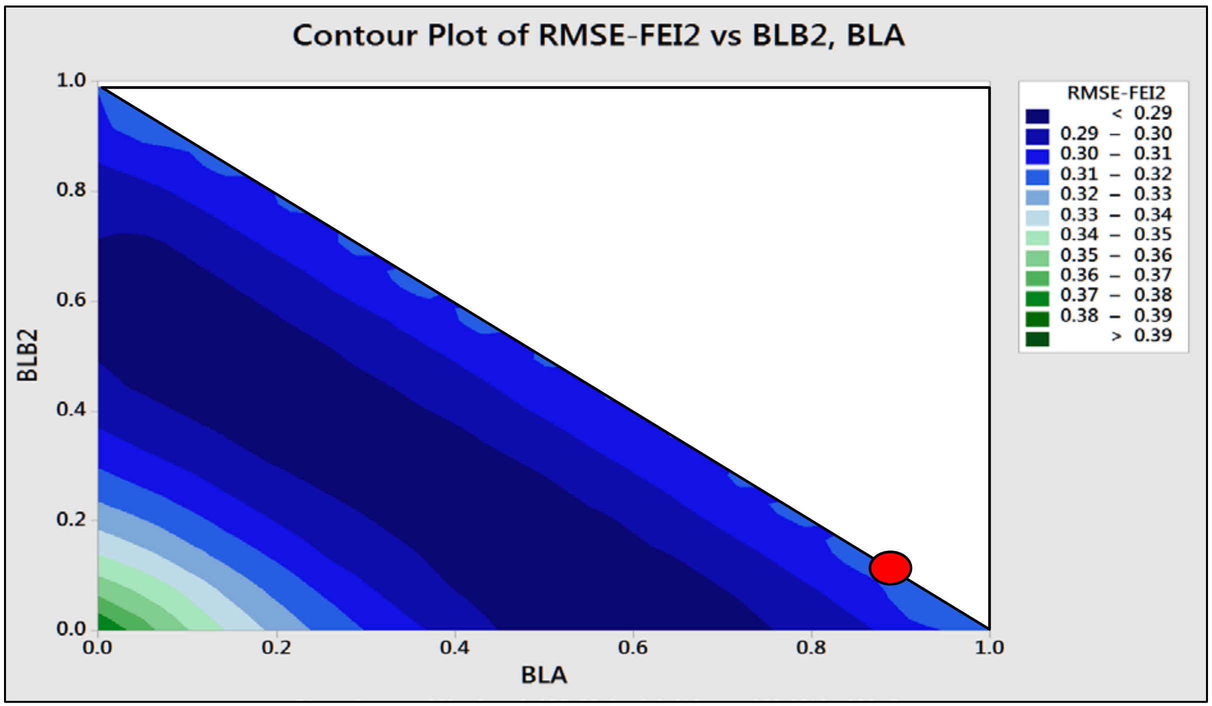
Evaluating Baseline Weight Scenarios

- 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

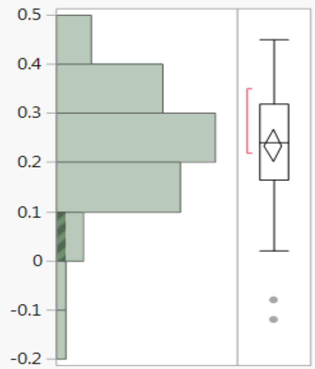
- Plot of RMSE vs. baseline weight combinations for FEI2 shown below
  - RMSE of weights can be interpreted from plot- if BL weights sum to 1.0
  - VID FEI2 Baseline weights of 10% & 90% shown in red circle
  - Other BL weighting combinations provide slight improvement to precision
  - No compelling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



BL Shift

- Not enough data to change limits at this time
- BLB12 Shift Range: (-0.12, 0.45); BLB23 Shift Range: (-0.07, 0.36)
- BLA Shift Range: (-2.39, 1.03)

BLSFDT12



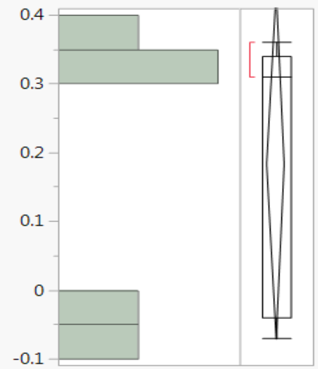
Quantiles

100.0%	maximum	0.45
99.5%		0.45
97.5%		0.4465
90.0%		0.378
75.0%	quartile	0.32
50.0%	median	0.24
25.0%	quartile	0.165
10.0%		0.094
2.5%		-0.106
0.5%		-0.12
0.0%	minimum	-0.12

Summary Statistics

Mean	0.2328302
Std Dev	0.1180511
Std Err Mean	0.0162156
Upper 95% Mean	0.2653691
Lower 95% Mean	0.2002913
N	53

BLSFDT23



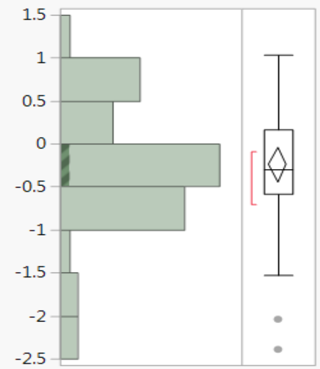
Quantiles

100.0%	maximum	0.36
99.5%		0.36
97.5%		0.36
90.0%		0.36
75.0%	quartile	0.34
50.0%	median	0.31
25.0%	quartile	-0.04
10.0%		-0.07
2.5%		-0.07
0.5%		-0.07
0.0%	minimum	-0.07

Summary Statistics

Mean	0.182
Std Dev	0.2046216
Std Err Mean	0.0915096
Upper 95% Mean	0.4360713
Lower 95% Mean	-0.072071
N	5

BLSFDT2A



Quantiles

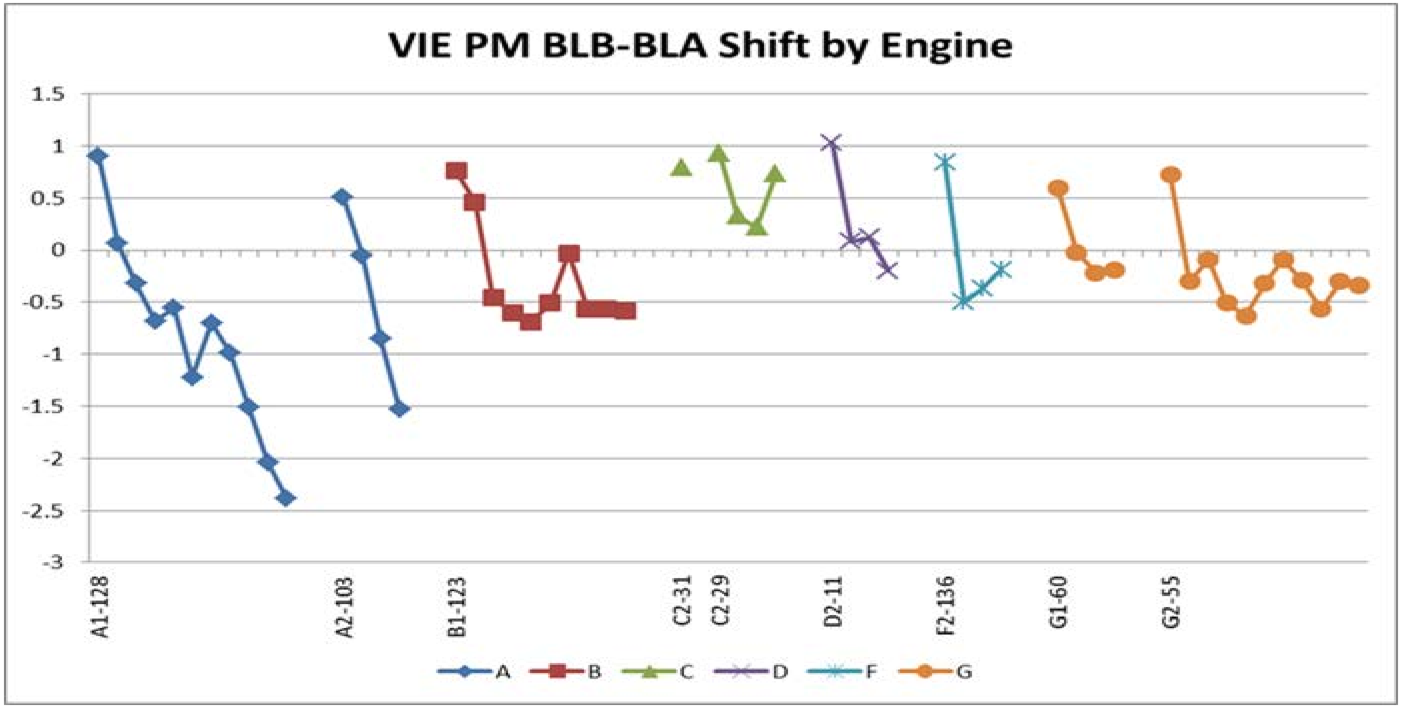
100.0%	maximum	1.03
99.5%		1.03
97.5%		0.995
90.0%		0.778
75.0%	quartile	0.17
50.0%	median	-0.3
25.0%	quartile	-0.575
10.0%		-1.128
2.5%		-2.2675
0.5%		-2.39
0.0%	minimum	-2.39

Summary Statistics

Mean	-0.243396
Std Dev	0.719877
Std Err Mean	0.0988827
Upper 95% Mean	-0.044974
Lower 95% Mean	-0.441819
N	53

BLB-BLA Shift by Engine

- Lab A profile appears to be different than the other labs
- The first BLB-BLA shift in each engine is the largest
- SP should review BLB-BLA shift



Agenda

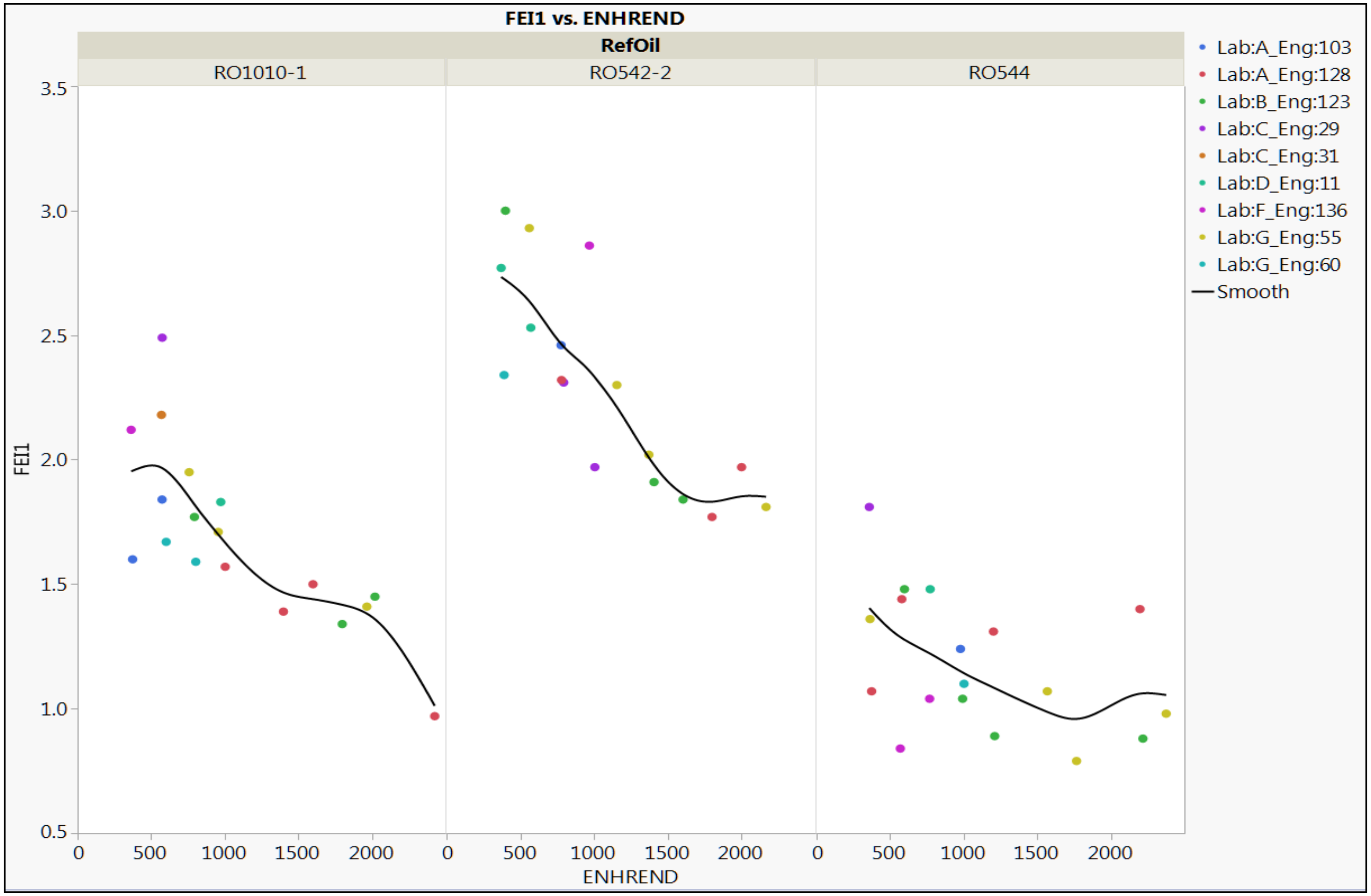
- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- **Evaluating Alternatives for Engine Hour Adjustment**
- Analyzing PM Data
  - FEI1 – LnEngHr Model
  - FEI1 – Ice Hockey Stick Model
  - FEI2 – LnEngHr Model
  - FEI2 – Ice Hockey Stick Model
  - Comparing VIE Precision and Oil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

Evaluating Alternatives for Engine Hour Adjustment

- Analysis of the 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
- Various transforms of engine hours were evaluated (Ln, power, etc.) to try to approximate the relationship of engine age on FEI test results
- Highlights of a natural log transform and Ice Hockey Stick (IHS) are shown on the following slides

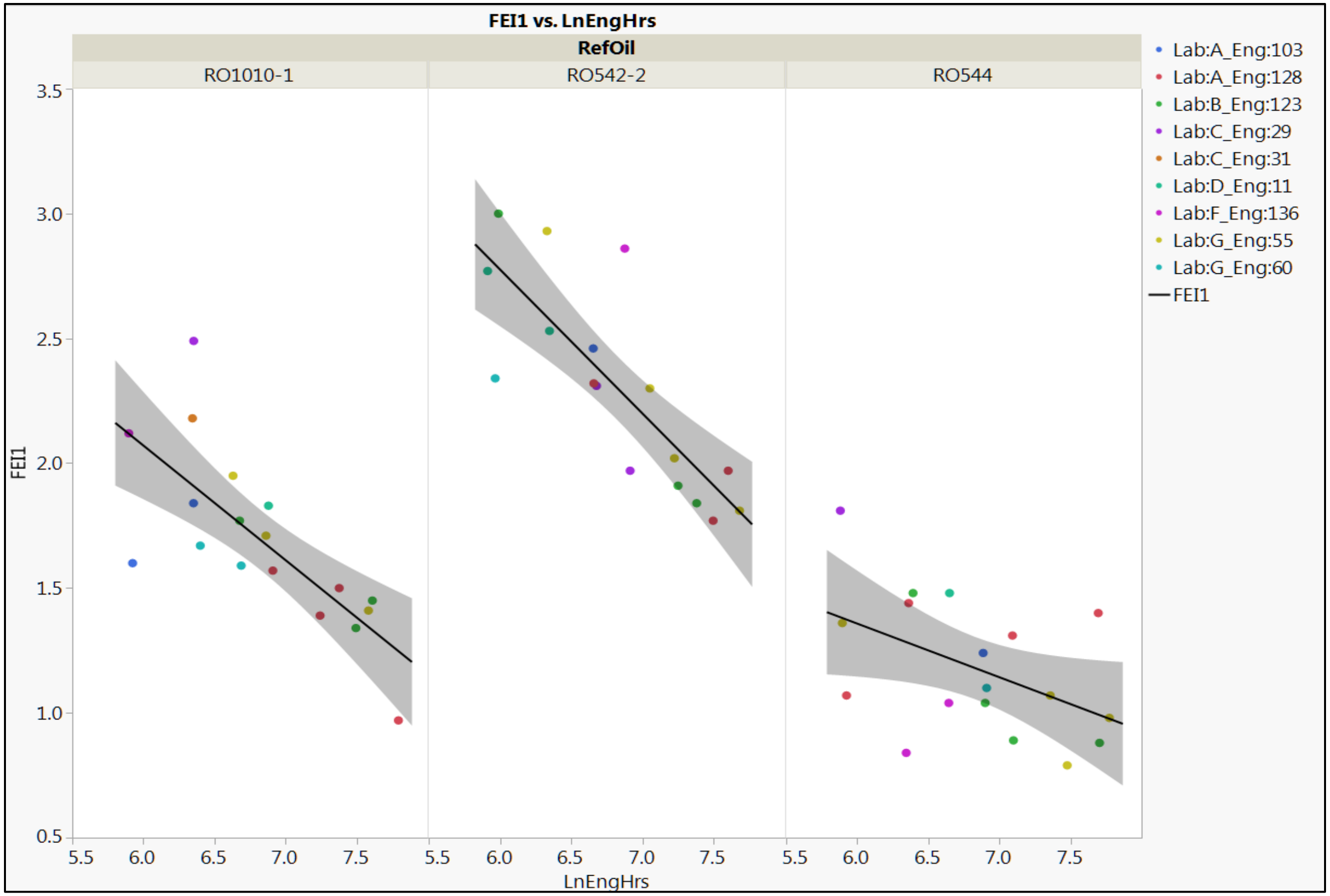
Evaluating Alternatives for Engine Hour Adjustment

- FEI1 Ice Hockey Stick (IHS) Engine hour adjustment approach
  - Data suggests a possible horizontal line at 1650 hours



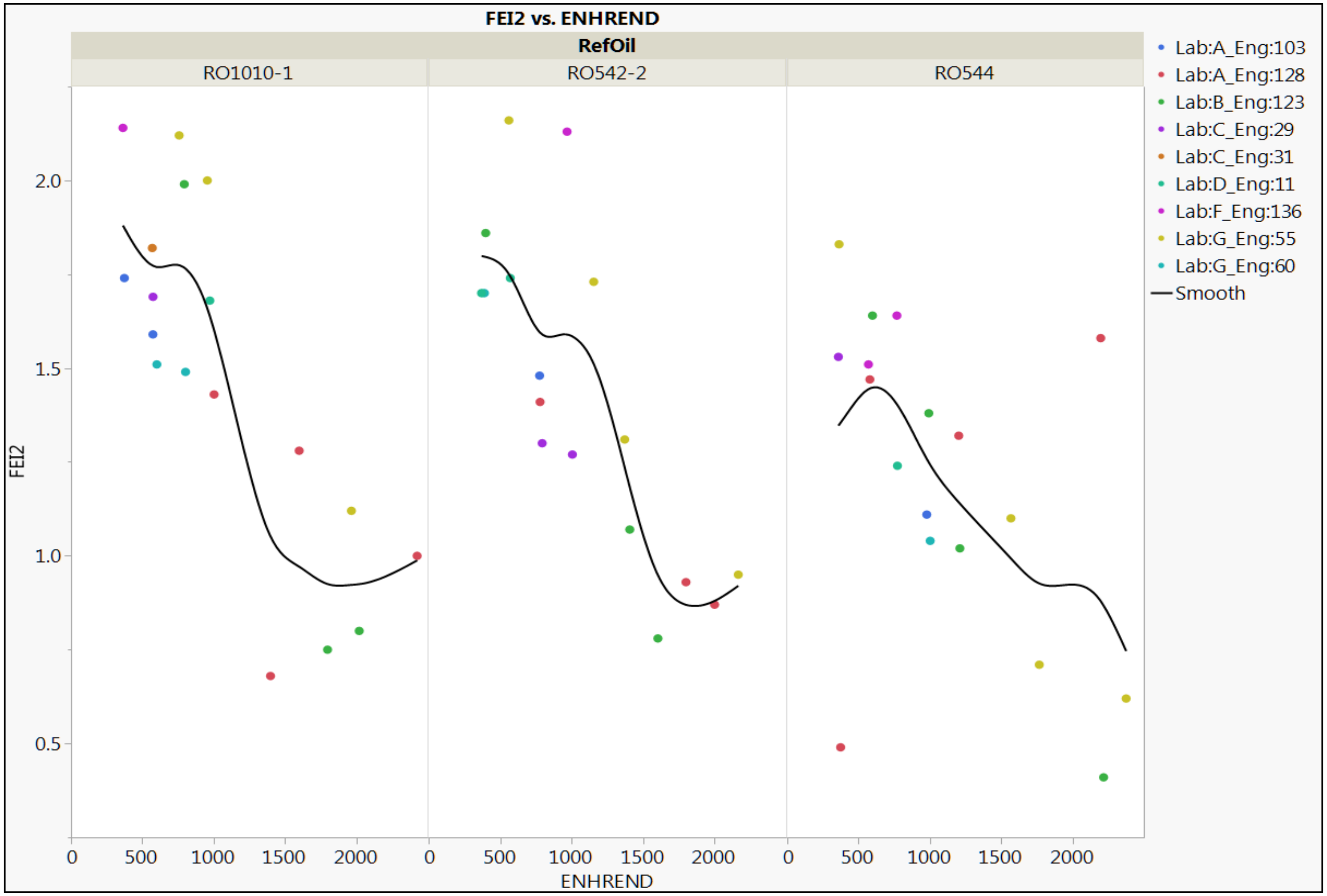
Evaluating Alternatives for Engine Hour Adjustment

- Natural Log Engine hour adjustment approach
  - Linear relationship exhibited between FEI1 and Ln(EngHrEnd)



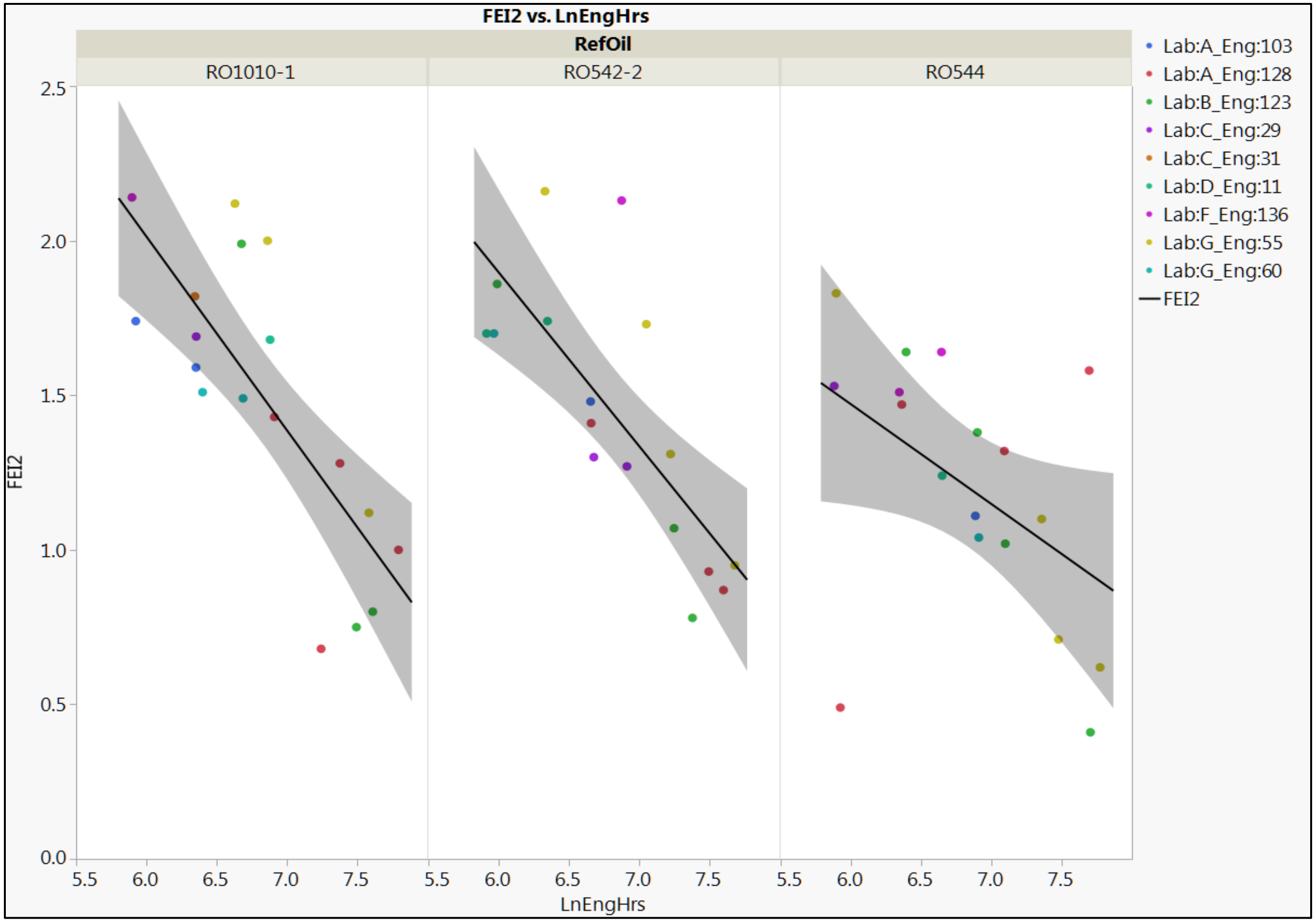
Evaluating Alternatives for Engine Hour Adjustment

- FEI2 Ice Hockey Stick (IHS) Engine hour adjustment approach
  - Data suggests a possible horizontal line at 1800 hours



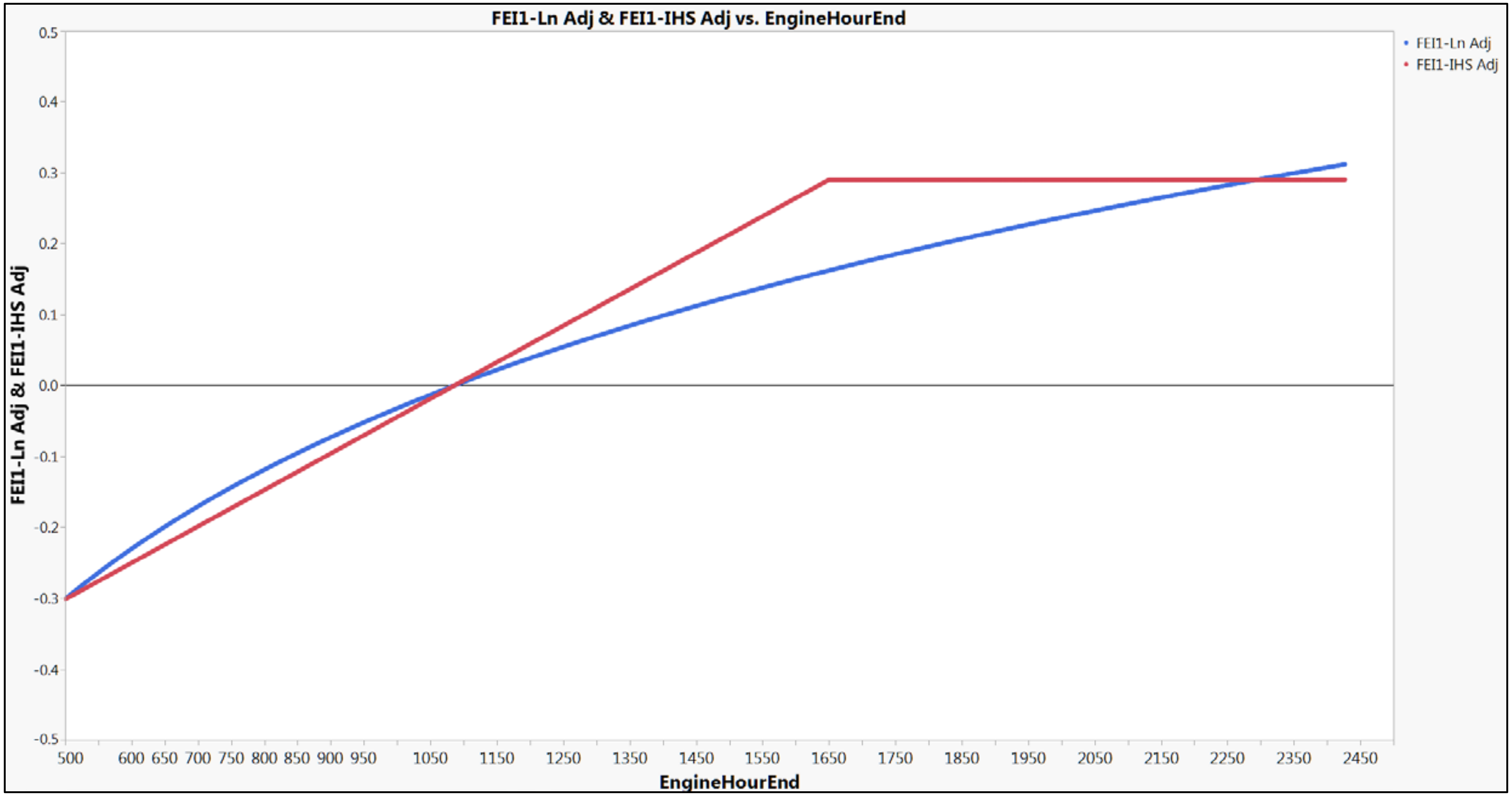
Evaluating Alternatives for Engine Hour Adjustment

- Natural Log Engine hour adjustment approach
  - Linear relationship exhibited between FEI1 and Ln(EngHrEnd)



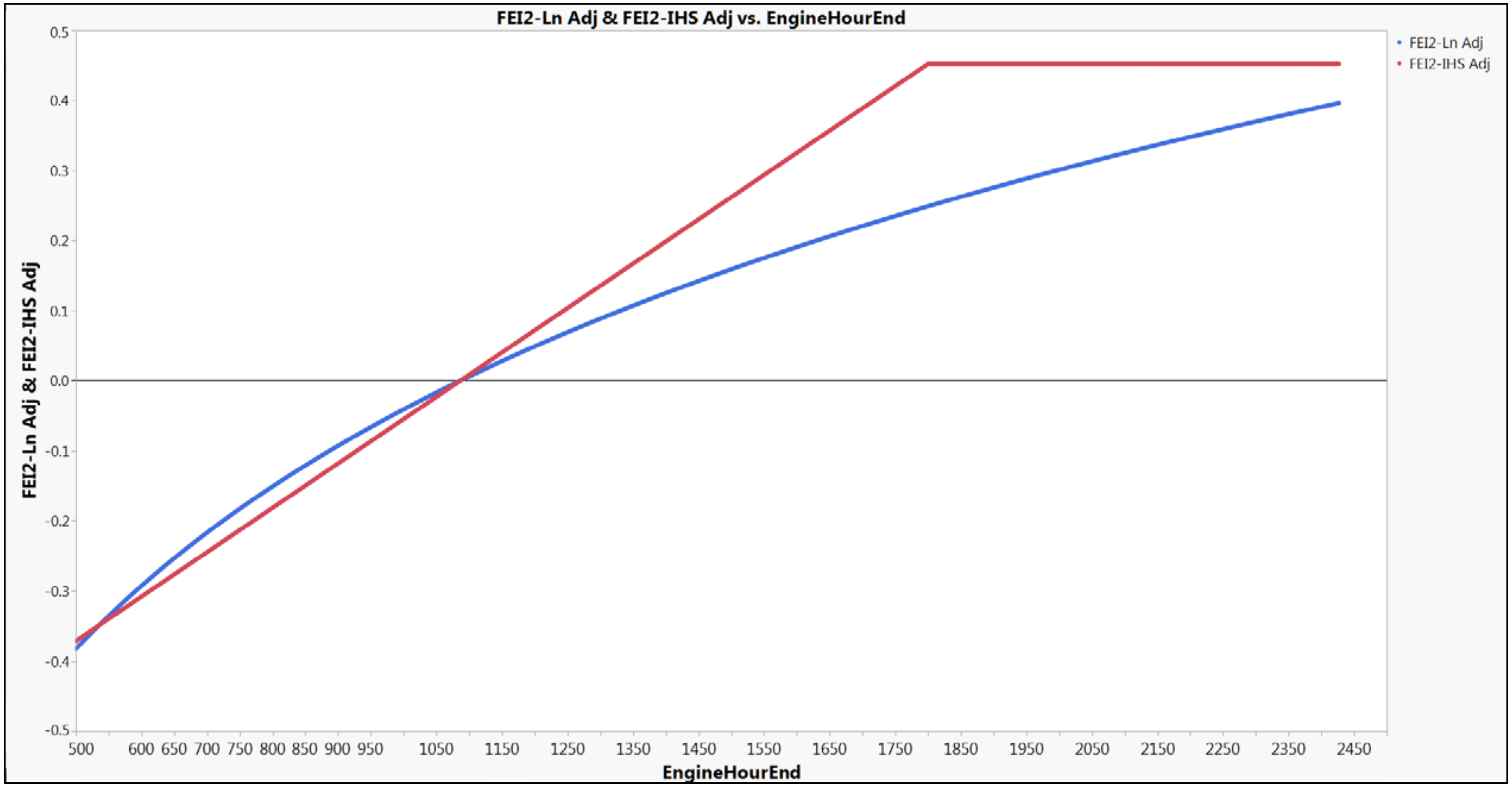
Evaluating Alternatives for Engine Hour Adjustment

- FEI1 Adjustment approaches are summarized below
  - Both adjustment approaches are aligned to EngHr Average of 1086
  - FEI1 Ln Adj = 0.388*(Ln(EngHrs)-Ln(1086))
  - FEI1 IHS Adj = 0.000514*(min(1650,EngHrs)-1086)



Evaluating Alternatives for Engine Hour Adjustment

- FEI2 Adjustment approaches are summarized below
  - Both adjustment approaches are aligned to EngHr Average of 1086
  - FEI2 Ln Adj = 0.493*(LN(EngHrs)-Ln(1086))
  - FEI2 IHS Adj = 0.000633*(min(1800,EngHrs)-1086)



Evaluating Alternatives for Engine Hour Adjustment

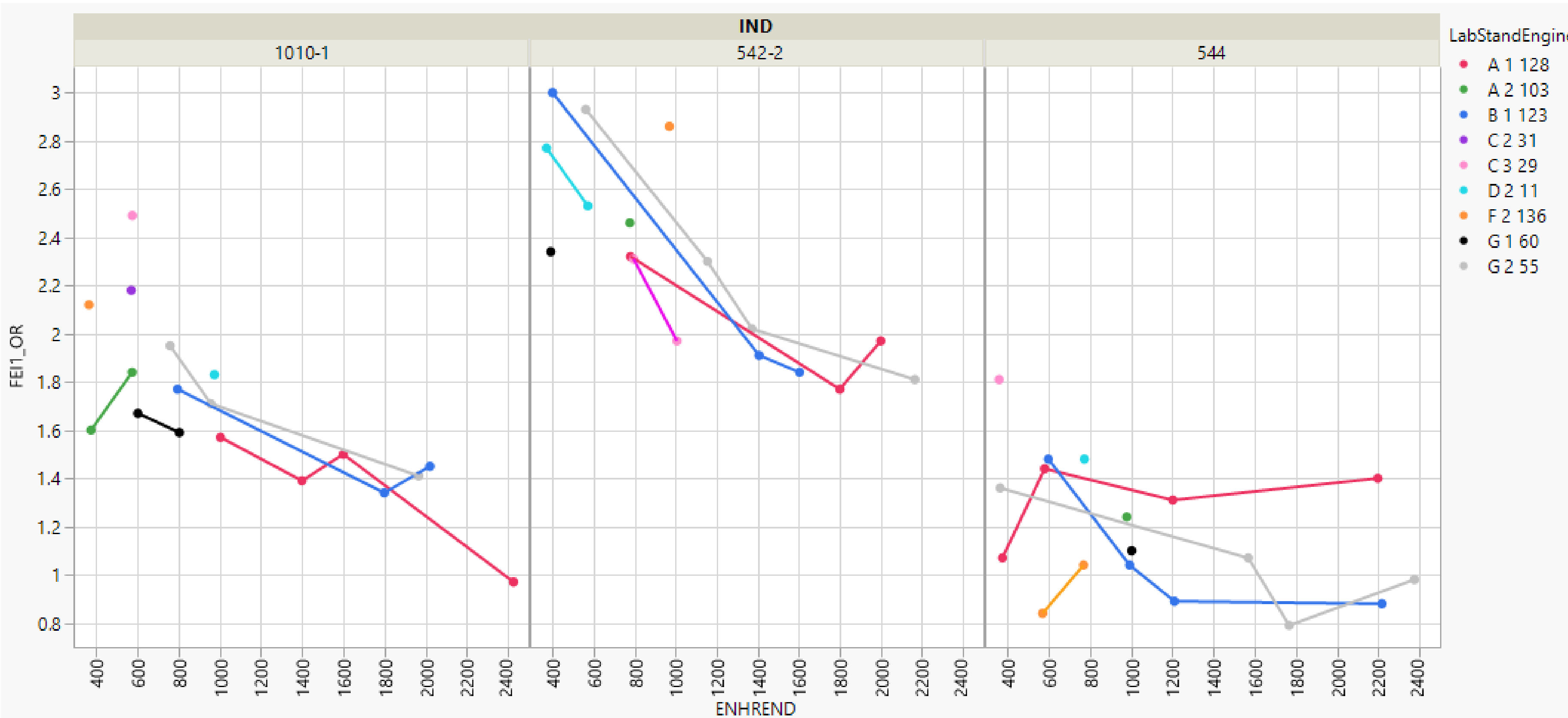
- Review of correction factor approaches for EngHrEnd indicates that no one engine hour transform for FEI1 or FEI2 performs overwhelmingly better in terms of RMSE, Rsquare, or model fit residual diagnostics.
- Additional reference tests will clarify the true engine hour effect at higher engine hours.
- At this time, it is recommend that Subject Matter Experts (SMEs) in the Surveillance Panel choose from one of the two proposed engine hours adjustment methods (IHS vs. Ln) for FEI1 and FEI2.

Agenda

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

Analyzing PM Data

- Plot of FEI1_OR



Analyzing PM Data (FEI1 – LnEngHr Model)

- Overall ANOVA Summary of FEI1 data:
  - Ln(EngHr) & Reference Oil factors are statistically Significant
  - VIE PM Test Precision: 0.26 *(contrast w/ VID PM test precision of 0.12)*

Class Level Information		
Class	**Levels**	**Values**
IND	3	1010-1 542-2 544
LTMSLAB	6	A B C D F G
ENGNO	9	11 29 31 55 60 103 123 128 136

Number of Observations Read	53
Number of Observations Used	53

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	14.29502745	1.29954795	18.91	<.0001
Error	41	2.81825179	0.06873785		
Corrected Total	52	17.11327925			

R-Square	Coeff Var	Root MSE	FEI1_OR Mean
0.835318	15.31859	0.262179	1.711509

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LnEngHr	1	1.88819141	1.88819141	27.47	<.0001
IND	2	10.23490298	5.11745149	74.45	<.0001
LTMSLAB	5	0.30655752	0.06131150	0.89	0.4954
ENGNO(LTMSLAB)	3	0.14145292	0.04715097	0.69	0.5658

Analyzing PM Data (FEI1 – LnEngHr Model)

- Difference between reference oil LsMeans for FEI1:
  - All oil contrasts are significantly different
  - {544 < 1010-1 < 542-2}
  - Higher VIE FEIs as compared to VID is partially due to correction at reduced number of engine hours

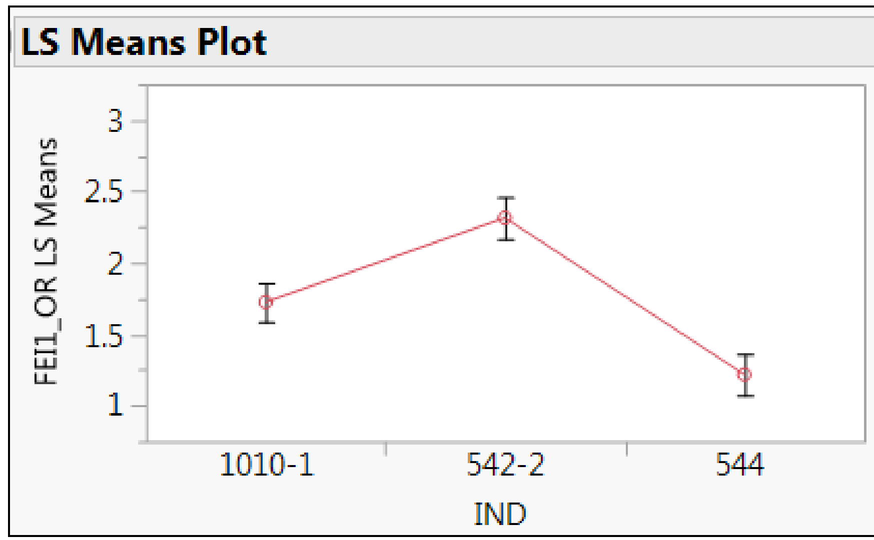
FEI1 Response Model - Ln(EngHr)

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

IND	FEI1_OR LSMEAN	LSMEAN Number
1010-1	1.72449215	1
542-2	2.31476980	2
544	1.21786606	3

Least Squares Means for effect IND
Pr > \|t\| for H0: LSMean(i)=LSMean(j)
Dependent Variable: FEI1_OR

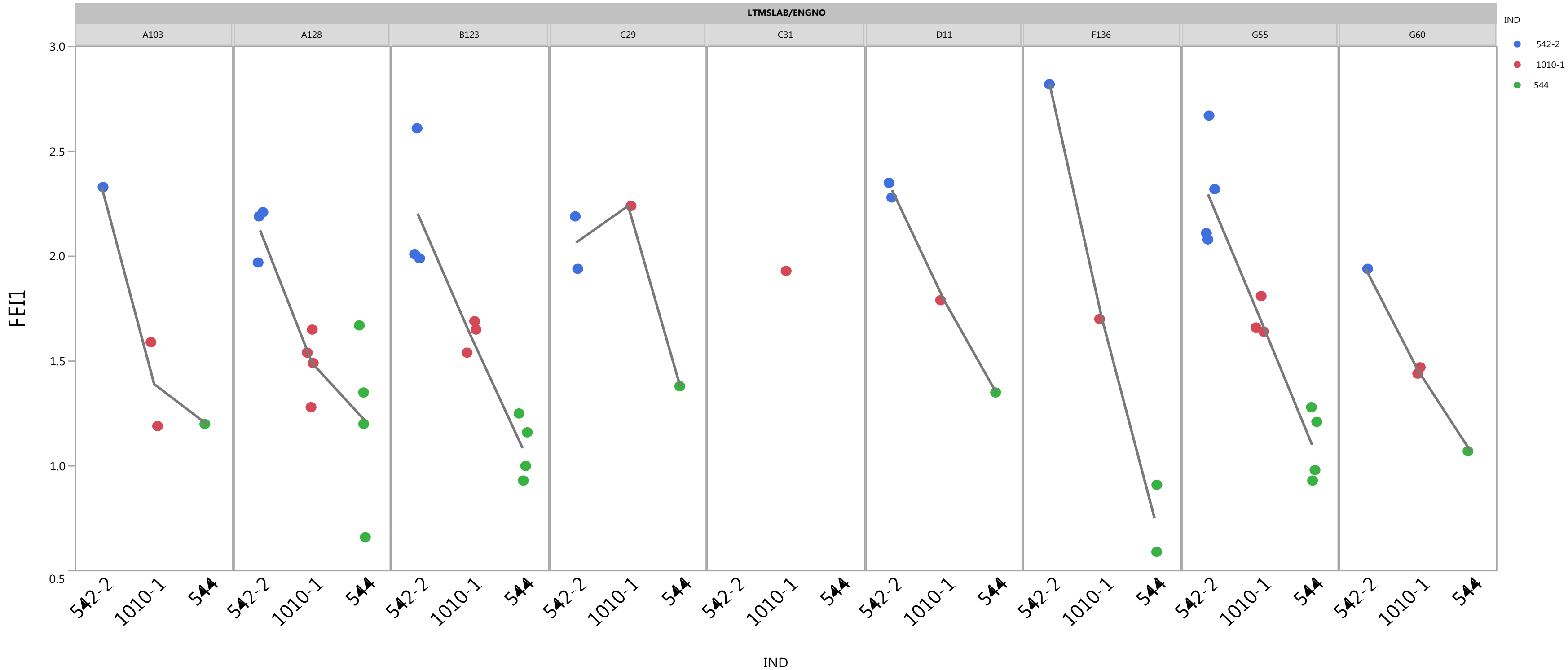
i/j	1	2	3
1		<.0001	<.0001
2	<.0001		<.0001
3	<.0001	<.0001	



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

Analyzing PM Data (FEI1 – LnEngHr Model)

- FEI1Adj Oil Discrimination by Engine
  - Contrast below plot with oil ranking of {544 < 1010-1 < 542-2}
  - Oil discrimination is not consistent across labs; in particular, Lab C, though sample size is small and inferences can be impacted by variation



Analyzing PM Data (FEI1 – LnEngHr Model)

- Difference between test Lab LSMeans for FEI1
  - No significant difference between Labs

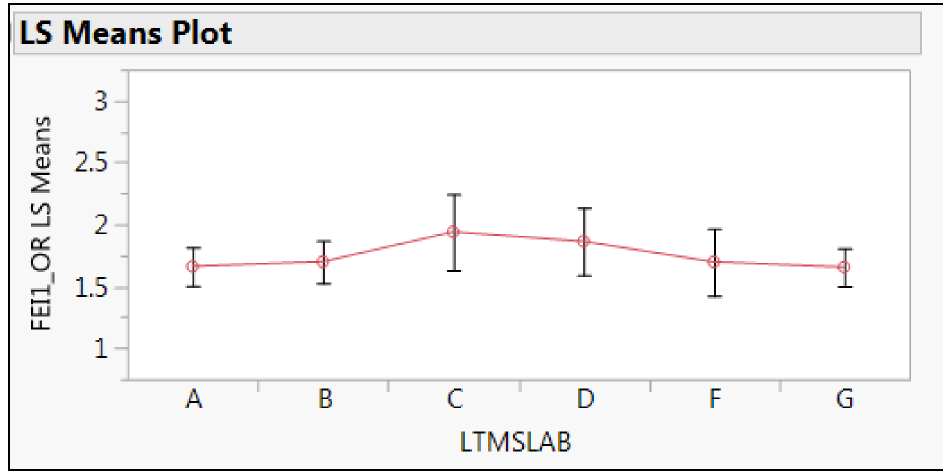
FEI1 Response Model - Ln(EngHr)

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

LTMSLAB	FEI1_OR LSMEAN	LSMEAN Number
A	1.66128306	1
B	1.69858887	2
C	1.93921214	3
D	1.86310364	4
F	1.69689483	5
G	1.65517348	6

Least Squares Means for effect LTMSLAB
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: FEI1_OR

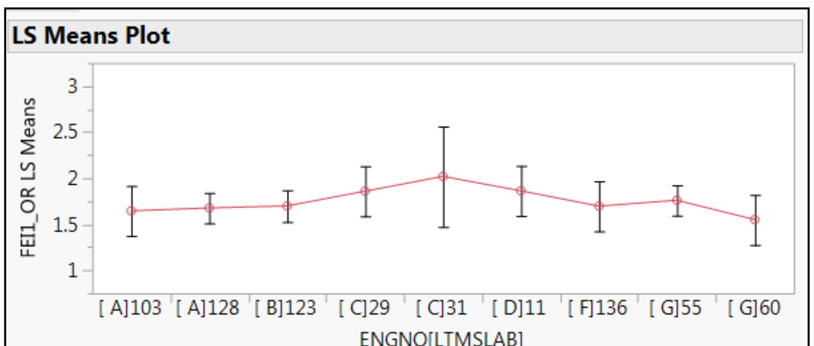
i/j	1	2	3	4	5	6
1		0.9995	0.5733	0.7821	0.9999	1.0000
2	0.9995		0.7534	0.9107	1.0000	0.9989
3	0.5733	0.7534		0.9989	0.8274	0.5526
4	0.7821	0.9107	0.9989		0.9468	0.7585
5	0.9999	1.0000	0.8274	0.9468		0.9998
6	1.0000	0.9989	0.5526	0.7585	0.9998	



Analyzing PM Data (FEI1 – LnEngHr Model)

- LSMean difference between engines within the same Lab
  - Contrasts: {A-103 vs. A-128}, {C-29 vs. C-31}, {G-55 vs. G-60}
  - Conclusion: No Significant[1] Difference between engines within a Lab
    - Lab G engines significantly differ when additional significant model terms are added (lab*oil & oil*engine hours interactions)

ENGNO	LTMSLAB	FEI1_OR LSMEAN	LSMEAN Number
103	A	1.64572710	1
128	A	1.67683903	2
123	B	1.69858887	3
29	C	1.85895265	4
31	C	2.01947163	5
11	D	1.86310364	6
136	F	1.69689483	7
55	G	1.76024335	8
60	G	1.55010360	9



Least Squares Means for Effect ENGNO(LTMSLAB)
t for H0: LSMean(i)=LSMean(j) / Pr > |t|
Dependent Variable: FEI1_OR

i/j	1	2	3	4	5	6	7	8	9
1		-0.19309	-0.32557	-1.14148	-1.26292	-1.16371	-0.274	-0.71036	0.515744
		1.0000	1.0000	0.9639	0.9363	0.9596	1.0000	0.9984	0.9998
2	0.193092		-0.18958	-1.12792	-1.20383	-1.15226	-0.12457	-0.74391	0.790552
	1.0000		1.0000	0.9663	0.9511	0.9619	1.0000	0.9977	0.9966
3	0.325573	0.189578		-0.9891	-1.12245	-1.0136	0.010482	-0.5376	0.918709
	1.0000	1.0000		0.9849	0.9673	0.9824	1.0000	0.9998	0.9906
4	1.14148	1.127917	0.989097		-0.53599	-0.02239	0.8678	0.615507	1.653322
	0.9639	0.9663	0.9849		0.9998	1.0000	0.9935	0.9994	0.7700
5	1.262924	1.203834	1.122453	0.535986		0.522165	1.077508	0.90764	1.585473
	0.9363	0.9511	0.9673	0.9998		0.9998	0.9743	0.9913	0.8069
6	1.163713	1.152259	1.0136	0.022391	-0.52216		0.89003	0.640647	1.675475
	0.9596	0.9619	0.9824	1.0000	0.9998		0.9923	0.9992	0.7573
7	0.273997	0.12457	-0.01048	-0.8678	-1.07751	-0.89003		-0.3947	0.78599
	1.0000	1.0000	1.0000	0.9935	0.9743	0.9923		1.0000	0.9967
8	0.710356	0.743914	0.537604	-0.61551	-0.90764	-0.64065	0.394703		1.30988
	0.9984	0.9977	0.9998	0.9994	0.9913	0.9992	1.0000		0.9226
9	-0.51574	-0.79055	-0.91871	-1.65332	-1.58547	-1.67548	-0.78599	-1.30988	
	0.9998	0.9966	0.9906	0.7700	0.8069	0.7573	0.9967	0.9226	

[1] *Familywise error rate critical t of 2.49 selected for 3 contrasts*

Familywise Error Rate	Bonferonni for 3 contrasts	DOF	Critical t
0.05	0.0167	41	2.496
0.10	0.0333	41	2.202

Analyzing PM Data (FEI1 – LnEngHr Model)

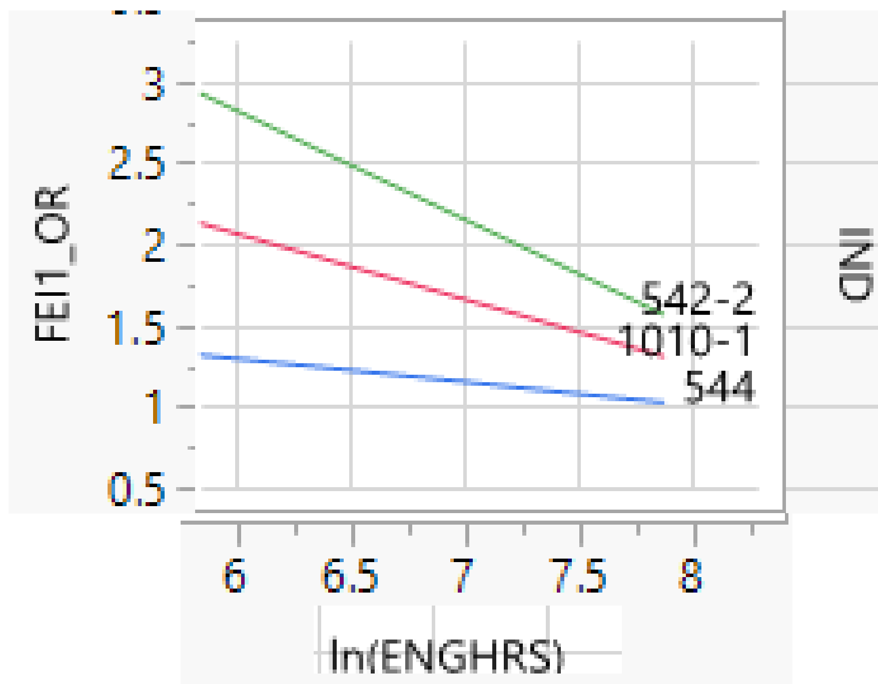
- When additional significant model terms are added to the model (lab*oil & oil*engine hours interactions) we find that oil discrimination changes over the range of hours

Model terms:

Effect Tests

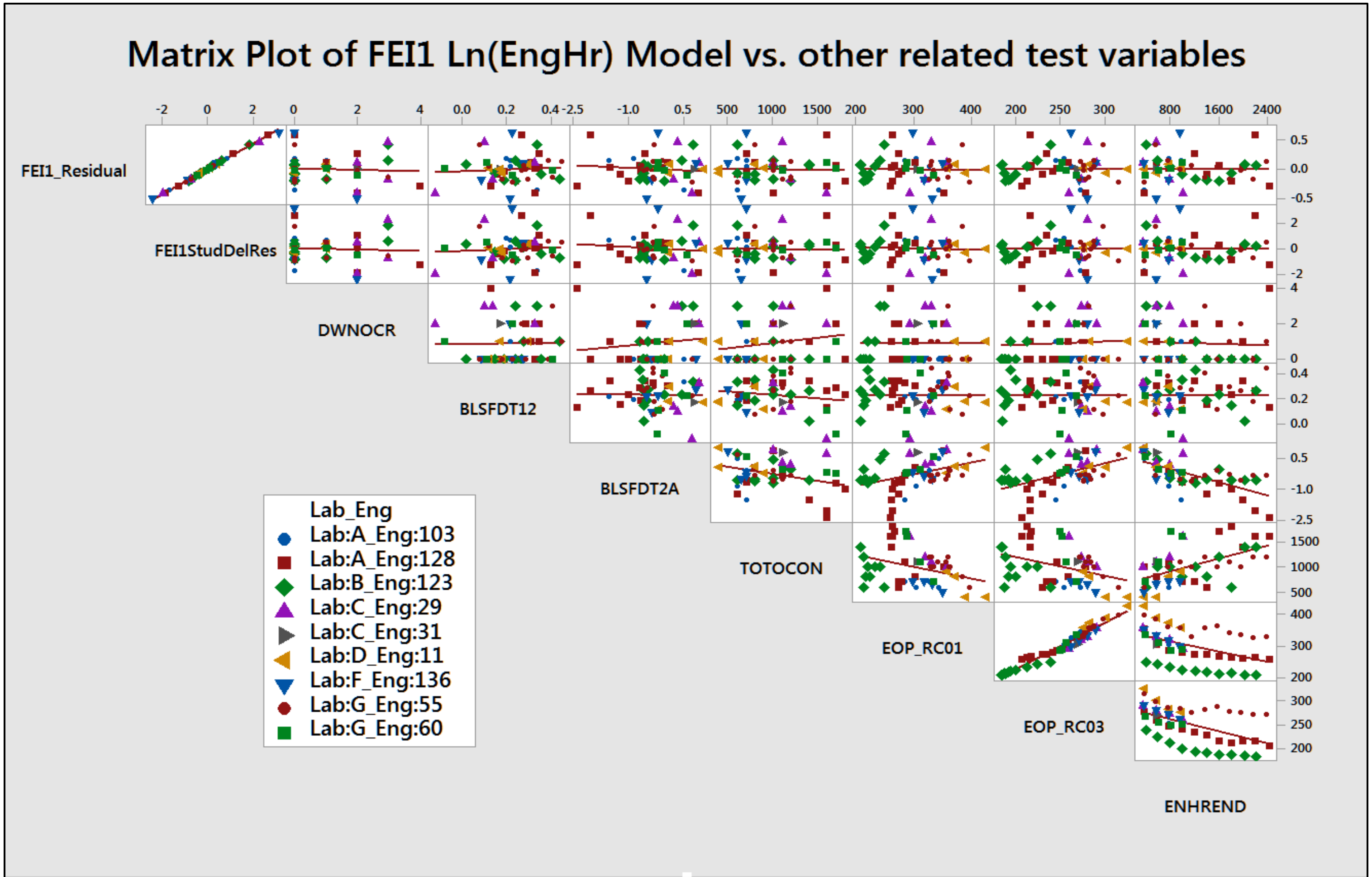
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2560614	1.5378	0.2090
IND	2	2	6.5647797	98.5648	<.0001*
ENGNO[LTMSLAB]	3	3	0.2624177	2.6267	0.0692
ln(ENGHRS)(5.85793,7.87702)	1	1	1.5782034	47.3908	<.0001*
LTMSLAB*IND	10	10	1.3710040	4.1169	0.0013*
ln(ENGHRS)*IND	2	2	0.5871054	8.8149	0.0010*

Model Predicted FEI1_OR vs. Engine Hours by Oil



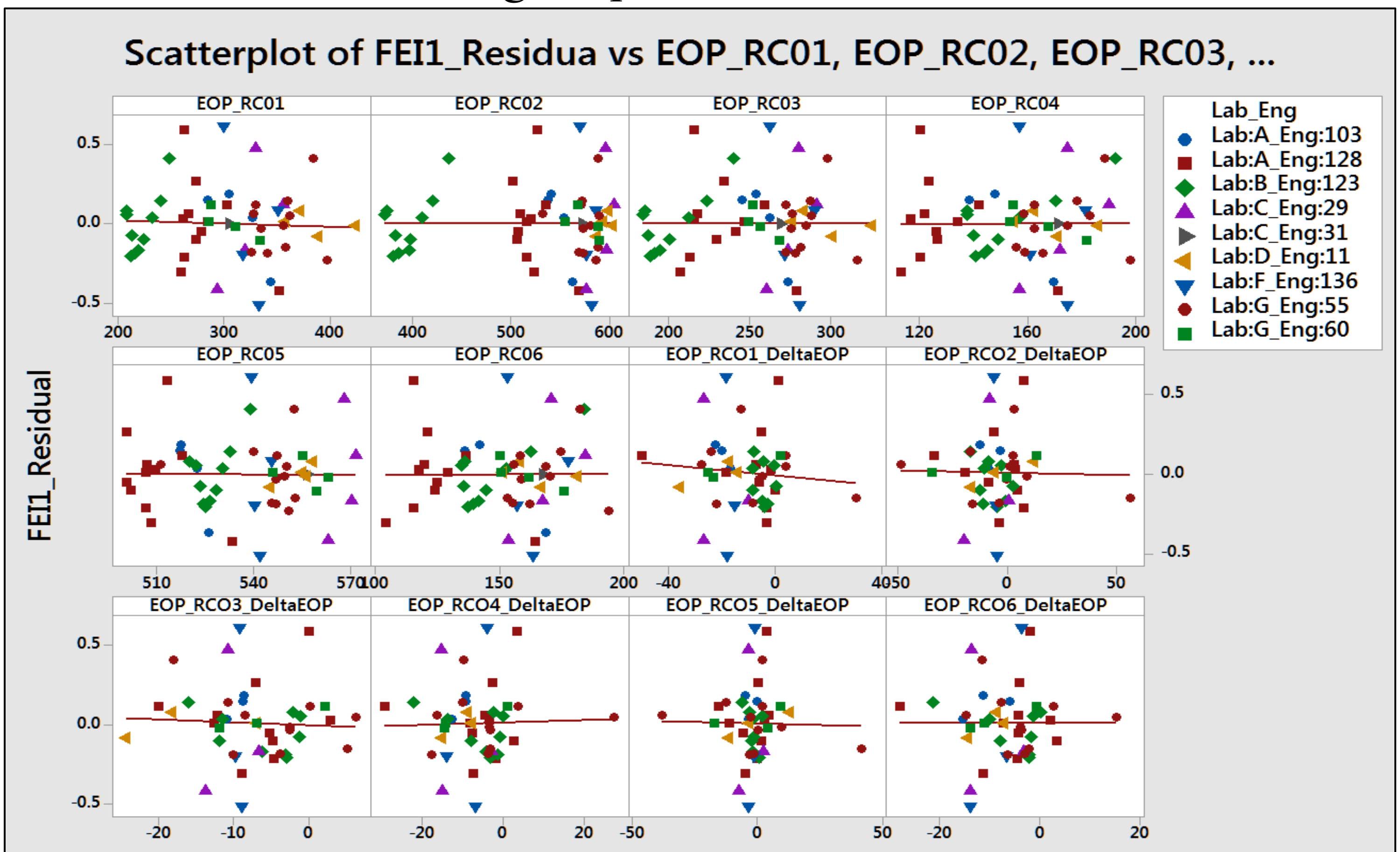
Analyzing PM Data (FEI1 – LnEngHr Model)

- Matrix Plot of FEI1 residuals vs. other related test variables
  - No observable trend that correlates with FEI1 residual data



Analyzing PM Data (FEI1 – LnEngHr Model)

- Plot of FEI1 residuals vs. oil pressure variable data
  - Oil pressure $\text{delta}_{(t)}$ = $[\text{Eng Oil Pressure}]_{(t)}$ - $[\text{Eng Oil Pressure}]_{(t\text{-}1)}$
  - No evidence found relating oil pressure to FEI1 residuals



FEI1 Precision (LnEngHr Model)

Model: Oil, Lab, Engine(Lab), LnEngHr

Model RMSE	Repeatability	Reproducibility
• s = 0.26 • VIE Prove-out s=0.21 • VID Precision Matrix s=0.14 • VID current data s=0.12	• s = 0.26 • r = 0.72	• s = 0.26 • R = 0.72

FEI1 Precision (LnEngHr Model)

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 1.3 – 2.0 for the VIE and 1.6 – 2.0 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 Alternatives for Engine Hour Adjustment
- **Analyzing PM Data**
  - FEI1 – LnEngHr Model
  - **FEI1 – Ice Hockey Stick Model**
  - FEI2 – LnEngHr Model
  - FEI2 – Ice Hockey Stick Model
  - Comparing VIE Precision and Oil Discrimination with other Tests

Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

- Overall ANOVA Summary of FEI1 data:
  - FEI1_EnHrEnd & Reference Oil factors are statistically Significant
  - VIE PM Test Precision: 0.26 *(contrast w/ VID PM test precision of 0.12)*

Class Level Information		
Class	Levels	Values
IND	3	1010-1 542-2 544
LTMSLAB	6	A B C D F G
ENGNO	9	11 29 31 55 60 103 123 128 136

Number of Observations Read	53
Number of Observations Used	53

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	14.43825486	1.31256862	20.12	<.0001
Error	41	2.67502439	0.06524450		
Corrected Total	52	17.11327925			

R-Square	Coeff Var	Root MSE	FEI1_OR Mean
0.843687	14.92425	0.255430	1.711509

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FEI1_EnhrEnd	1	2.03141881	2.03141881	31.14	<.0001
IND	2	10.42552907	5.21276454	79.90	<.0001
LTMSLAB	5	0.26523417	0.05304683	0.81	0.5473
ENGNO(LTMSLAB)	3	0.18307782	0.06102594	0.94	0.4323

Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

- Difference between reference oil LsMeans for FEI1:
  - All oil contrasts are significantly different
  - {544 < 1010-1 < 542-2}

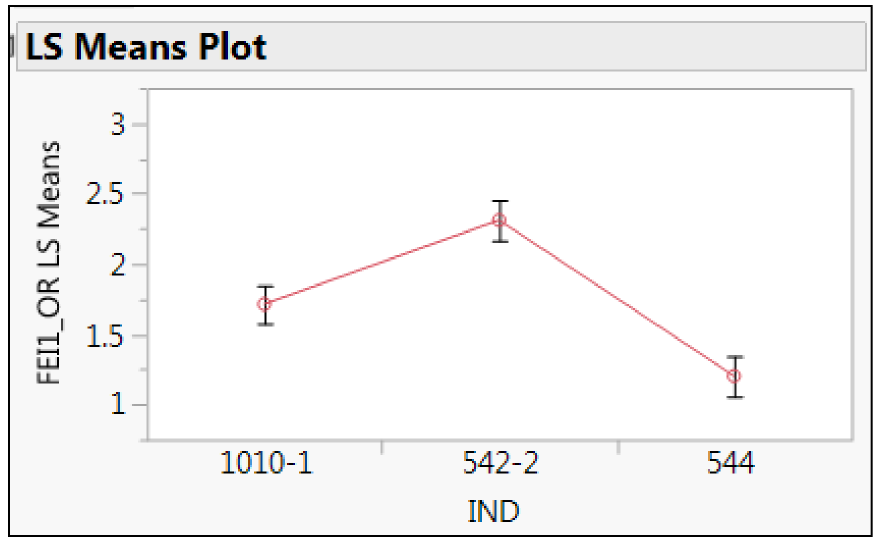
FEI1 Response Model - Ice Hockey Stick

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

IND	FEI1_OR LSMEAN	LSMEAN Number
1010-1	1.71386076	1
542-2	2.31121484	2
544	1.20314456	3

Least Squares Means for effect IND
Pr > \|t\| for H0: LSMean(i)=LSMean(j)
Dependent Variable: FEI1_OR

i/j	1	2	3
1		<.0001	<.0001
2	<.0001		<.0001
3	<.0001	<.0001	



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

Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

- Difference between test Lab LSMeans for FEI1
  - No significant difference between Labs

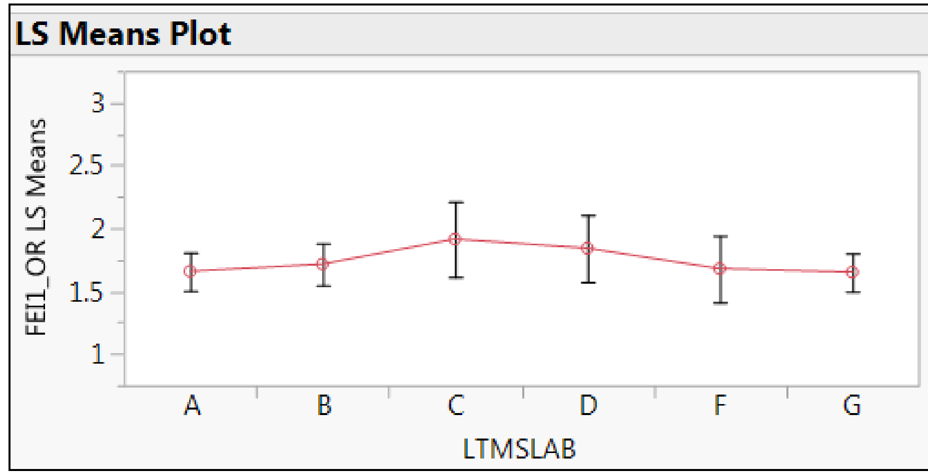
FEI1 Response Model - Ice Hockey Stick

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

LTMSLAB	FEI1_OR LSMEAN	LSMEAN Number
A	1.65754545	1
B	1.71472666	2
C	1.91370804	3
D	1.84139278	4
F	1.67872077	5
G	1.65034662	6

Least Squares Means for effect LTMSLAB
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: FEI1_OR

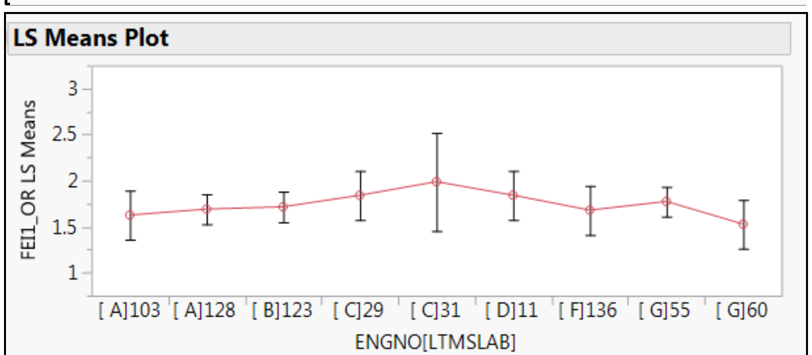
i/j	1	2	3	4	5	6
1		0.9956	0.6328	0.8273	1.0000	1.0000
2	0.9956		0.8625	0.9671	0.9999	0.9923
3	0.6328	0.8625		0.9990	0.8302	0.6072
4	0.8273	0.9671	0.9990		0.9458	0.8017
5	1.0000	0.9999	0.8302	0.9458		1.0000
6	1.0000	0.9923	0.6072	0.8017	1.0000	



Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

- LSMean difference between engines within the same Lab
  - Contrasts: {A-103 vs. A-128}, {C-29 vs. C-31}, {G-55 vs. G-60}
  - Conclusion: No Significant[1] Difference between engines within a Lab
    - Lab G engines significantly differ when additional significant model terms are added (lab*oil & oil*engine hours interactions)

ENGNO	LTMSLAB	FEI1_OR LSMEAN	LSMEAN Number
103	A	1.62529207	1
128	A	1.68979883	2
123	B	1.71472666	3
29	C	1.83981751	4
31	C	1.98759856	5
11	D	1.84139278	6
136	F	1.67872077	7
55	G	1.77316530	8
60	G	1.52752793	9



Least Squares Means for Effect ENGNO(LTMSLAB)
t for H0: LSMean(i)=LSMean(j) / Pr > |t|
Dependent Variable: FEI1_OR

i/j	1	2	3	4	5	6	7	8	9
1		-0.40743	-0.56022	-1.17878	-1.25635	-1.18745	-0.29366	-0.93365	0.541241
		1.0000	0.9997	0.9566	0.9381	0.9547	1.0000	0.9895	0.9998
2	0.407425		-0.22306	-0.94611	-1.06894	-0.95397	0.070083	-0.76323	1.029497
	1.0000		1.0000	0.9886	0.9755	0.9880	1.0000	0.9973	0.9806
3	0.560224	0.223061		-0.78511	-0.97494	-0.7934	0.226751	-0.52307	1.177486
	0.9997	1.0000		0.9967	0.9862	0.9965	1.0000	0.9998	0.9568
4	1.178777	0.946108	0.785115		-0.50636	-0.00872	0.885449	0.423229	1.715964
	0.9566	0.9886	0.9967		0.9999	1.0000	0.9926	1.0000	0.7335
5	1.256346	1.068945	0.974944	0.506359		0.501037	1.058715	0.767127	1.594822
	0.9381	0.9755	0.9862	0.9999		0.9999	0.9769	0.9972	0.8020
6	1.187451	0.953971	0.793395	0.008721	-0.50104		0.894099	0.43231	1.724526
	0.9547	0.9880	0.9965	1.0000	0.9999		0.9921	1.0000	0.7284
7	0.293662	-0.07008	-0.22675	-0.88545	-1.05872	-0.8941		-0.59942	0.830989
	1.0000	1.0000	1.0000	0.9926	0.9769	0.9921		0.9995	0.9952
8	0.93365	0.763229	0.523074	-0.42323	-0.76713	-0.43231	0.599423		1.557643
	0.9895	0.9973	0.9998	1.0000	0.9972	1.0000	0.9995		0.8212
9	-0.54124	-1.0295	-1.17749	-1.71596	-1.59482	-1.72453	-0.83099	-1.55764	
	0.9998	0.9806	0.9568	0.7335	0.8020	0.7284	0.9952	0.8212	

[1] *Familywise error rate critical t of 2.49 selected for 3 contrasts*

Familywise Error Rate	Bonferonni for 3 contrasts	DOF	Critical t
0.05	0.0167	41	2.496
0.10	0.0333	41	2.202

Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

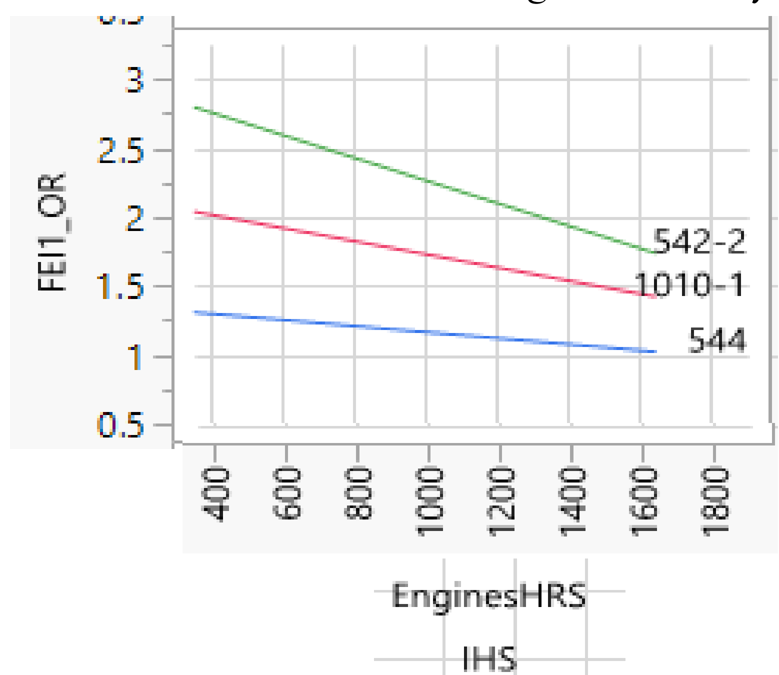
- When additional significant model terms are added to the model (lab*oil & oil*engine hours interactions) we find that oil discrimination changes over the range of hours

Model terms:

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2298268	1.4982	0.2210
IND	2	2	7.0439007	114.7932	<.0001*
ENGNO[LTMSLAB]	3	3	0.2448488	2.6602	0.0668
LTMSLAB*IND	10	10	1.3659171	4.4520	0.0008*
EnginesHRS IHS	1	1	1.6223632	52.8787	<.0001*
EnginesHRS IHS*IND	2	2	0.4982961	8.1206	0.0016*

Model Predicted FEI1_OR vs. Engine Hours by Oil



FEI1 Precision (IHS Model)

Model: Oil, Lab, Engine(Lab), min(1650,EngHr)

Model RMSE

- s = 0.26
- VIE Prove-out s=0.21
- VID Precision Matrix s=0.14
- VID current data s=0.12

Repeatability

- s = 0.26
- r = 0.72

Reproducibility

- s = 0.26
- R = 0.72

FEI1 Precision (IHS Model)

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 1.3 – 2.0 for the VIE and 1.6 – 2.0 for the VID.

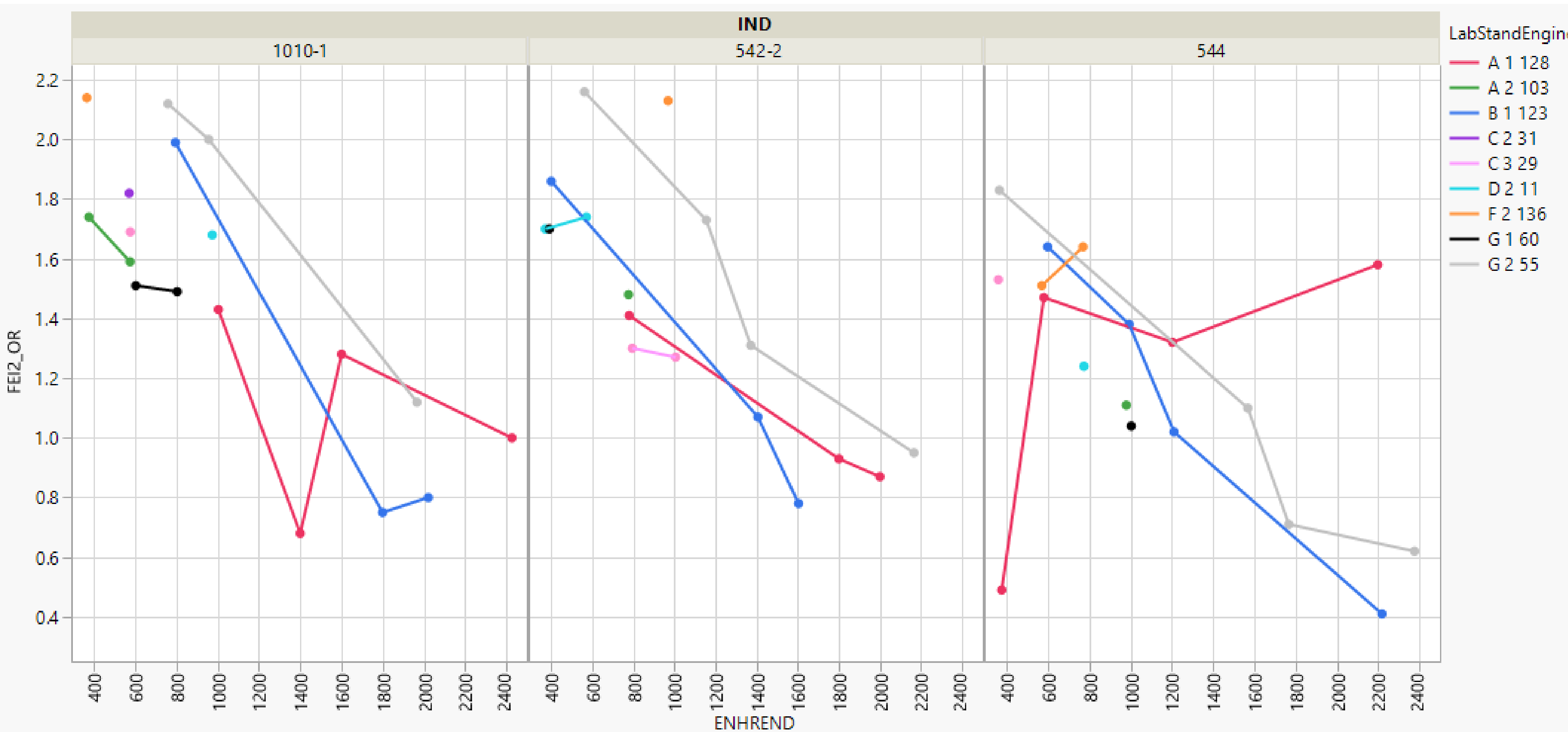
Note 1: An FEI1 of 2.0 was arbitrarily selected in the calculations as the upper pass/fail limit.

Agenda

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

Analyzing PM Data

- Plot of FEI2_OR



Analyzing PM Data (FEI2 – LnEngHr Model)

- ANOVA Summary of FEI2 data
  - Ln(EngHr) & Reference Oil factors are statistically Significant
  - VIE PM Test Precision: 0.32 *(contrast w/ VID PM test precision: 0.14)*

Class Level Information		
Class	Levels	Values
IND	3	1010-1 542-2 544
LTMSLAB	6	A B C D F G
ENGNO	9	11 29 31 55 60 103 123 128 136

Number of Observations Read	53
Number of Observations Used	53

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	6.29159104	0.57196282	5.56	<.0001
Error	41	4.21932971	0.10291048		
Corrected Total	52	10.51092075			

R-Square	Coeff Var	Root MSE	FEI2_OR Mean
0.598577	23.33547	0.320797	1.374717

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LnEngHr	1	3.03988904	3.03988904	29.54	<.0001
IND	2	0.97487524	0.48743762	4.74	0.0141
LTMSLAB	5	0.61497246	0.12299449	1.20	0.3285
ENGNO(LTMSLAB)	3	0.31579986	0.10526662	1.02	0.3924

Analyzing PM Data (FEI2 – LnEngHr Model)

- Difference between reference oil LSmeans for FEI2
  - Significant Oil Contrast: 544 < 1010-1

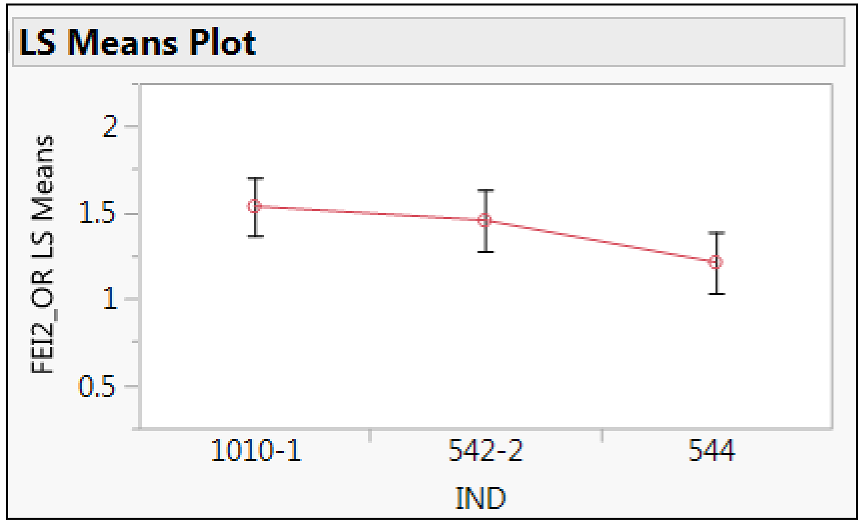
FEI2 Response Model - Ln(EngHr)

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

IND	FEI2_OR LSMEAN	LSMEAN Number
1010-1	1.53598087	1
542-2	1.45455392	2
544	1.21166083	3

Least Squares Means for effect IND
Pr > \|t\| for H0: LSMean(i)=LSMean(j)
Dependent Variable: FEI2_OR

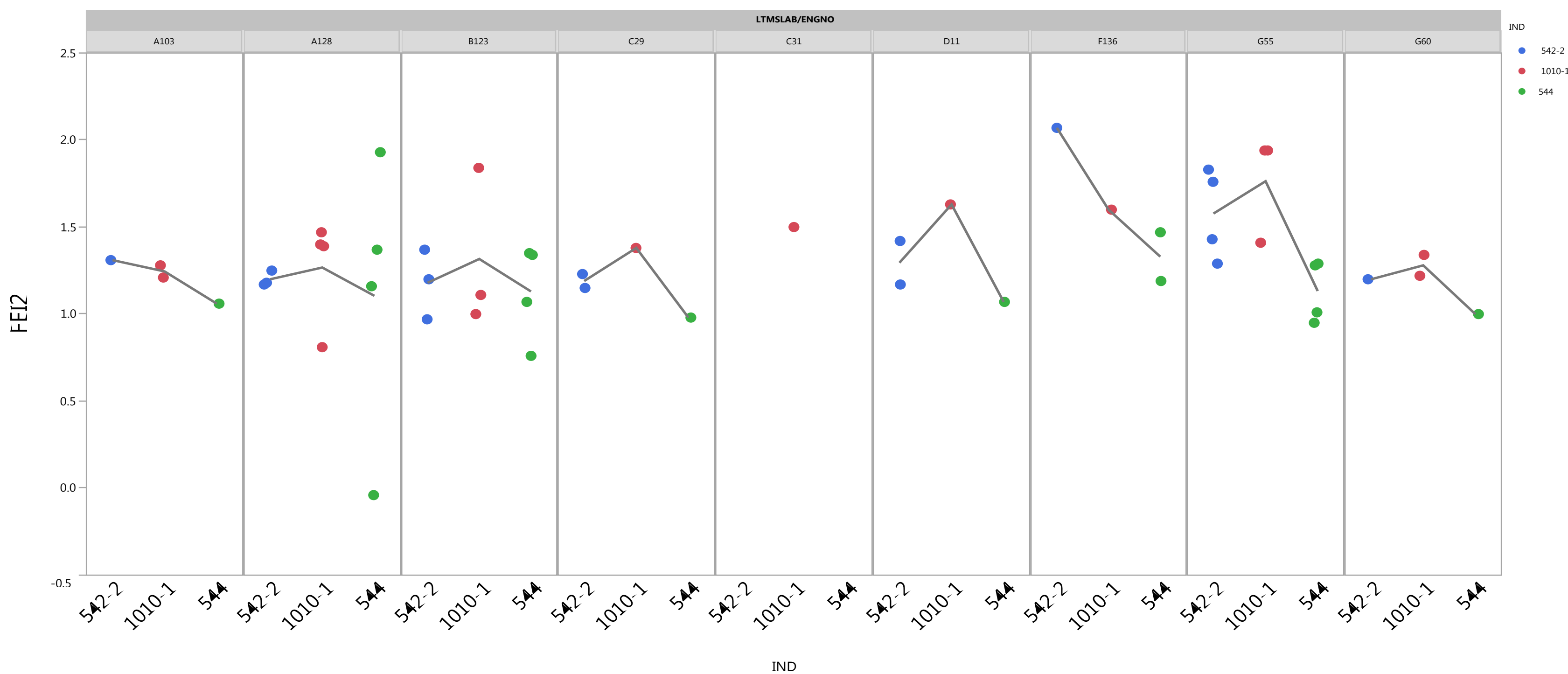
i/j	1	2	3
1		0.7492	0.0144
2	0.7492		0.0818
3	0.0144	0.0818	



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

Analyzing PM Data (FEI2 – LnEngHr Model)

- FEI2Adj Oil Discrimination by Engine
  - Contrast below plot with oil ranking of {544 < 1010-1}
  - Oil discrimination is not consistent across labs; in particular, Lab F, though sample size is small and inferences can be impacted by variation



Analyzing PM Data (FEI2 – LnEngHr Model)

- Difference between test Lab LSMeans for FEI2
  - No significant difference between labs

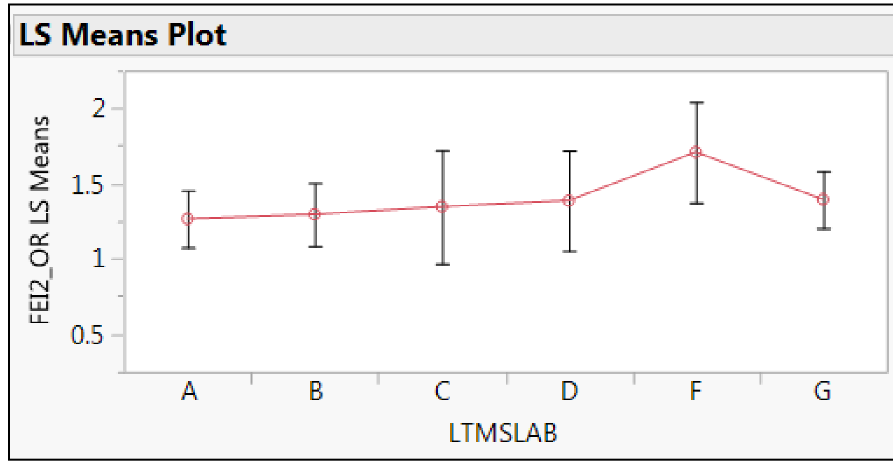
FEI2 Response Model - Ln(EngHr)

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

LTMSLAB	FEI2_OR LSMEAN	LSMEAN Number
A	1.26676675	1
B	1.29693320	2
C	1.34759006	3
D	1.38774418	4
F	1.70974374	5
G	1.39561331	6

Least Squares Means for effect LTMSLAB
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: FEI2_OR

i/j	1	2	3	4	5	6
1		0.9999	0.9987	0.9874	0.2013	0.9241
2	0.9999		0.9999	0.9973	0.3138	0.9807
3	0.9987	0.9999		1.0000	0.6766	0.9999
4	0.9874	0.9973	1.0000		0.7213	1.0000
5	0.2013	0.3138	0.6766	0.7213		0.5643
6	0.9241	0.9807	0.9999	1.0000	0.5643	



Analyzing PM Data (FEI2 – LnEngHr Model)

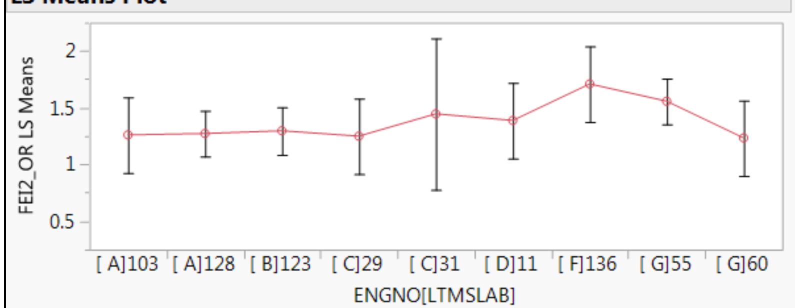
- LSMeans difference between engines within the same Lab
  - Contrasts: {A-103 vs. A-128}, {C-29 vs. C-31}, {G-55 vs. G-60}
  - Conclusion: No [1]Significant Difference between engines with Lab
    - Lab G engines significantly differ when additional significant model terms are added (lab*oil & oil*engine hours interactions)

ENGNO	LTMSLAB	FEI2_OR LSMEAN	LSMEAN Number
103	A	1.26062811	1
128	A	1.27290538	2
123	B	1.29693320	3
29	C	1.24949353	4
31	C	1.44568658	5
11	D	1.38774418	6
136	F	1.70974374	7
55	G	1.55735707	8
60	G	1.23386956	9

Least Squares Means for Effect ENGNO(LTMSLAB)
t for H0: LSMean(i)=LSMean(j) / Pr > |t|
Dependent Variable: FEI2_OR

i/j	1	2	3	4	5	6	7	8	9
1		-0.06227	-0.18274	0.048716	-0.51107	-0.55616	-1.96551	-1.50431	0.117951
		1.0000	1.0000	1.0000	0.9999	0.9997	0.5747	0.8471	1.0000
2	0.062274		-0.17116	0.118506	-0.49614	-0.5806	-2.2175	-2.07353	0.199005
	1.0000		1.0000	1.0000	0.9999	0.9996	0.4140	0.5043	1.0000
3	0.182744	0.171165		0.239135	-0.42526	-0.45727	-2.08748	-1.85587	0.318891
	1.0000	1.0000		1.0000	1.0000	0.9999	0.4953	0.6462	1.0000
4	-0.04872	-0.11851	-0.23913		-0.5354	-0.60947	-2.01424	-1.56892	0.068355
	1.0000	1.0000	1.0000		0.9998	0.9995	0.5428	0.8155	1.0000
5	0.511069	0.496138	0.425262	0.5354		0.158134	-0.72086	-0.31955	0.584755
	0.9999	0.9999	1.0000	0.9998		1.0000	0.9982	1.0000	0.9996
6	0.556163	0.580599	0.457265	0.609466	-0.15813		-1.40921	-0.86337	0.673176
	0.9997	0.9996	0.9999	0.9995	1.0000		0.8878	0.9937	0.9989
7	1.965515	2.217499	2.087479	2.014243	0.720864	1.409205		0.775977	2.082461
	0.5747	0.4140	0.4953	0.5428	0.9982	0.8878		0.9970	0.4985
8	1.504309	2.073532	1.855866	1.568923	0.319549	0.863373	-0.77598		1.647968
	0.8471	0.5043	0.6462	0.8155	1.0000	0.9937	0.9970		0.7730
9	-0.11795	-0.19901	-0.31889	-0.06836	-0.58476	-0.67318	-2.08246	-1.64797	
	1.0000	1.0000	1.0000	1.0000	0.9996	0.9989	0.4985	0.7730	

LS Means Plot

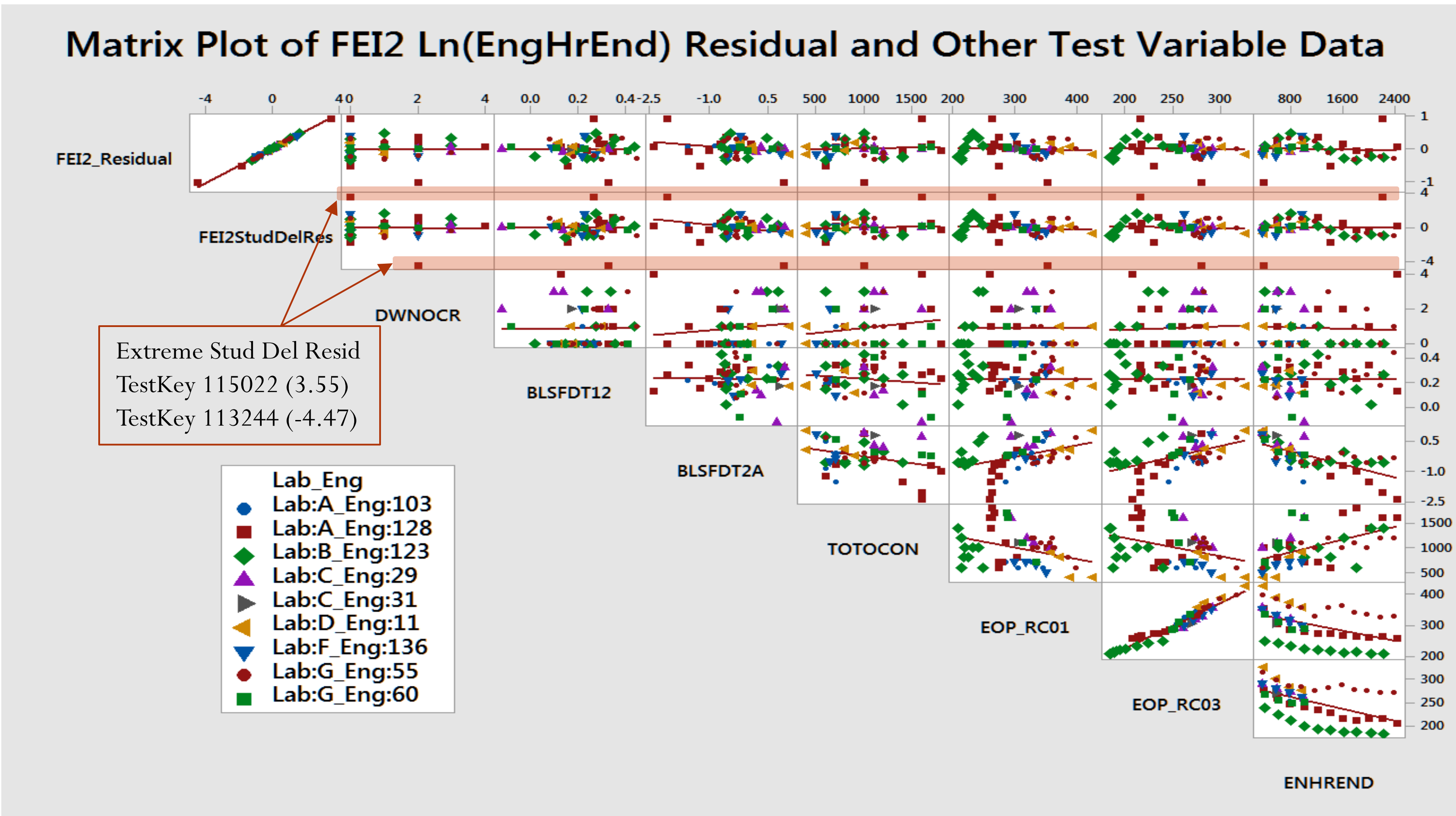


[1] *Familywise error rate critical t of 2.49 selected for 3 contrasts*

Familywise Error Rate	Bonferonni for 3 contrasts	DOF	Critical t
0.05	0.0167	41	2.496
0.10	0.0333	41	2.202

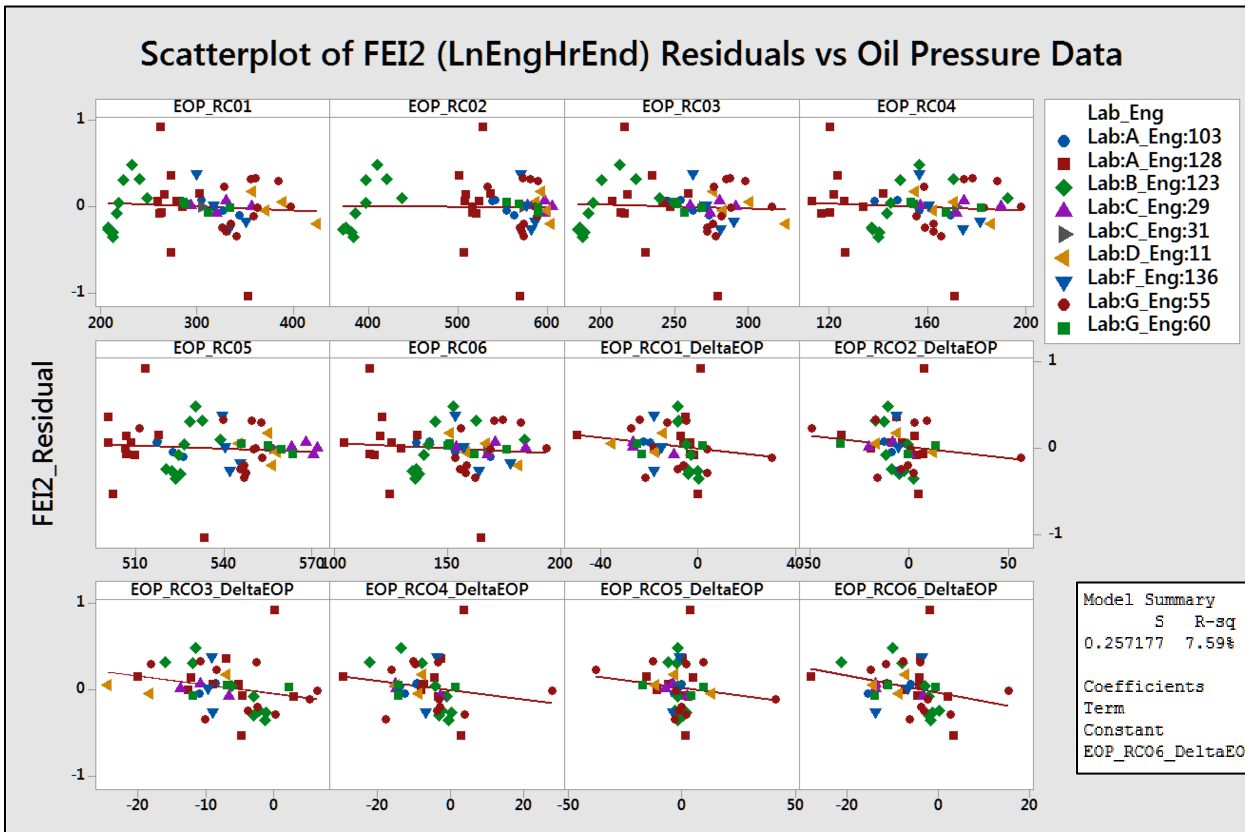
Analyzing PM Data (FEI2 – LnEngHr Model)

- Matrix Plot of FEI2 residuals vs. other variables
  - 2 unusual studentized deleted residual results for Engine128 in Lab A



Analyzing PM Data (FEI2 – LnEngHr Model)

- Plot of FEI2 residuals vs. oil pressure variable data
  - Oil pressure delta$_{(t)}$ = [Eng Oil Pressure]$_{(t)}$- [Eng Oil Pressure]$_{(t\text{-}1)}$
  - Possible evidence of relationship between oil pressure delta and FEI2 residuals




```
Model Summary
       S    R-sq  R-sq(adj)  R-sq(pred)
0.257177   7.59%      5.39%       0.00%

Coefficients
Term                   Coef  SE Coef  T-Value  P-Value   VIF
Constant            -0.0341   0.0527    -0.65    0.522
EOP_RCO6_DeltaEOP  -0.01007  0.00542    -1.86    0.070  1.00
```

FEI2 Precision (LnEngHr Model)

Model: Oil, Lab, Engine(Lab), LnEngHr

Model RMSE	Repeatability	Reproducibility
• s = 0.32 • VIE Prove-out s=0.16 • VID Precision Matrix s=0.16 • VID current data s=0.13	• s = 0.32 • r = 0.89	• s = 0.33 • R = 0.91

FEI2 Precision (LnEngHr Model)

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[1,2] of 0.4 – 1.5 for the VIE and 1.0 – 1.5 for the VID.

Note 1: An FEI2 of 1.5 was arbitrarily selected in the calculations as the upper pass/fail limit.
Note 2: If the identified statistical outliers (test keys 115022 & 113244) are from a different population and not representative of real VIE repeatability, the above statement may not represent the true precision of the test.

Agenda

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

Analyzing PM Data (FEI2 – Ice Hockey Stick Model)

- ANOVA Summary of FEI2 data
  - FEI2_EnHrEnd & Reference Oil factors are statistically Significant
  - VIE PM Test Precision: 0.29 *(contrast w/ VID PM test precision: 0.14)*

Class Level Information		
Class	**Levels**	**Values**
IND	3	1010-1 542-2 544
LTMSLAB	6	A B C D F G
ENGNO	9	11 29 31 55 60 103 123 128 136

Number of Observations Read	53
Number of Observations Used	53

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	6.94808406	0.63164401	7.27	<.0001
Error	41	3.56283669	0.08689846		
Corrected Total	52	10.51092075			

R-Square	Coeff Var	Root MSE	FEI2_OR Mean
0.661035	21.44335	0.294785	1.374717

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FEI2_EnhrEnd	1	3.69638206	3.69638206	42.54	<.0001
IND	2	1.03811130	0.51905565	5.97	0.0053
LTMSLAB	5	0.52295898	0.10459180	1.20	0.3246
ENGNO(LTMSLAB)	3	0.43819994	0.14606665	1.68	0.1860

Analyzing PM Data (FEI2 – Ice Hockey Stick Model)

- Difference between reference oil LSmeans for FEI2
  - Significant Oil Contrast: 544 < 1010-1 and 544 < 542-2
  - Higher VIE FEIs as compared to VID is partially due to correction at reduced number of engine hours

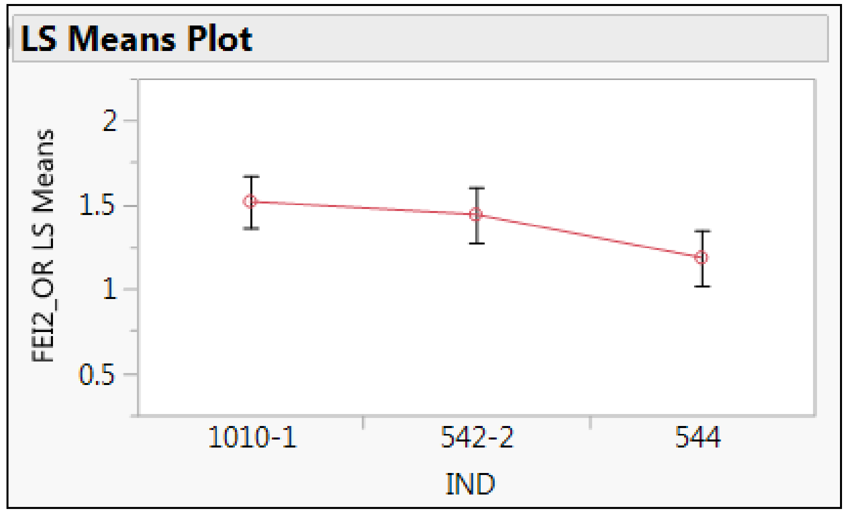
FEI2 Response Model - Ice Hockey Stick

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

IND	FEI2_OR LSMEAN	LSMEAN Number
1010-1	1.51942810	1
542-2	1.44159526	2
544	1.18640600	3

Least Squares Means for effect IND
Pr > \|t\| for H0: LSMean(i)=LSMean(j)
Dependent Variable: FEI2_OR

i/j	1	2	3
1		0.7317	0.0058
2	0.7317		0.0406
3	0.0058	0.0406	



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

Analyzing PM Data (FEI2 – Ice Hockey Stick Model)

- Difference between test Lab LSMeans for FEI2
  - No significant difference between labs

FEI2 Response Model - Ice Hockey Stick

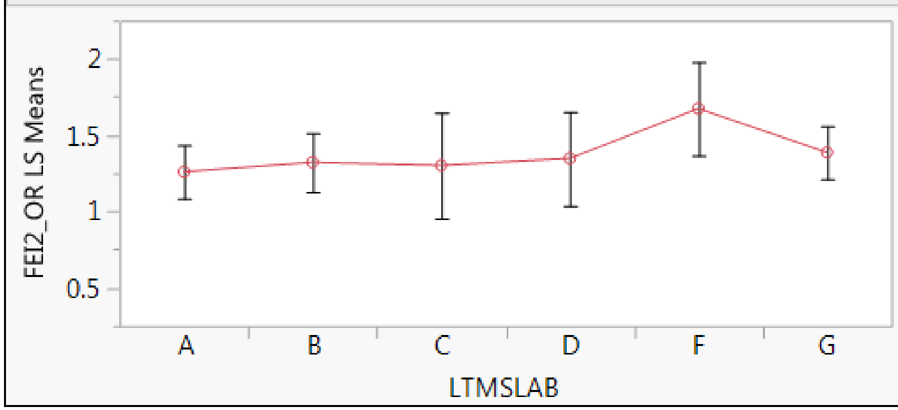
The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

LTMSLAB	FEI2_OR LSMEAN	LSMEAN Number
A	1.26042650	1
B	1.32265707	2
C	1.30227312	3
D	1.34811725	4
F	1.67422213	5
G	1.38716266	6

Least Squares Means for effect LTMSLAB
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: FEI2_OR

i/j	1	2	3	4	5	6
1		0.9967	0.9999	0.9958	0.1886	0.9013
2	0.9967		1.0000	1.0000	0.4049	0.9960
3	0.9999	1.0000		0.9999	0.5667	0.9976
4	0.9958	1.0000	0.9999		0.6329	0.9999
5	0.1886	0.4049	0.5667	0.6329		0.5717
6	0.9013	0.9960	0.9976	0.9999	0.5717	

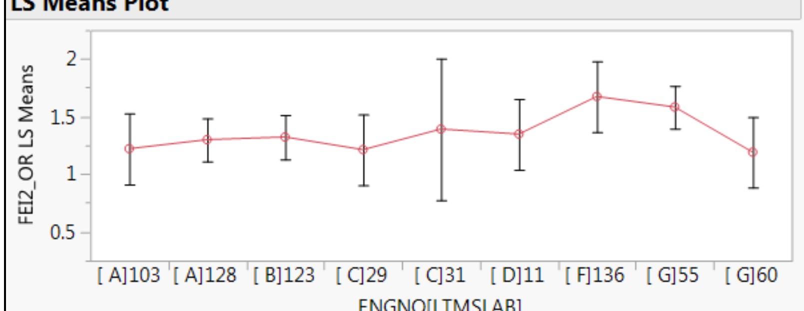
LS Means Plot



Analyzing PM Data (FEI2 – Ice Hockey Stick Model)

- LSMeans difference between engines within the same Lab for FEI2
  - Contrasts: {A-103 vs. A-128}, {C-29 vs. C-31}, {G-55 vs. G-60}
  - Conclusion: No [1]Significant Difference between engines with Lab
    - Lab G engines significantly differ when additional significant model terms are added (lab*oil & oil*engine hours interactions)

ENGNO	LTMSLAB	FEI2_OR LSMEAN	LSMEAN Number
103	A	1.22119310	1
128	A	1.29965990	2
123	B	1.32265707	3
29	C	1.21290267	4
31	C	1.39164356	5
11	D	1.34811725	6
136	F	1.67422213	7
55	G	1.58308625	8
60	G	1.19123907	9



Least Squares Means for Effect ENGNO(LTMSLAB)
t for H0: LSMean(i)=LSMean(j) / Pr > |t|
Dependent Variable: FEI2_OR

i/j	1	2	3	4	5	6	7	8	9
1		-0.42936	-0.55116	0.039472	-0.5122	-0.60432	-2.15757	-1.97972	0.143694
		1.0000	0.9997	1.0000	0.9999	0.9995	0.4509	0.5654	1.0000
2	0.429363		-0.17829	0.474116	-0.28623	-0.26429	-2.05331	-2.24837	0.595698
	1.0000		1.0000	0.9999	1.0000	1.0000	0.5173	0.3956	0.9995
3	0.551163	0.178289		0.597468	-0.21375	-0.13834	-1.92029	-2.01973	0.716558
	0.9997	1.0000		0.9995	1.0000	1.0000	0.6043	0.5392	0.9983
4	-0.03947	-0.47412	-0.59747		-0.53072	-0.64867	-2.19707	-2.037	0.103146
	1.0000	0.9999	0.9995		0.9998	0.9991	0.4265	0.5279	1.0000
5	0.512197	0.286233	0.213754	0.530721		0.129256	-0.83933	-0.59374	0.602035
	0.9999	1.0000	1.0000	0.9998		1.0000	0.9948	0.9996	0.9995
6	0.604324	0.26429	0.138344	0.648674	-0.12926		-1.55309	-1.29045	0.746906
	0.9995	1.0000	1.0000	0.9991	1.0000		0.8235	0.9285	0.9977
7	2.157566	2.053311	1.920289	2.197072	0.839332	1.553091		0.501251	2.300204
	0.4509	0.5173	0.6043	0.4265	0.9948	0.8235		0.9999	0.3655
8	1.979717	2.248367	2.019726	2.037001	0.593741	1.290453	-0.50125		2.152069
	0.5654	0.3956	0.5392	0.5279	0.9996	0.9285	0.9999		0.4543
9	-0.14369	-0.5957	-0.71656	-0.10315	-0.60204	-0.74691	-2.3002	-2.15207	
	1.0000	0.9995	0.9983	1.0000	0.9995	0.9977	0.3655	0.4543	

[1]*Familywise error rate critical t of 2.49 selected for 3 contrasts*

Familywise Error Rate	Bonferonni for 3 contrasts	DOF	Critical t
0.05	0.0167	41	2.496
0.10	0.0333	41	2.202

FEI2 Precision (IHS Model)

Model: Oil, Lab, Engine(Lab), Min(EngHr,1800)

Model RMSE	Repeatability	Reproducibility
• s = 0.29 • VIE Prove-out s=0.16 • VID Precision Matrix s=0.16 • VID current data s=0.13	• s = 0.29 • r = 0.81	• s = 0.31 • R = 0.87

FEI2 Precision (IHS Model)

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[1,2] of 0.7 – 1.5 for the VIE and 1.0 – 1.5 for the VID.

Note 1: An FEI2 of 1.5 was arbitrarily selected in the calculations as the upper pass/fail limit.
Note 2: If the identified statistical outliers (test keys 115022 & 113244) are from a different population and not representative of real VIE repeatability, the above statement may not represent the true precision of the test.

Agenda

- Review PM Data for Analysis
- Evaluating Baseline Weighting Scenarios
- Evaluating Alternatives for Engine Hour Adjustment
- **Analyzing PM Data**
  - FEI1 – LnEngHr Model
  - FEI1 – Ice Hockey Stick Model
  - FEI2 – LnEngHr Model
  - FEI2 – Ice Hockey Stick Model
  - **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 devs)**	1.15
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	**Span of Oil 1010 - Oil 542 (st devs)**	2.14
1010		1.1		

Sequence VIE FEI1

Oil	LS Mean (Regression)		
1010-1	1.72	Regression RMSE	0.26
542-2	2.31	**Full span of results (st devs)**	4.26
544	1.22	**Span of Oil 1010 - Oil 542 (st devs)**	2.29

Sequence VIE FEI2

Oil	LS Mean (Regression)		
1010-1	1.54	Regression RMSE	0.32
542-2	1.45	**Full span of results (st devs)**	1.03
544	1.21	**Span of Oil 1010 - Oil 542 (st devs)**	0.28

Models contain lab, engine(lab), oil, ln(ENHREND)

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

Next Steps

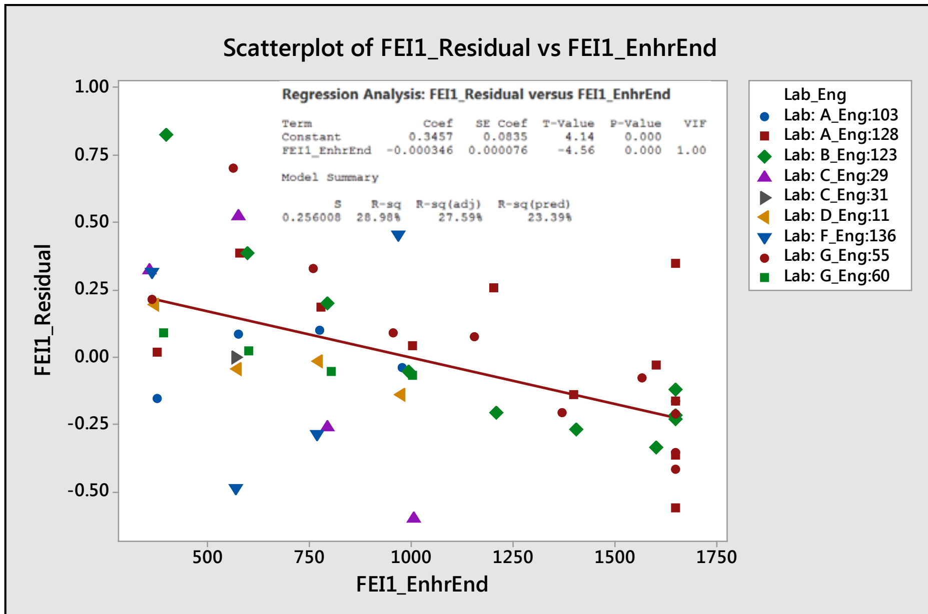
- Choose Engine Hour Adjustment (Ln vs IHS)
- Review BLB-BLA Shift
- Review Operational Data
- Decide on LTMS

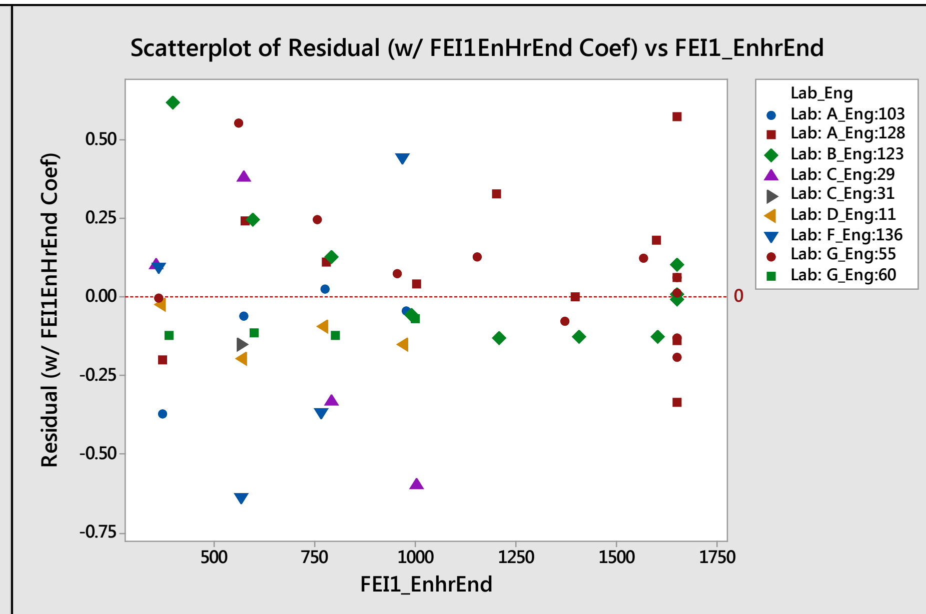
Appendix A

Evaluating FEI1 Eng Hour Adjustment Approach

Evaluating Alternatives for FEI1 Engine Hour Adjustment

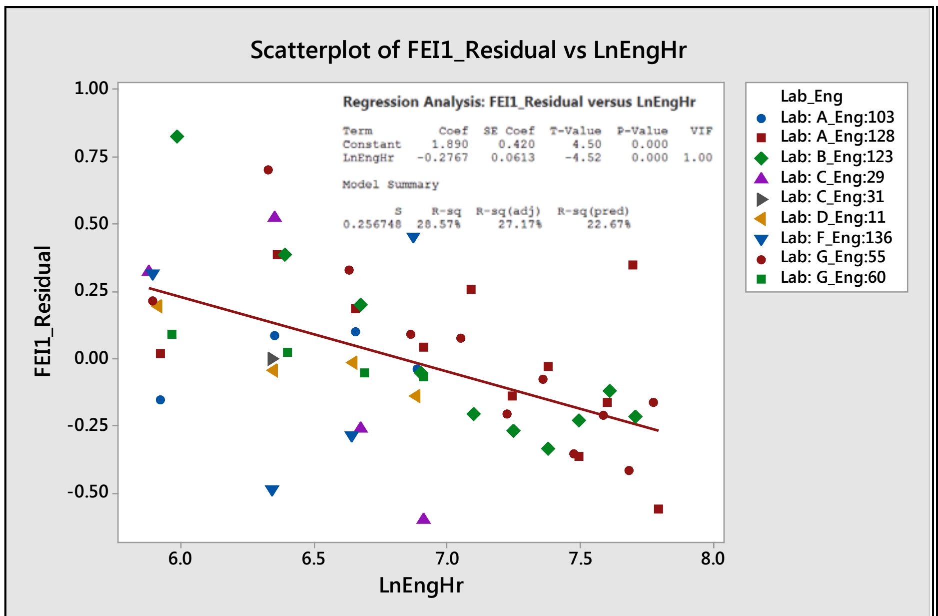
- Model factors: Lab, Eng(LAB), Oil
- FEI1 model residuals (*y*) vs. EngHrEnd *[Ice Hockey Stick]* (*x*) data are shown below
- Model RMSE and Rsquare are 0.256 and 28.98, respectively

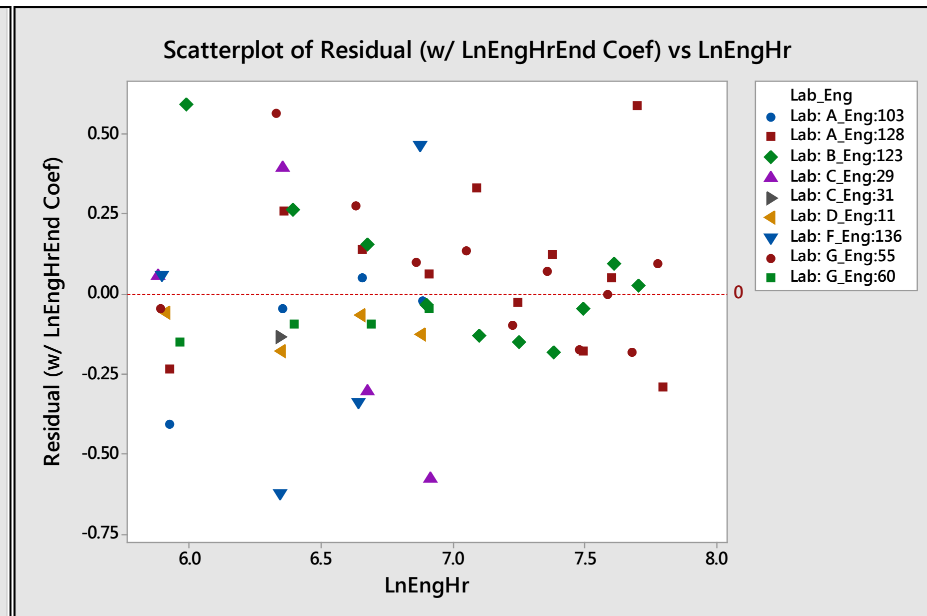




Evaluating Alternatives for FEI1 Engine Hour Adjustment

- Model factors: Lab, Eng(Lab), Oil
- Fit of FEI1 model residuals (*y*) vs. Ln(EngHrEnd) (*x*) data are shown below
- Model RMSE and Rsquare are 0.257 and 28.57, respectively

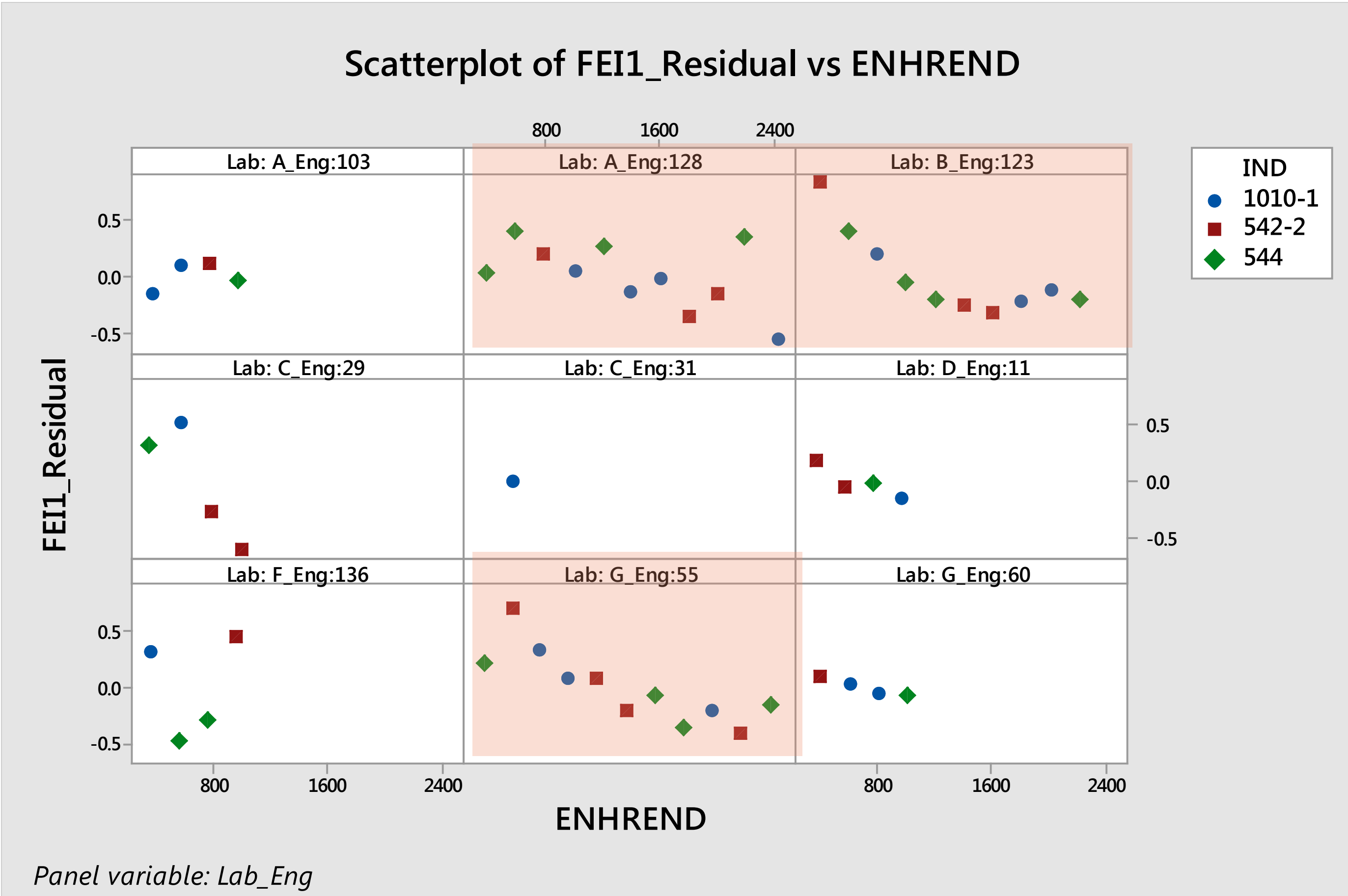




Ln(EngHrEnd) Transform

Evaluating Alternatives for FEI1 Engine Hour Adjustment

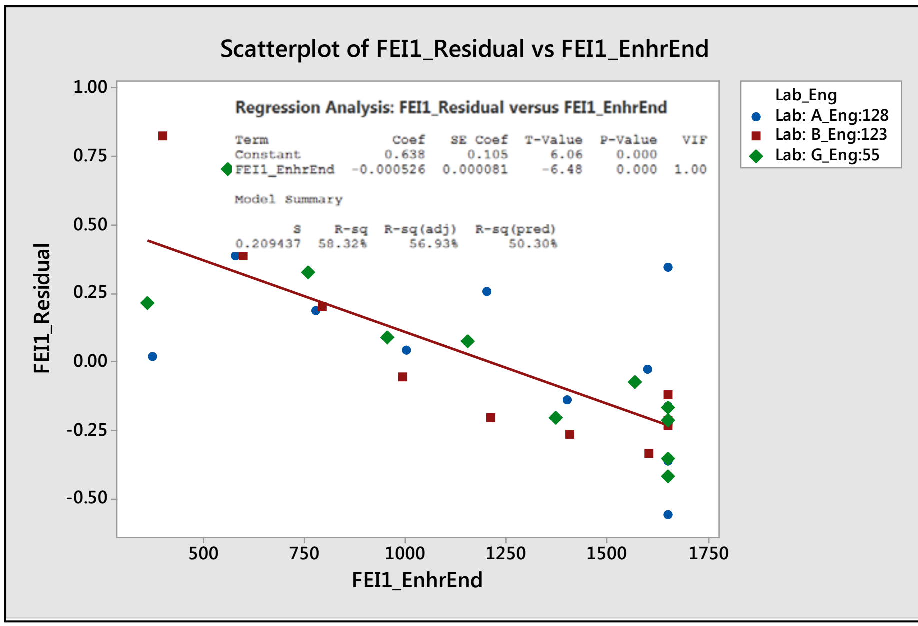
- Exploring the same data set for those engines that have a higher engine hour age (with Engines 128, 123, and 55, exclusively)



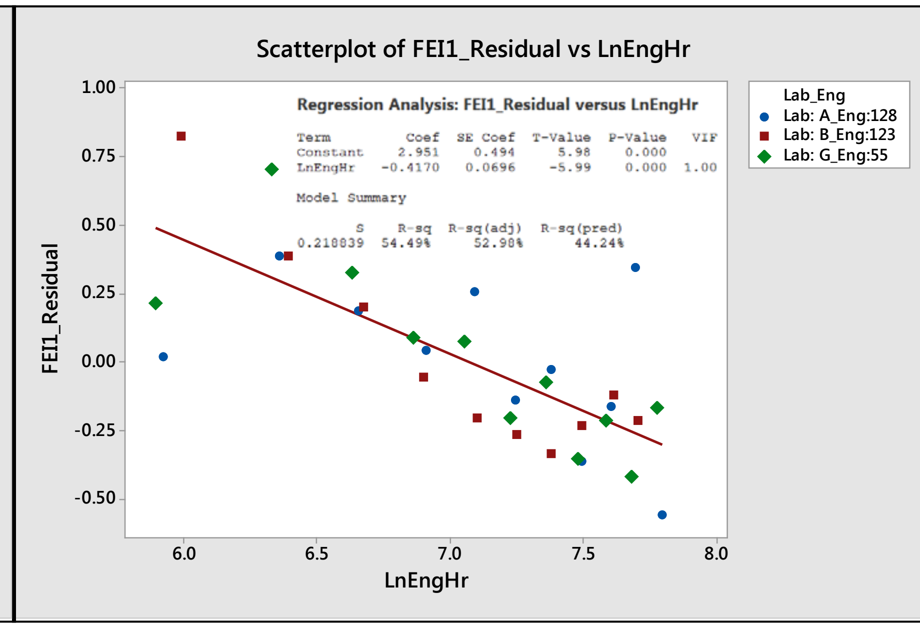
- The observed range of engine hour effects by engine is similar to what is observed in the VID (see Appendix D)

Evaluating Alternatives for FEI1 Engine Hour Adjustment

- Higher aged engines have similar model fit results when comparing the Ice Hockey Stick and transformed (natural log) engine hours with respect to the FEI1 model fit residuals.



IHS EngHrEnd Transform

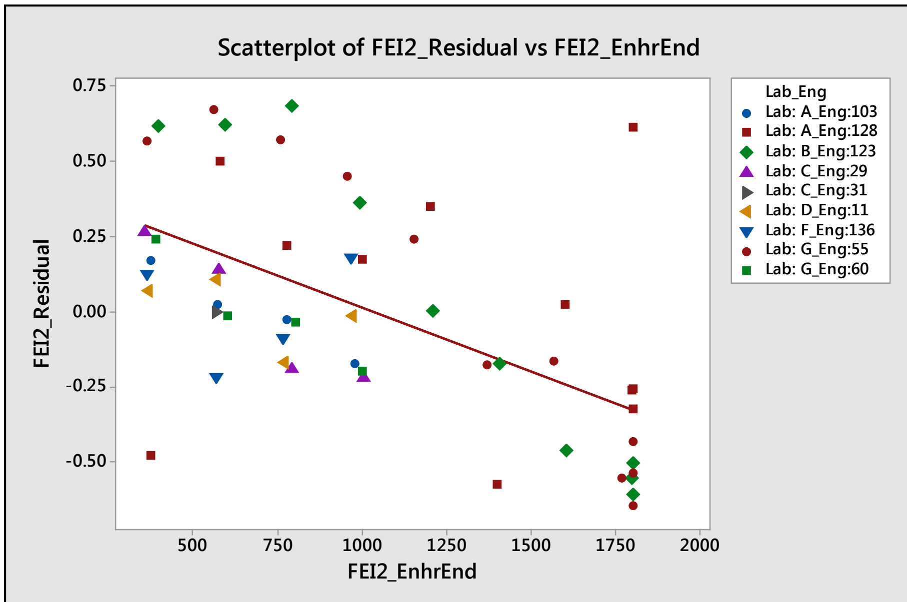


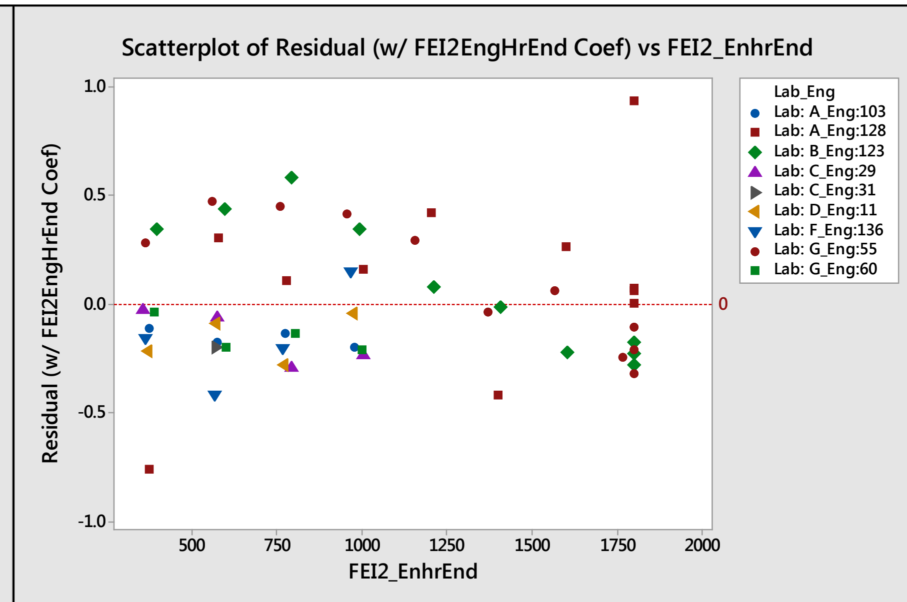
Ln(EngHrEnd) Transform

Evaluating FEI2 Eng Hour Adjustment

Evaluating Alternatives for FEI2 Engine Hour Adjustment

- Linear fit of FEI2 model residuals (*y*) vs. Ice Hockey Stick EngHrEnd (*x*) data are shown below
- Model RMSE and Rsquare are 0.306 and 34.26, respectively





IHS EngHrEnd Transform

Regression Analysis: FEI2_Residual versus FEI2_EnhrEnd

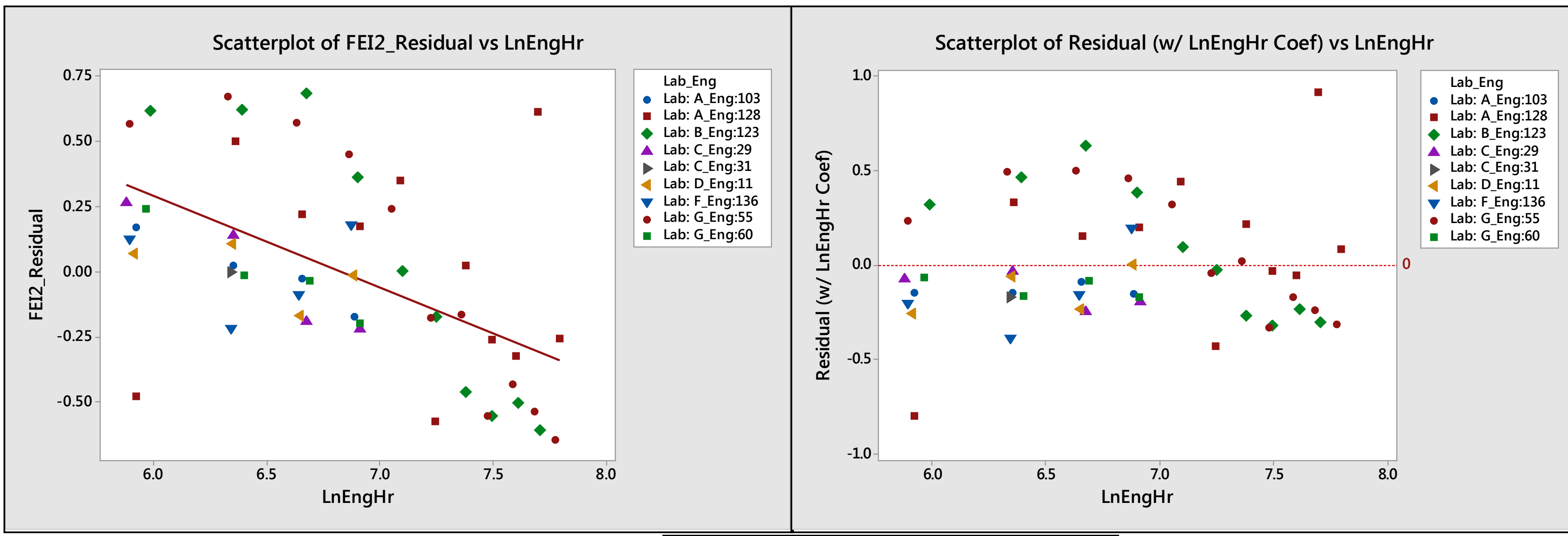
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.4390	0.0950	4.62	0.000	
FEI2_EnhrEnd	-0.000426	0.000083	-5.16	0.000	1.00

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.305900	34.26%	32.97%	28.56%

Evaluating Alternatives for FEI2 Engine Hour Adjustment

- Fit of FEI2 model residuals (*y*) vs. Ln(EngHrEnd) (*x*) data are shown below
- Model RMSE and Rsquare are 0.316 and 29.82, respectively



Ln(EngHrEnd) Transform

Regression Analysis: FEI2_Residual versus LnEngHr

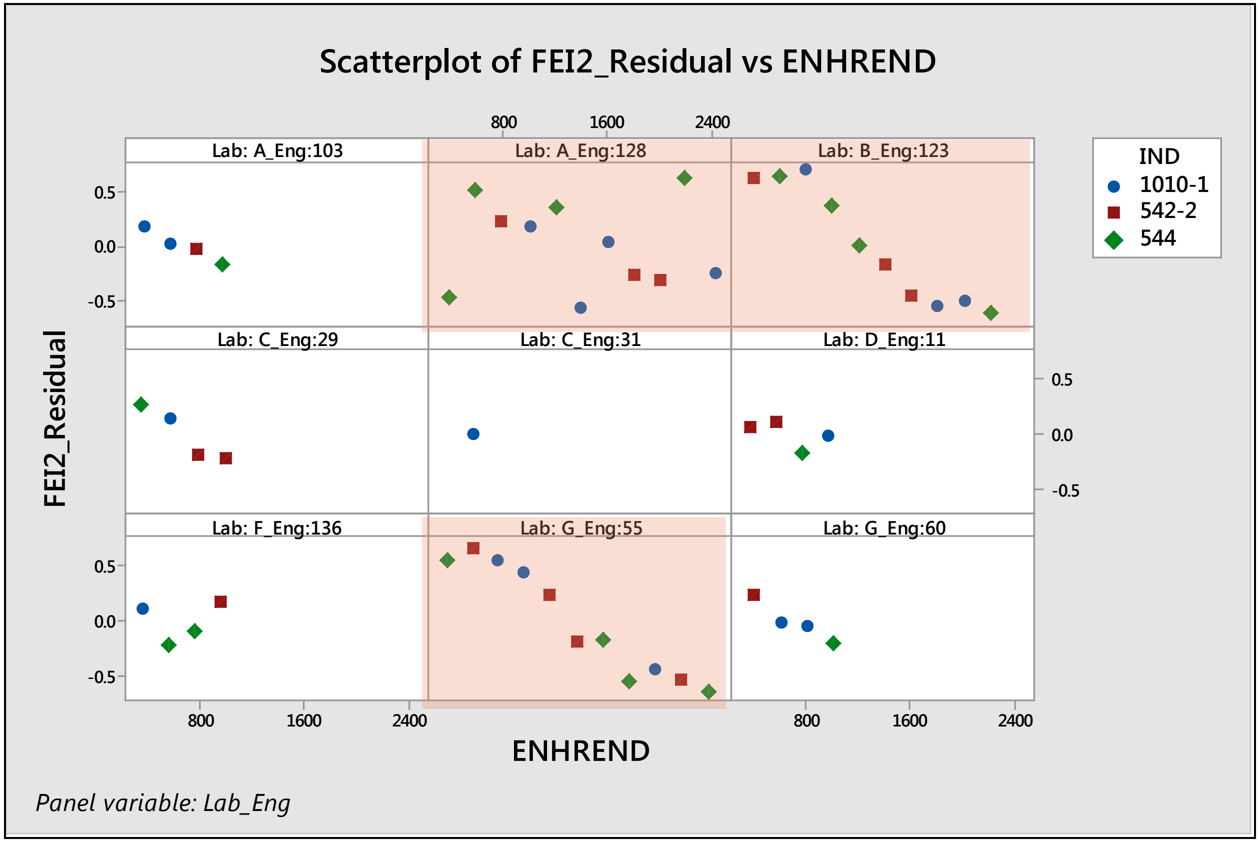
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2.398	0.517	4.64	0.000	
LnEngHr	−0.3511	0.0754	−4.66	0.000	1.00

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.316059	29.82%	28.44%	23.52%

Evaluating Alternatives for FEI2 Engine Hour Adjustment

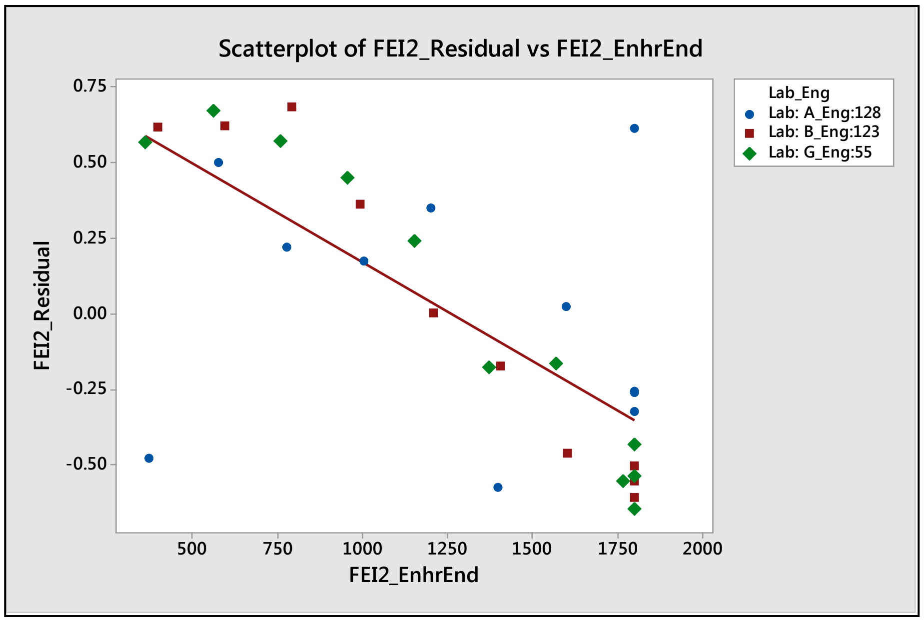
- Exploring the same data set for those engines that have a higher engine hour age (with Engines 128, 123, and 55, exclusively)

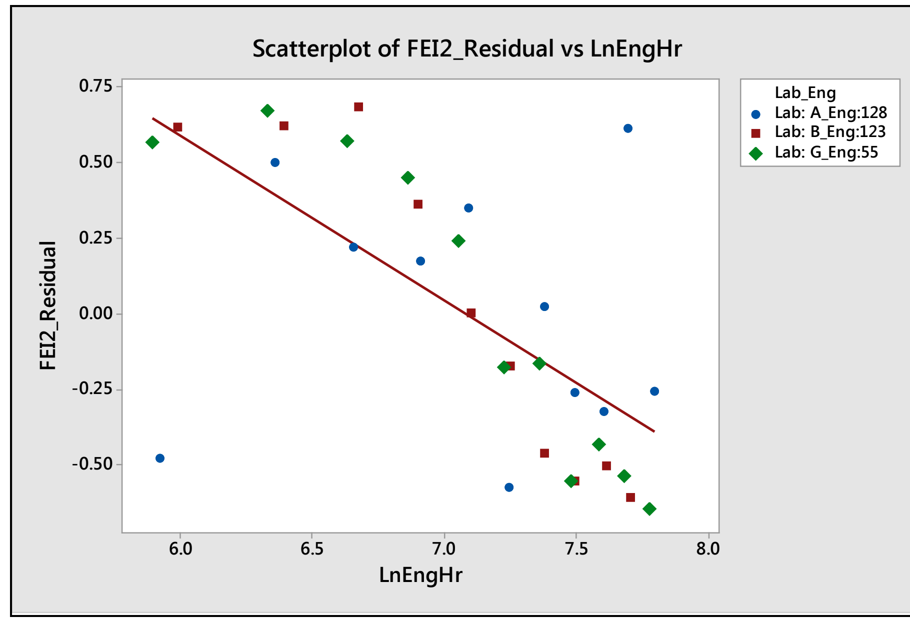


- The observed range of engine hour effects by engine is similar to what is observed in the VID (see Appendix D)

Evaluating Alternatives for FEI2 Engine Hour Adjustment

- Higher aged engines have similar results when comparing the untransformed and transformed (natural log) engine hours with respect to the FEI2 model fit residuals.





IHS EngHrEnd Transform

Regression Analysis: FEI2_Residual versus FEI2_EnhrEnd

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.826	0.157	5.27	0.000	
FEI2_EnhrEnd	-0.000653	0.000115	-5.68	0.000	1.00

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.330118	51.78%	50.18%	42.53%

Ln(EngHrEnd) Transform

Regression Analysis: FEI2_Residual versus LnEngHr

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	3.859	0.807	4.78	0.000	
LnEngHr	-0.545	0.114	-4.79	0.000	1.00

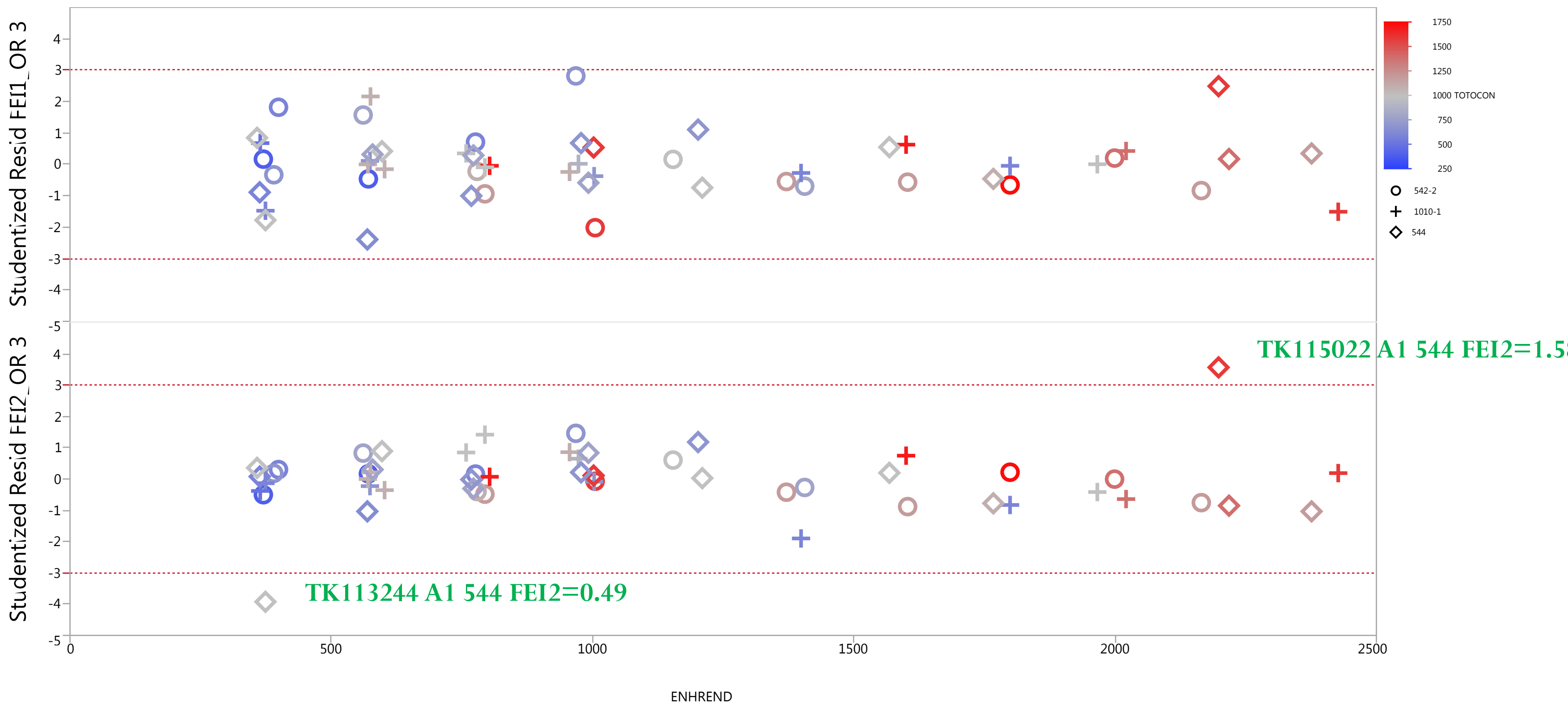
Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.357736	43.38%	41.49%	30.68%

Appendix B

Residual Diagnostics for LnEngHrEnd Model

Outliers (included in analysis)
Model: Oil, Lab, Engine(Lab), LnEngHr

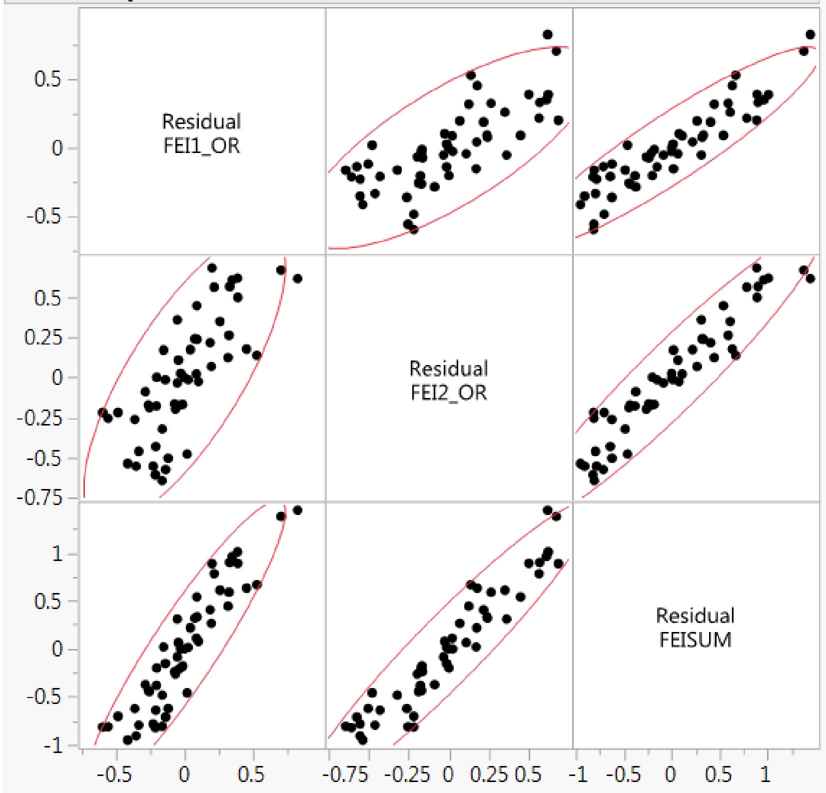


Correlation
Model: Oil, Lab, Engine(Lab), LnEngHr

Correlations

	Residual FEI1_OR	Residual FEI2_OR	Residual FEISUM
Residual FEI1_OR	1.0000	0.7557	0.9221
Residual FEI2_OR	0.7557	1.0000	0.9502
Residual FEISUM	0.9221	0.9502	1.0000

Scatterplot Matrix



Appendix C

Further Analyses of Reference Oil Ranking with Lab*Oil and Oil*ENHREND Interaction Terms

Analyzing PM Data (FEI1 – LnEngHr Model)

Summary of Fit

RSquare	0.943567
RSquare Adj	0.89881
Root Mean Square Error	0.182488
Mean of Response	1.711509
Observations (or Sum Wgts)	53

Analysis of Variance

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	1.7418334	0.036758	47.39	<.0001*	.
LTMSLAB[A]	-0.064584	0.056921	-1.13	0.2658	2.9187461
LTMSLAB[B]	-0.066017	0.064862	-1.02	0.3172	3.098683
LTMSLAB[C]	0.1153368	0.107632	1.07	0.2927	6.3009709
LTMSLAB[D]	0.0708869	0.088056	0.81	0.4274	3.8922824
LTMSLAB[F]	0.0845182	0.089667	0.94	0.3537	4.0360155
IND[1010-1]	0.005789	0.048112	0.12	0.9051	2.502299
IND[542-2]	0.5348536	0.044184	12.11	<.0001*	2.0507054
LTMSLAB[A]:ENGNO[103]	-0.029432	0.062884	-0.47	0.6433	1.6713853
LTMSLAB[C]:ENGNO[29]	0.1567662	0.129039	1.21	0.2342	2.4151288
LTMSLAB[G]:ENGNO[55]	0.1473057	0.058225	2.53	0.0171*	1.4329142
ln(ENGHRS)(5.85793,7.87702)	-0.410783	0.059671	-6.88	<.0001*	1.8417033
LTMSLAB[A]*IND[1010-1]	-0.187655	0.073783	-2.54	0.0166*	3.4298692
LTMSLAB[A]*IND[542-2]	0.0608241	0.075661	0.80	0.4280	3.2628494
LTMSLAB[B]*IND[1010-1]	-0.002385	0.09287	-0.03	0.9797	4.3979428
LTMSLAB[B]*IND[542-2]	0.0426186	0.084358	0.51	0.6172	3.6286835
LTMSLAB[C]*IND[1010-1]	0.2627448	0.129884	2.02	0.0524	6.5758527
LTMSLAB[C]*IND[542-2]	-0.457588	0.111115	-4.12	0.0003*	4.8127232
LTMSLAB[D]*IND[1010-1]	0.0167116	0.127751	0.13	0.8968	5.8808399
LTMSLAB[D]*IND[542-2]	-0.193228	0.116131	-1.66	0.1069	5.2570321
LTMSLAB[F]*IND[1010-1]	-0.104595	0.139529	-0.75	0.4595	7.5888118
LTMSLAB[F]*IND[542-2]	0.5040111	0.128228	3.93	0.0005*	6.4092682
ln(ENGHRS)*IND[1010-1]	0.0024651	0.082584	0.03	0.9764	2.4690009
ln(ENGHRS)*IND[542-2]	-0.268137	0.075248	-3.56	0.0013*	1.9902932

Effect Tests

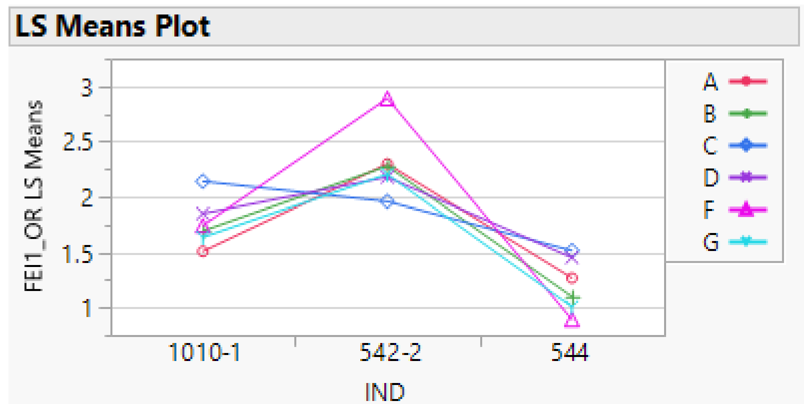
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2560614	1.5378	0.2090
IND	2	2	6.5647797	98.5648	<.0001*
ENGNO[LTMSLAB]	3	3	0.2624177	2.6267	0.0692
ln(ENGHRS)(5.85793,7.87702)	1	1	1.5782034	47.3908	<.0001*
LTMSLAB*IND	10	10	1.3710040	4.1169	0.0013*
ln(ENGHRS)*IND	2	2	0.5871054	8.8149	0.0010*

Analyzing PM Data (FEI1 – LnEngHr Model)

- Significant oil differences; oil discrimination is not consistent across labs/engines (In particular, Lab C)

Effect Tests

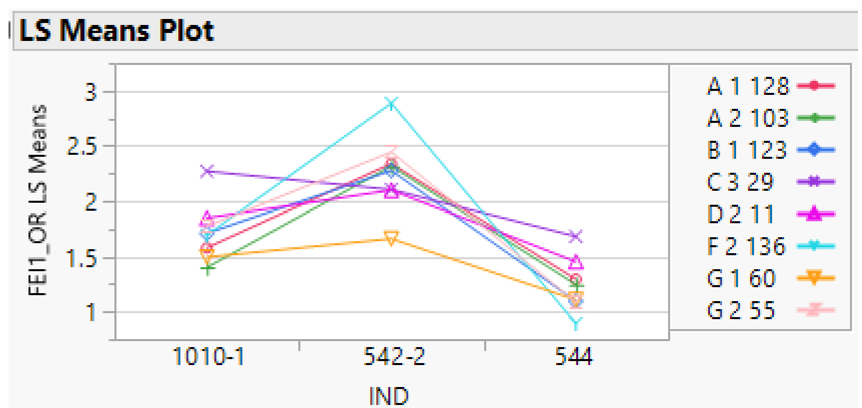
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2560614	1.5378	0.2090
IND	2	2	6.5647797	98.5648	<.0001*
ENGNO[LTMSLAB]	3	3	0.2624177	2.6267	0.0692
ln(ENGHRS)(5.85793,7.87702)	1	1	1.5782034	47.3908	<.0001*
LTMSLAB*IND	10	10	1.3710040	4.1169	0.0013*
ln(ENGHRS)*IND	2	2	0.5871054	8.8149	0.0010*



Different Model specified to demonstrate oil differences by engine; had to remove Lab C's first engine as well (52 obs)

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
ln(ENGHRS)(5.85793,7.87702)	1	1	1.5293693	52.5401	<.0001*
ln(ENGHRS)*IND	2	2	0.7412295	12.7321	0.0002*
IND	2	2	5.9485872	102.1793	<.0001*
LabStandEngine	7	7	0.6757856	3.3166	0.0123*
LabStandEngine*IND	14	14	1.6090433	3.9484	0.0014*

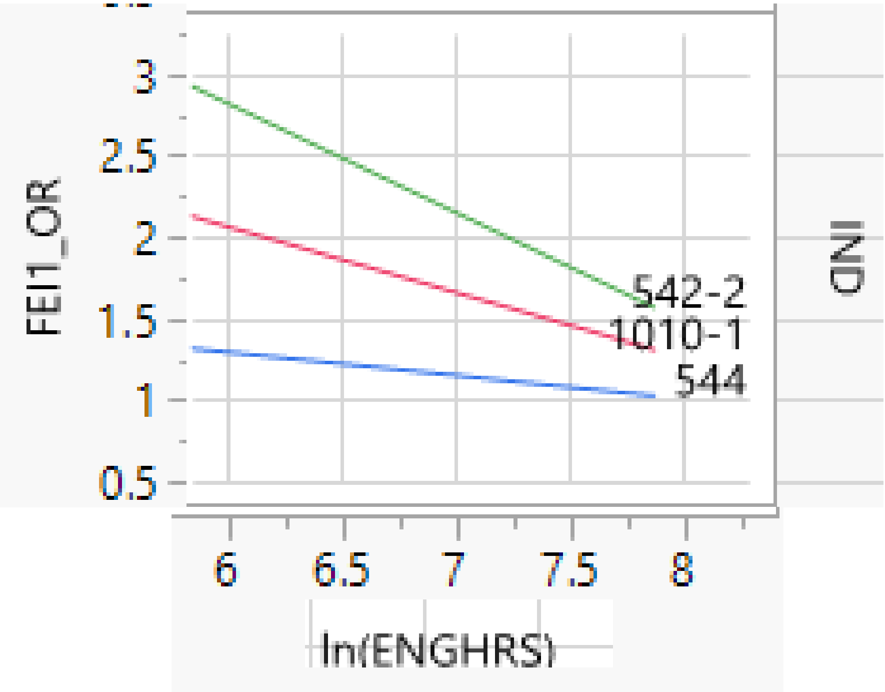


Analyzing PM Data (FEI1 – LnEngHr Model)

- Oil discrimination changes over the range of hours; less discrimination at higher hours

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2560614	1.5378	0.2090
IND	2	2	6.5647797	98.5648	<.0001*
ENGNO[LTMSLAB]	3	3	0.2624177	2.6267	0.0692
ln(ENGHRS)(5.85793,7.87702)	1	1	1.5782034	47.3908	<.0001*
LTMSLAB*IND	10	10	1.3710040	4.1169	0.0013*
ln(ENGHRS)*IND	2	2	0.5871054	8.8149	0.0010*



Analyzing PM Data (FEI1 – LnEngHr Model)

- Lab G engines differ from one another

Summary of Fit

RSquare	0.943567
RSquare Adj	0.89881
Root Mean Square Error	0.182488
Mean of Response	1.711509
Observations (or Sum Wgts)	53

Analysis of Variance

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	1.7418334	0.036758	47.39	<.0001*	.
LTMSLAB[A]	-0.064584	0.056921	-1.13	0.2658	2.9187461
LTMSLAB[B]	-0.066017	0.064862	-1.02	0.3172	3.098683
LTMSLAB[C]	0.1153368	0.107632	1.07	0.2927	6.3009709
LTMSLAB[D]	0.0708869	0.088056	0.81	0.4274	3.8922824
LTMSLAB[F]	0.0845182	0.089667	0.94	0.3537	4.0360155
IND[1010-1]	0.005789	0.048112	0.12	0.9051	2.502299
IND[542-2]	0.5348536	0.044184	12.11	<.0001*	2.0507054
LTMSLAB[A]:ENGNO[103]	-0.029432	0.062884	-0.47	0.6433	1.6713853
LTMSLAB[C]:ENGNO[29]	0.1567662	0.129039	1.21	0.2342	2.4151288
LTMSLAB[G]:ENGNO[55]	0.1473057	0.058225	2.53	0.0171*	1.4329142
ln(ENGHRS)(5.85793,7.87702)	-0.410783	0.059671	-6.88	<.0001*	1.8417033
LTMSLAB[A]*IND[1010-1]	-0.187655	0.073783	-2.54	0.0166*	3.4298692
LTMSLAB[A]*IND[542-2]	0.0608241	0.075661	0.80	0.4280	3.2628494
LTMSLAB[B]*IND[1010-1]	-0.002385	0.09287	-0.03	0.9797	4.3979428
LTMSLAB[B]*IND[542-2]	0.0426186	0.084358	0.51	0.6172	3.6286835
LTMSLAB[C]*IND[1010-1]	0.2627448	0.129884	2.02	0.0524	6.5758527
LTMSLAB[C]*IND[542-2]	-0.457588	0.111115	-4.12	0.0003*	4.8127232
LTMSLAB[D]*IND[1010-1]	0.0167116	0.127751	0.13	0.8968	5.8808399
LTMSLAB[D]*IND[542-2]	-0.193228	0.116131	-1.66	0.1069	5.2570321
LTMSLAB[F]*IND[1010-1]	-0.104595	0.139529	-0.75	0.4595	7.5888118
LTMSLAB[F]*IND[542-2]	0.5040111	0.128228	3.93	0.0005*	6.4092682
ln(ENGHRS)*IND[1010-1]	0.0024651	0.082584	0.03	0.9764	2.4690009
ln(ENGHRS)*IND[542-2]	-0.268137	0.075248	-3.56	0.0013*	1.9902932

Analyzing PM Data (FEI1 – LnEngHr Model)

- Oils Differ (542-2 > 1010-1 > 544)

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2560614	1.5378	0.2090
IND	2	2	6.5647797	98.5648	<.0001*
ENGNO[LTMSLAB]	3	3	0.2624177	2.6267	0.0692
ln(ENGHRS)(5.85793,7.87702)	1	1	1.5782034	47.3908	<.0001*
LTMSLAB*IND	10	10	1.3710040	4.1169	0.0013*
ln(ENGHRS)*IND	2	2	0.5871054	8.8149	0.0010*

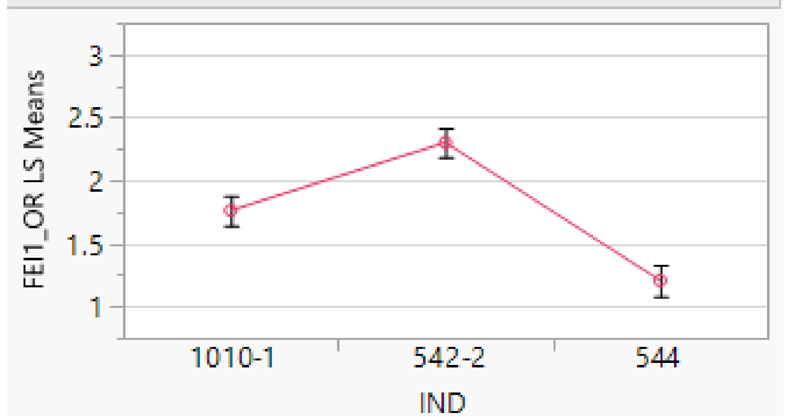
Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
1010-1	1.7626071	0.05729445	1.68778
542-2	2.3016023	0.05631592	2.30059
544	1.2065161	0.06063913	1.17889

Level				Least Sq Mean
542-2	A			2.3016023
1010-1		B		1.7626071
544			C	1.2065161

Levels not connected by same letter are significantly different.

LS Means Plot



Analyzing PM Data (FEI2 – LnEngHr Model)

Summary of Fit

RSquare	0.693929
RSquare Adj	0.451182
Root Mean Square Error	0.333068
Mean of Response	1.374717
Observations (or Sum Wgts)	53

Analysis of Variance

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	1.3716498	0.067088	20.45	<.0001*	.
LTMSLAB[A]	-0.128337	0.103889	-1.24	0.2266	2.9187461
LTMSLAB[B]	-0.084756	0.118383	-0.72	0.4797	3.098683
LTMSLAB[C]	-0.03994	0.196444	-0.20	0.8403	6.3009709
LTMSLAB[D]	-0.013171	0.160715	-0.08	0.9352	3.8922824
LTMSLAB[F]	0.309937	0.163655	1.89	0.0683	4.0360155
IND[1010-1]	0.1048375	0.087811	1.19	0.2422	2.502299
IND[542-2]	0.0611305	0.080643	0.76	0.4545	2.0507054
LTMSLAB[A]:ENGNO[103]	-0.079198	0.114773	-0.69	0.4957	1.6713853
LTMSLAB[C]:ENGNO[29]	-0.06184	0.235516	-0.26	0.7947	2.4151288
LTMSLAB[G]:ENGNO[55]	0.2263377	0.10627	2.13	0.0418*	1.4329142
ln(ENGHRS)(5.85793,7.87702)	-0.571148	0.108909	-5.24	<.0001*	1.8417033
LTMSLAB[A]*IND[1010-1]	-0.039832	0.134666	-0.30	0.7695	3.4298692
LTMSLAB[A]*IND[542-2]	-0.008276	0.138093	-0.06	0.9526	3.2628494
LTMSLAB[B]*IND[1010-1]	0.0730973	0.169502	0.43	0.6695	4.3979428
LTMSLAB[B]*IND[542-2]	-0.107951	0.153966	-0.70	0.4888	3.6286835
LTMSLAB[C]*IND[1010-1]	-0.055955	0.237057	-0.24	0.8151	6.5758527
LTMSLAB[C]*IND[542-2]	-0.096539	0.202802	-0.48	0.6376	4.8127232
LTMSLAB[D]*IND[1010-1]	0.2260238	0.233164	0.97	0.3404	5.8808399
LTMSLAB[D]*IND[542-2]	-0.212942	0.211957	-1.00	0.3234	5.2570321
LTMSLAB[F]*IND[1010-1]	-0.348484	0.254662	-1.37	0.1817	7.5888118
LTMSLAB[F]*IND[542-2]	0.392685	0.234035	1.68	0.1041	6.4092682
ln(ENGHRS)*IND[1010-1]	-0.15929	0.150728	-1.06	0.2993	2.4690009
ln(ENGHRS)*IND[542-2]	-0.131988	0.13734	-0.96	0.3445	1.9902932

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.5062845	0.9128	0.4865
IND	2	2	0.4290340	1.9337	0.1628
ENGNO[LTMSLAB]	3	3	0.5271050	1.5838	0.2146
ln(ENGHRS)(5.85793,7.87702)	1	1	3.0509481	27.5023	<.0001*
LTMSLAB*IND	10	10	0.6849399	0.6174	0.7865
ln(ENGHRS)*IND	2	2	0.4859681	2.1903	0.1300

Evidence of Lab G engine differences

Marginal lab difference

With 2 odd looking tests removed:

1. Lab G engines still differ
2. Oil 544 < 1010-1 & 542-2
3. Hours*oil becomes even less significant

Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

Summary of Fit

RSquare	0.948009
RSquare Adj	0.906774
Root Mean Square Error	0.175159
Mean of Response	1.711509
Observations (or Sum Wgts)	53

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.2605937	0.067759	33.36	<.0001*
LTMSLAB[A]	-0.067207	0.054439	-1.23	0.2269
LTMSLAB[B]	-0.038803	0.062626	-0.62	0.5404
LTMSLAB[C]	0.0925637	0.10282	0.90	0.3754
LTMSLAB[D]	0.0651897	0.083962	0.78	0.4438
LTMSLAB[F]	0.0834185	0.084607	0.99	0.3323
IND[1010-1]	0.0090584	0.045434	0.20	0.8434
IND[542-2]	0.5471812	0.041922	13.05	<.0001*
LTMSLAB[A]:ENGNO[103]	-0.032497	0.059464	-0.55	0.5889
LTMSLAB[C]:ENGNO[29]	0.1561887	0.123857	1.26	0.2173
LTMSLAB[G]:ENGNO[55]	0.1400792	0.055548	2.52	0.0174*
LTMSLAB[A]*IND[1010-1]	-0.182901	0.070798	-2.58	0.0151*
LTMSLAB[A]*IND[542-2]	0.052721	0.072328	0.73	0.4719
LTMSLAB[B]*IND[1010-1]	-0.032961	0.088766	-0.37	0.7131
LTMSLAB[B]*IND[542-2]	0.0969565	0.081495	1.19	0.2438
LTMSLAB[C]*IND[1010-1]	0.2740095	0.124431	2.20	0.0358*
LTMSLAB[C]*IND[542-2]	-0.494086	0.106186	-4.65	<.0001*
LTMSLAB[D]*IND[1010-1]	-0.013185	0.121771	-0.11	0.9145
LTMSLAB[D]*IND[542-2]	-0.1515	0.109864	-1.38	0.1784
LTMSLAB[F]*IND[1010-1]	-0.030984	0.128644	-0.24	0.8114
LTMSLAB[F]*IND[542-2]	0.4472894	0.12149	3.68	0.0009*
EnginesHRS IHS	-0.000505	6.938e-5	-7.27	<.0001*
(EnginesHRS IHS-999.509)*IND[1010-1]	2.9025e-5	9.317e-5	0.31	0.7576
(EnginesHRS IHS-999.509)*IND[542-2]	-0.000314	8.634e-5	-3.63	0.0011*

Effect Tests

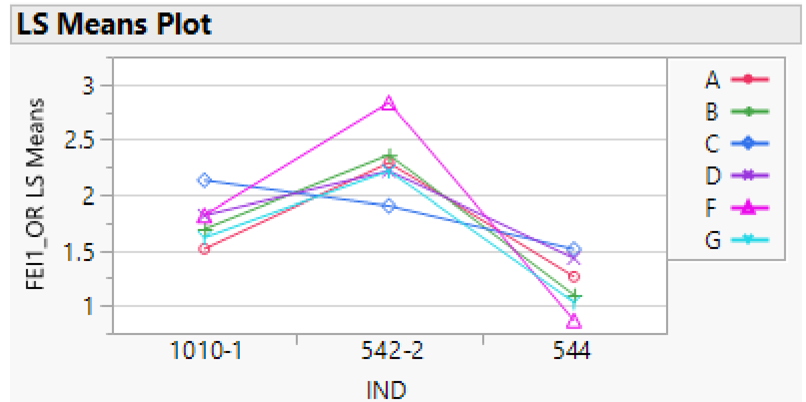
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2298268	1.4982	0.2210
IND	2	2	7.0439007	114.7932	<.0001*
ENGNO[LTMSLAB]	3	3	0.2448488	2.6602	0.0668
LTMSLAB*IND	10	10	1.3659171	4.4520	0.0008*
EnginesHRS IHS	1	1	1.6223632	52.8787	<.0001*
EnginesHRS IHS*IND	2	2	0.4982961	8.1206	0.0016*

Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

- Significant oil differences; Oil discrimination not consistent across labs/engines (In particular, Lab C)

Effect Tests

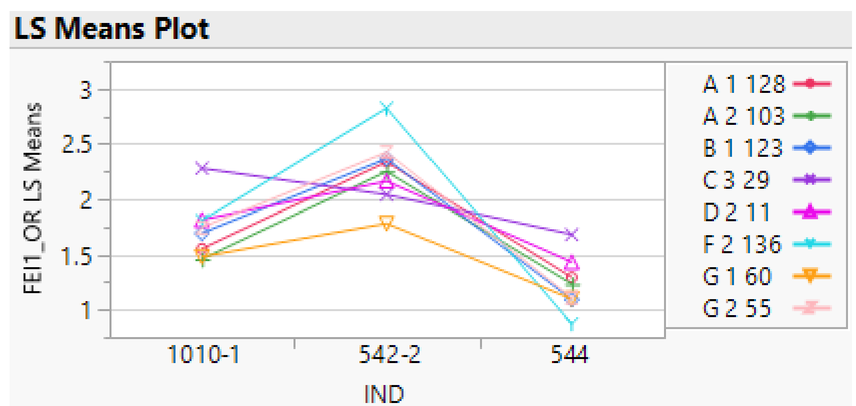
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2298268	1.4982	0.2210
IND	2	2	7.0439007	114.7932	<.0001*
ENGNO[LTMSLAB]	3	3	0.2448488	2.6602	0.0668
LTMSLAB*IND	10	10	1.3659171	4.4520	0.0008*
EnginesHRS IHS	1	1	1.6223632	52.8787	<.0001*
EnginesHRS IHS*IND	2	2	0.4982961	8.1206	0.0016*



Different Model specified to demonstrate oil differences by engine; had to remove Lab C's first engine as well (52 obs)

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IND	2	2	6.4729179	108.3520	<.0001*
EnginesHRS IHS	1	1	1.5151329	50.7245	<.0001*
EnginesHRS IHS*IND	2	2	0.5893853	9.8659	0.0007*
LabStandEngine	7	7	0.5958892	2.8499	0.0249*
LabStandEngine*IND	14	14	1.5089141	3.6083	0.0025*

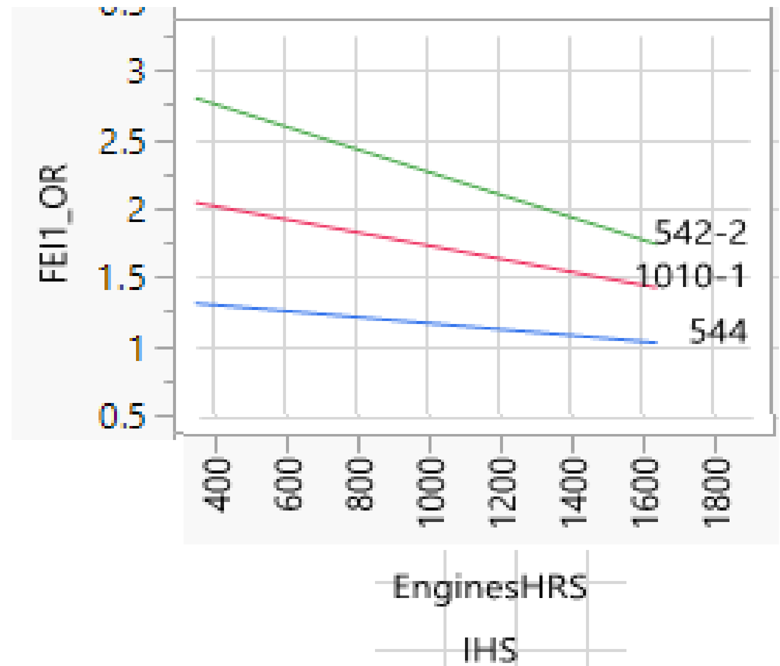


Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

- Oil discrimination changes over the range of hours; less discrimination at higher hours

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2298268	1.4982	0.2210
IND	2	2	7.0439007	114.7932	<.0001*
ENGNO[LTMSLAB]	3	3	0.2448488	2.6602	0.0668
LTMSLAB*IND	10	10	1.3659171	4.4520	0.0008*
EnginesHRS IHS	1	1	1.6223632	52.8787	<.0001*
EnginesHRS IHS*IND	2	2	0.4982961	8.1206	0.0016*



Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

- Lab G engines differ from one another

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.2605937	0.067759	33.36	<.0001*
LTMSLAB[A]	-0.067207	0.054439	-1.23	0.2269
LTMSLAB[B]	-0.038803	0.062626	-0.62	0.5404
LTMSLAB[C]	0.0925637	0.10282	0.90	0.3754
LTMSLAB[D]	0.0651897	0.083962	0.78	0.4438
LTMSLAB[F]	0.0834185	0.084607	0.99	0.3323
IND[1010-1]	0.0090584	0.045434	0.20	0.8434
IND[542-2]	0.5471812	0.041922	13.05	<.0001*
LTMSLAB[A]:ENGNO[103]	-0.032497	0.059464	-0.55	0.5889
LTMSLAB[C]:ENGNO[29]	0.1561887	0.123857	1.26	0.2173
LTMSLAB[G]:ENGNO[55]	0.1400792	0.055548	2.52	0.0174*
LTMSLAB[A]*IND[1010-1]	-0.182901	0.070798	-2.58	0.0151*
LTMSLAB[A]*IND[542-2]	0.052721	0.072328	0.73	0.4719
LTMSLAB[B]*IND[1010-1]	-0.032961	0.088766	-0.37	0.7131
LTMSLAB[B]*IND[542-2]	0.0969565	0.081495	1.19	0.2438
LTMSLAB[C]*IND[1010-1]	0.2740095	0.124431	2.20	0.0358*
LTMSLAB[C]*IND[542-2]	-0.494086	0.106186	-4.65	<.0001*
LTMSLAB[D]*IND[1010-1]	-0.013185	0.121771	-0.11	0.9145
LTMSLAB[D]*IND[542-2]	-0.1515	0.109864	-1.38	0.1784
LTMSLAB[F]*IND[1010-1]	-0.030984	0.128644	-0.24	0.8114
LTMSLAB[F]*IND[542-2]	0.4472894	0.12149	3.68	0.0009*
EnginesHRS IHS	-0.000505	6.938e-5	-7.27	<.0001*
(EnginesHRS IHS-999.509)*IND[1010-1]	2.9025e-5	9.317e-5	0.31	0.7576
(EnginesHRS IHS-999.509)*IND[542-2]	-0.000314	8.634e-5	-3.63	0.0011*

Analyzing PM Data (FEI1 – Ice Hockey Stick Model)

- Oils Differ (542-2 > 1010-1 > 544)

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.2298268	1.4982	0.2210
IND	2	2	7.0439007	114.7932	<.0001*
ENGNO[LTMSLAB]	3	3	0.2448488	2.6602	0.0668
LTMSLAB*IND	10	10	1.3659171	4.4520	0.0008*
EnginesHRS IHS	1	1	1.6223632	52.8787	<.0001*
EnginesHRS IHS*IND	2	2	0.4982961	8.1206	0.0016*

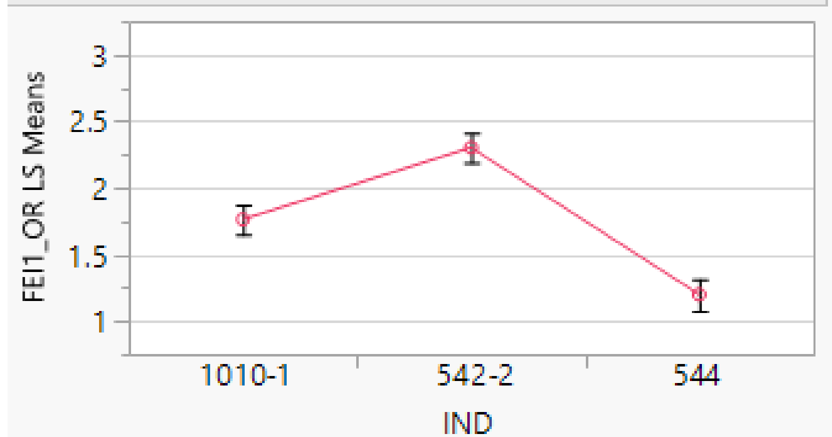
Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
1010-1	1.7653905	0.05473655	1.68778
542-2	2.3035133	0.05398531	2.30059
544	1.2000926	0.05860502	1.17889

Level				Least Sq Mean
542-2	A			2.3035133
1010-1		B		1.7653905
544			C	1.2000926

Levels not connected by same letter are significantly different.

LS Means Plot



Analyzing PM Data (FEI2 – Ice Hockey Stick Model)

Summary of Fit

RSquare	0.723496
RSquare Adj	0.504199
Root Mean Square Error	0.316572
Mean of Response	1.374717
Observations (or Sum Wgts)	53

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.1106389	0.122463	17.23	<.0001*
LTMSLAB[A]	-0.127923	0.098389	-1.30	0.2038
LTMSLAB[B]	-0.046219	0.113186	-0.41	0.6860
LTMSLAB[C]	-0.067121	0.185831	-0.36	0.7206
LTMSLAB[D]	-0.030285	0.151748	-0.20	0.8432
LTMSLAB[F]	0.3138286	0.152914	2.05	0.0493*
IND[1010-1]	0.1126975	0.082114	1.37	0.1804
IND[542-2]	0.0707297	0.075767	0.93	0.3583
LTMSLAB[A]:ENGNO[103]	-0.091552	0.107471	-0.85	0.4013
LTMSLAB[C]:ENGNO[29]	-0.062718	0.223851	-0.28	0.7813
LTMSLAB[G]:ENGNO[55]	0.2296207	0.100394	2.29	0.0297*
LTMSLAB[A]*IND[1010-1]	-0.024612	0.127957	-0.19	0.8488
LTMSLAB[A]*IND[542-2]	-0.020805	0.13072	-0.16	0.8746
LTMSLAB[B]*IND[1010-1]	0.0591246	0.16043	0.37	0.7151
LTMSLAB[B]*IND[542-2]	-0.058976	0.147289	-0.40	0.6918
LTMSLAB[C]*IND[1010-1]	-0.06807	0.224888	-0.30	0.7643
LTMSLAB[C]*IND[542-2]	-0.129029	0.191915	-0.67	0.5067
LTMSLAB[D]*IND[1010-1]	0.1856742	0.220081	0.84	0.4058
LTMSLAB[D]*IND[542-2]	-0.160012	0.198561	-0.81	0.4269
LTMSLAB[F]*IND[1010-1]	-0.254339	0.232502	-1.09	0.2830
LTMSLAB[F]*IND[542-2]	0.3308132	0.219574	1.51	0.1427
EnginesHRS IHS	-0.000723	0.000125	-5.77	<.0001*
(EnginesHRS IHS-999.509)*IND[1010-1]	-0.00019	0.000168	-1.13	0.2696
(EnginesHRS IHS-999.509)*IND[542-2]	-0.000131	0.000156	-0.84	0.4085

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	5	5	0.5187336	1.0352	0.4158
IND	2	2	0.5356598	2.6725	0.0861
ENGNO[LTMSLAB]	3	3	0.5604304	1.8640	0.1578
LTMSLAB*IND	10	10	0.4695112	0.4685	0.8967
EnginesHRS IHS	1	1	3.3344306	33.2718	<.0001*
EnginesHRS IHS*IND	2	2	0.3905317	1.9484	0.1607

Evidence of Lab G engine differences

Marginal lab difference

With 2 odd looking tests removed:

1. Lab G engines still differ
2. Oil 544 < 1010-1 & 542-2

Appendix D

Engine Hours Effect by Engine

VID vs. VIE comparison

Data Considered

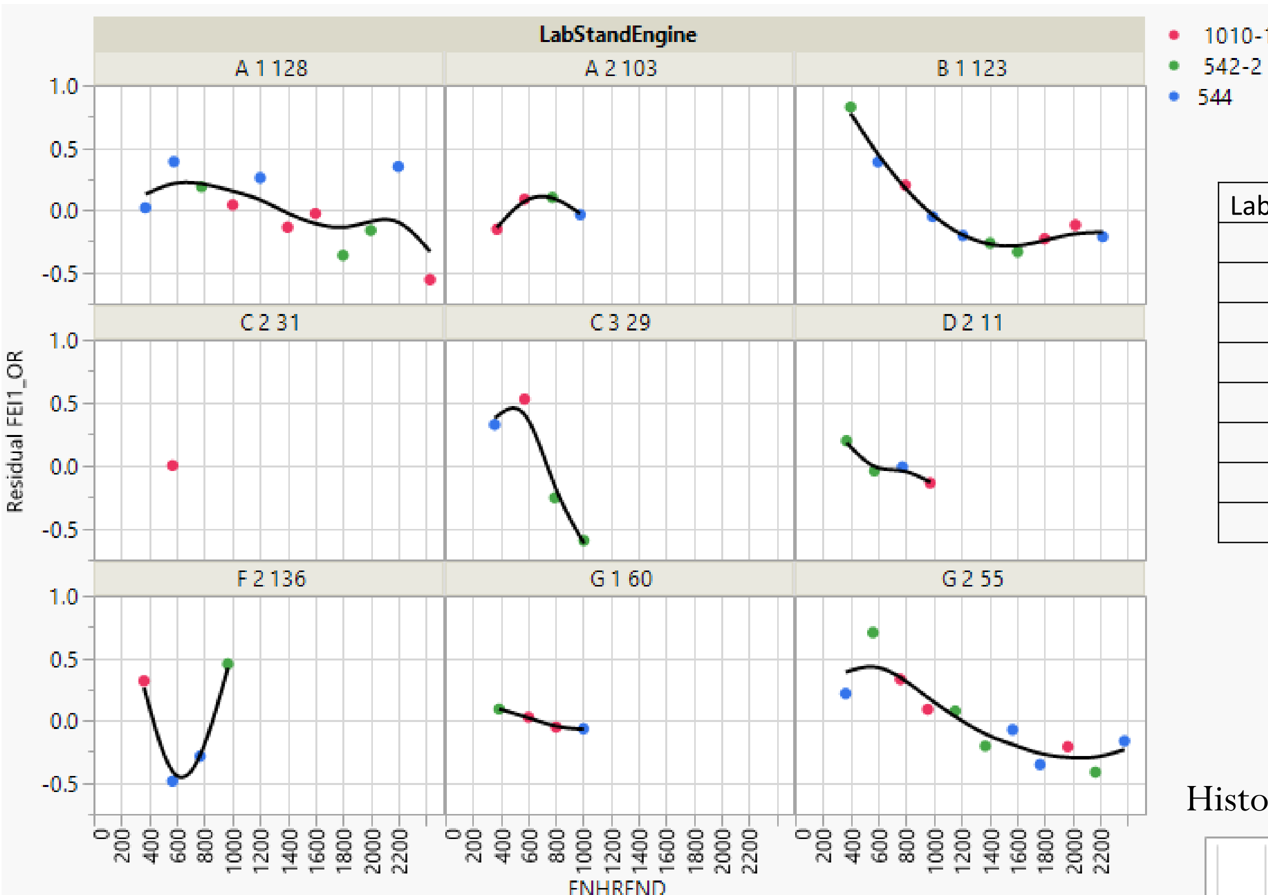
- 53 VIE valid matrix tests
- 572 VID test results
  - LTMS file; test results through 5-6-16
  - Validity codes AC, AO, OC, OO
  - These data include 118 unique engines

Number of Results	Number of Engines
1	2
2	1
3	18
4	37
5	32
6	14
7	8
8	1
9	1
11	1
12	2
14	1

For example, there are 37 engines each with 4 reference test results

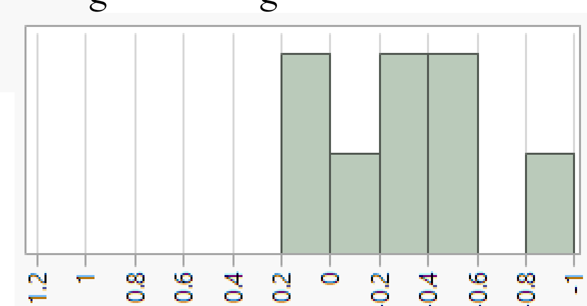
VIE FEI1 residuals vs. hours

- Residuals are from modeling FEI1_OR vs. oil, lab, engine(lab)



LabStandEngine	ln(ENGHOURS) Estimate
A 1 128	-0.23823
A 2 103	0.14865
B 1 123	-0.59689
C 3 29	-0.95117
D 2 11	-0.31168
F 2 136	0.02443
G 1 60	-0.17904
G 2 55	-0.45233

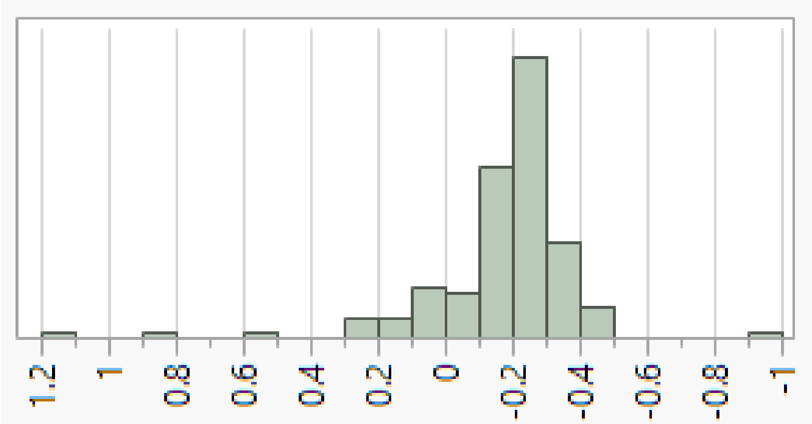
Histogram of Engine Hours estimates



VID FEI1 residuals vs. hours

- Residuals are from modeling FEI1_OR vs. oil, lab, engine(lab)

Histogram of Engine Hours estimates

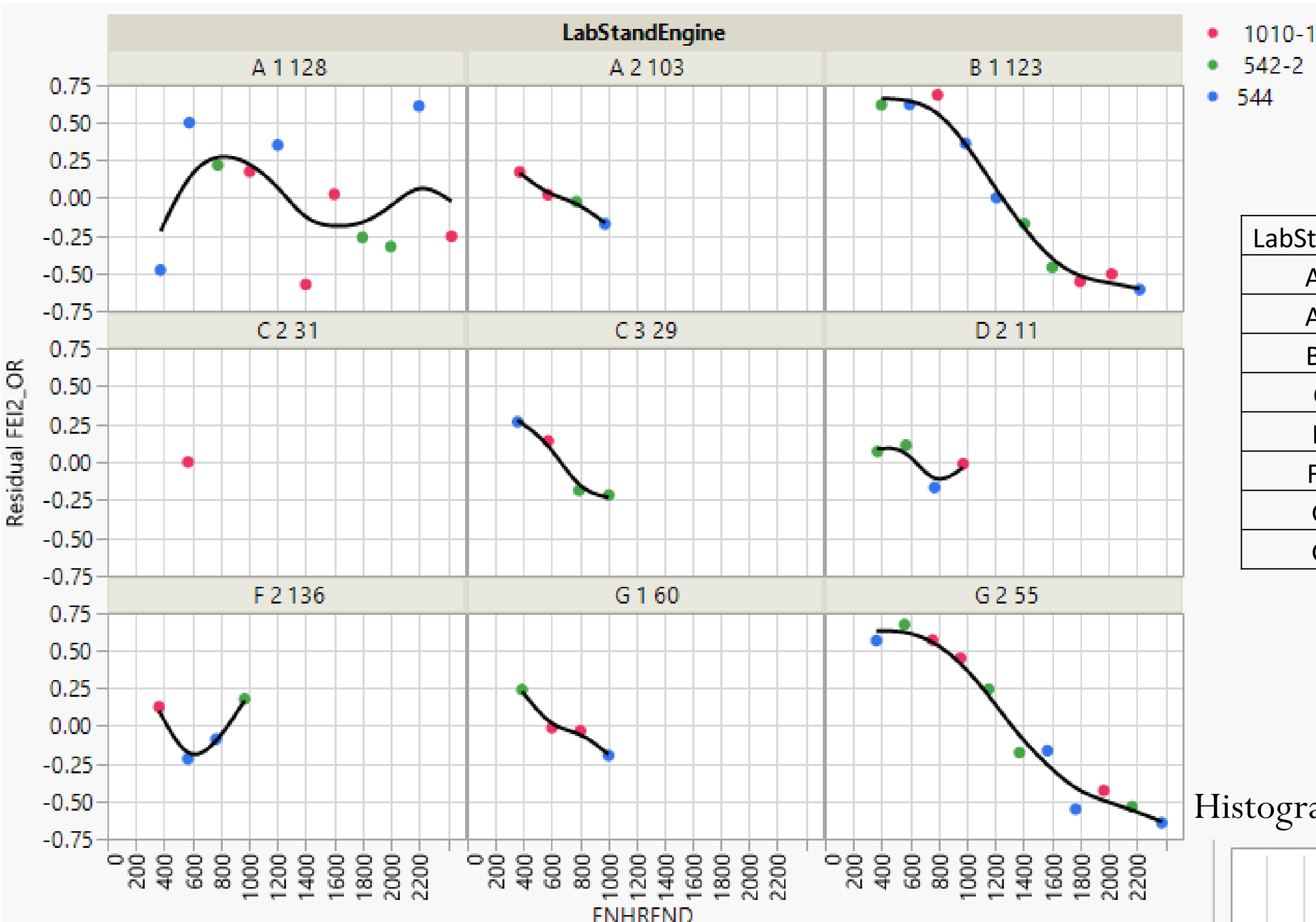


There are 116 estimates; one for each engine.
Engines with 1 reference result don't have an engine hours estimate.
Most VID estimates range from 0.2976 to -0.4854;
VIE estimate range from (0.1487 to -0.9512)

Range of estimates are similar between VID and VIE

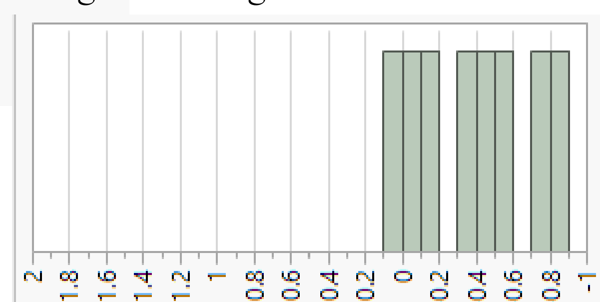
VIE FEI2 residuals vs. hours

- Residuals are from modeling FEI2_OR vs. oil, lab, engine(lab)



LabStandEngine	ln(ENGHOURS) Estimate
A 1 128	-0.0265
A 2 103	-0.3338
B 1 123	-0.8852
C 3 29	-0.5138
D 2 11	-0.1675
F 2 136	0.0234
G 1 60	-0.4293
G 2 55	-0.7884

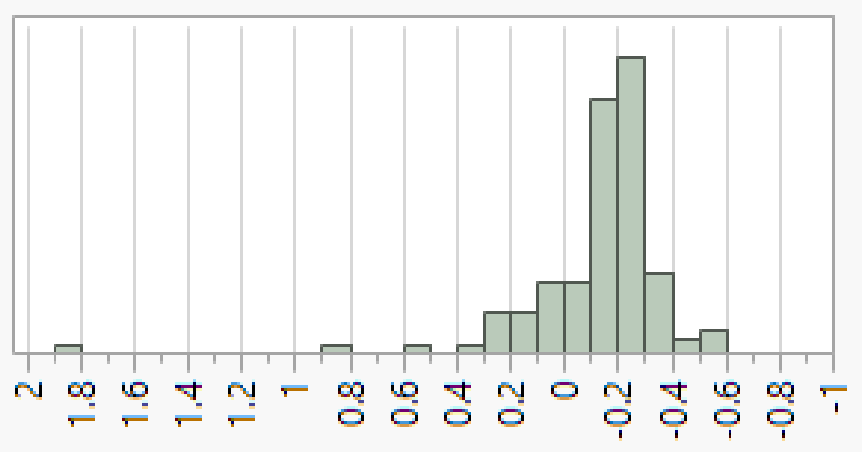
Histogram of Engine Hours estimates



VID FEI2 residuals vs. hours

- Residuals are from modeling FEI2_OR vs. oil, lab, engine(lab)

Histogram of Engine Hours estimates



There are 116 estimates; one for each engine.
Engines with 1 reference result don't have an engine hours estimate.
Most VID estimates range from 0.3155 to -0.5829;
VIE estimate range from (0.0234 to -0.8852)

Range of estimates are similar between VID and VIE