T-13 Oil Consumption Impact, RO 823-1 Targets and ICF Review

Statistics Group

July 30, 2024

Statistics Group

- Martin Chadwick, Intertek
- Seth Demel, Shell
- Todd Dvorak, Infineum
- Travis Kostan, SwRI
- Jo Martinez, Chevron Oronite
- Sean Moyer, TMC
- Elisa Santos, Infineum
- Phil Scinto, Lubrizol
- Amanda Stone, Afton/New Market

Summary

- No significant linear correlation between oil consumption and IRPH or KV40.

- Updated targets and ICF for RO 823-1

T-13 targets	IRPH		sqrt KV40		
	Mean	s	Mean	ICF	s
823	127.4	11.1	8.61		0.929
823-1 (n=5)	109.3	11.1	8.139	0.857	0.929
823-1 (n=12)	110.5	11.1	8.50	1.07	0.929

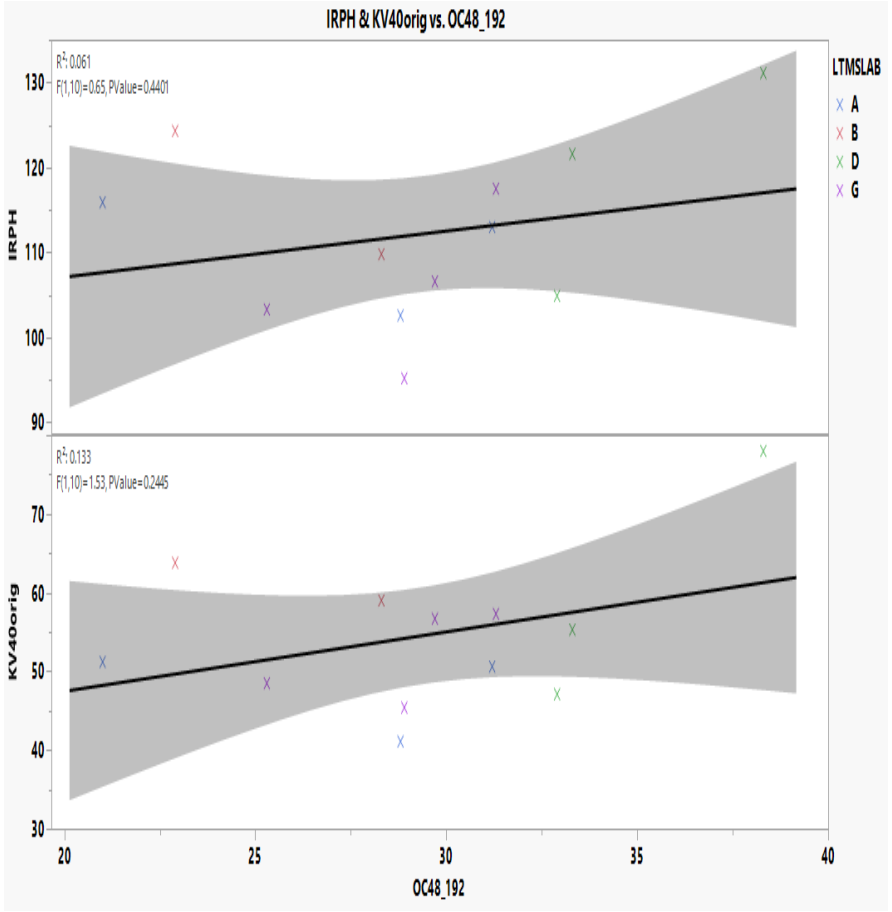
- Recommend freezing the targets with n=12

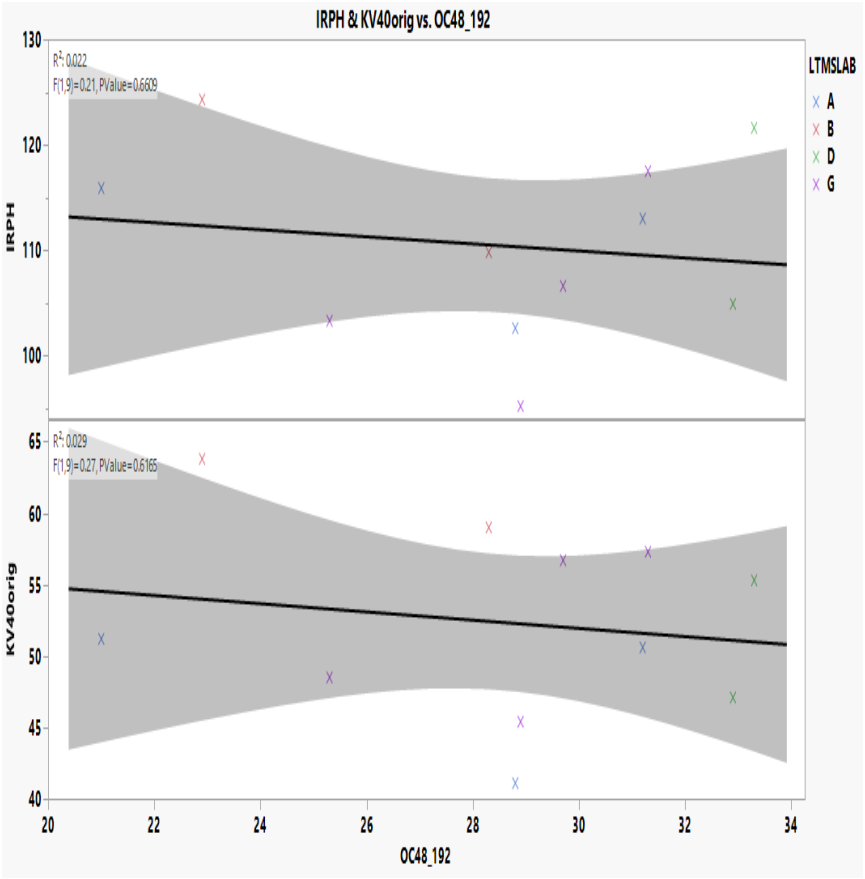
Data

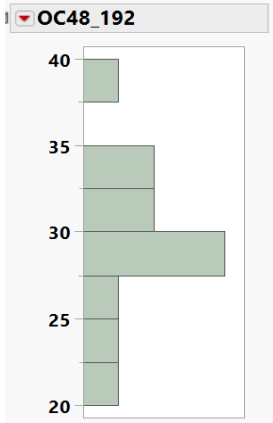
- Data was analyzed with the same models as when targets were set for 823-1 so this analysis is updating the 823-1 data with n=12

- Note that some testkeys in the LTMS database were not corrected for KV40 with ICF=0.857
  - TK 158057 – Lab B
  - TK 158885 – Lab B
  - TK 166371 – Lab B

No significant linear correlation between IRPH or KV40 and Oil Consumption







Quantiles

100.0%	maximum	38.3
99.5%		38.3
97.5%		38.3
90.0%		36.8
75.0%	quartile	32.5
50.0%	median	29.3
25.0%	quartile	26.05
10.0%		21.57
2.5%		21
0.5%		21
0.0%	minimum	21

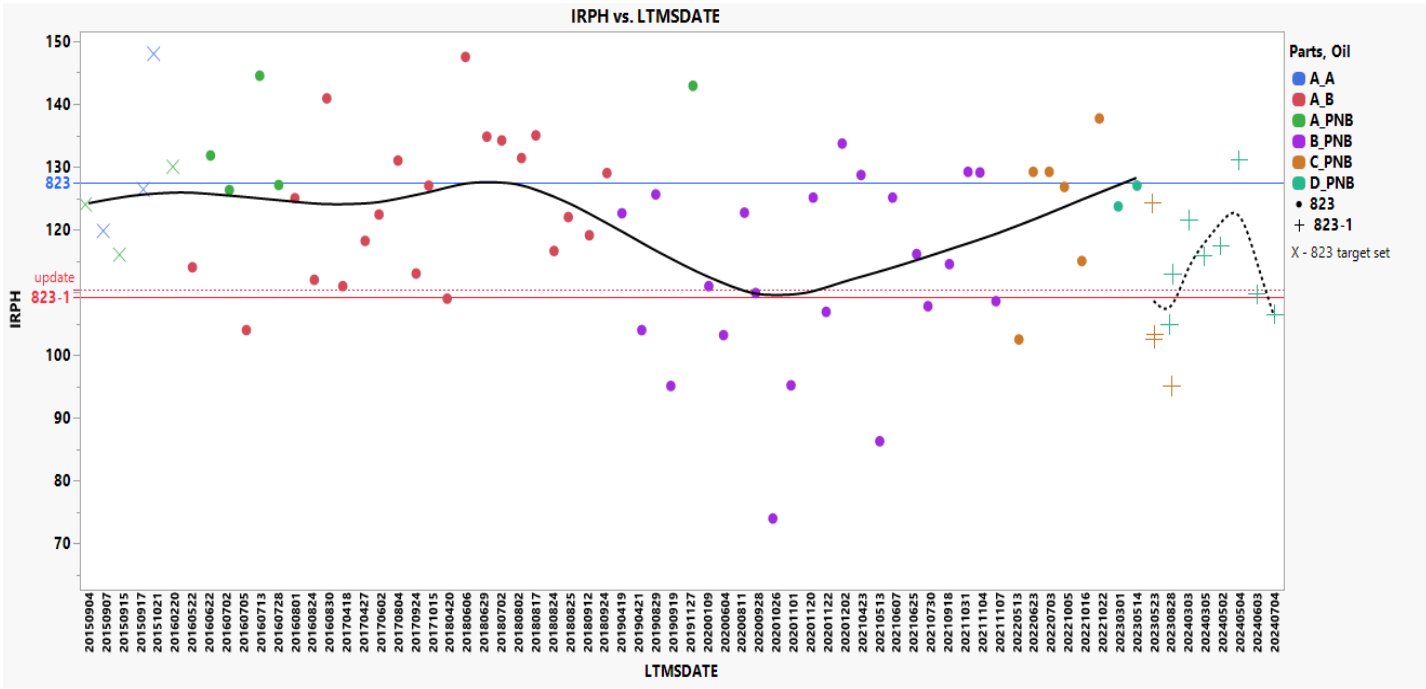
Summary Statistics

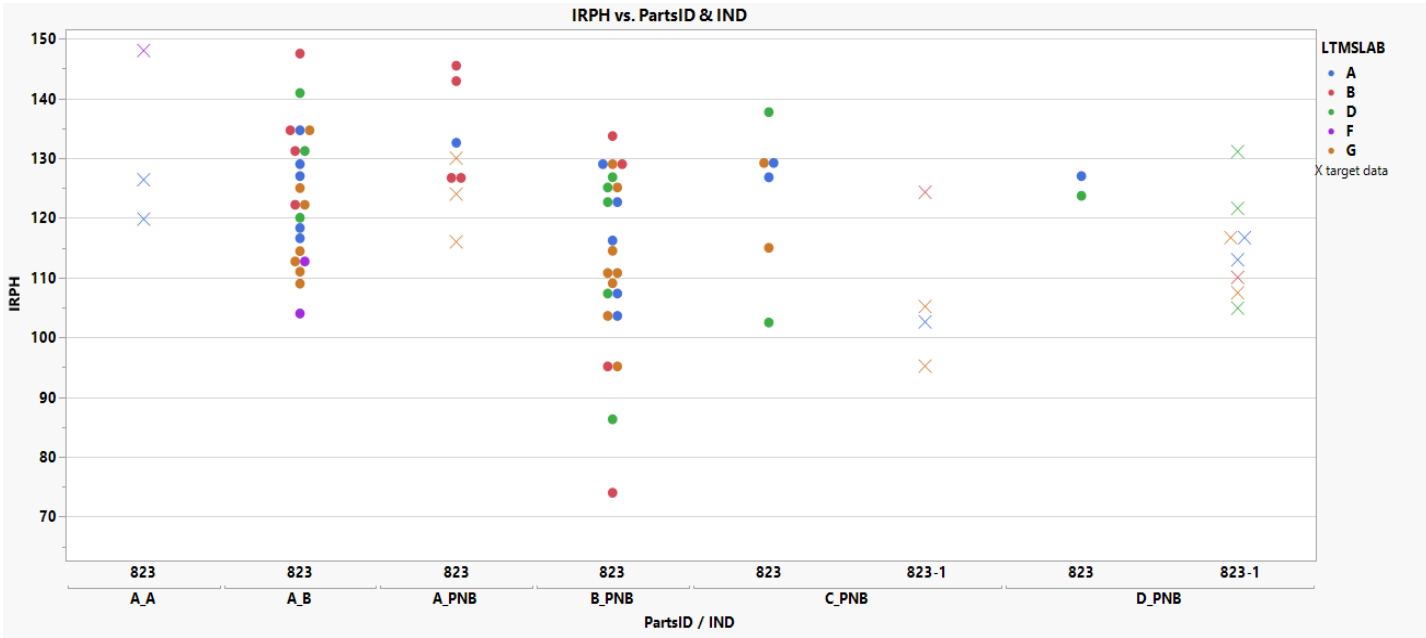
Mean	29.325
Std Dev	4.7192305
Std Err Mean	1.3623245
Upper 95% Mean	32.323456
Lower 95% Mean	26.326544
N	12

IRPH

There is some evidence that 823-1 is lower than 823

- The difference between oil re-blends (within liners C and D) is marginally significant
- The difference between 823-1 C&D liners and 823/A liner is statistically significant
- The difference between oil re-blends across liner batches is statistically significant





823-1 Targets and ICF (IRPH)

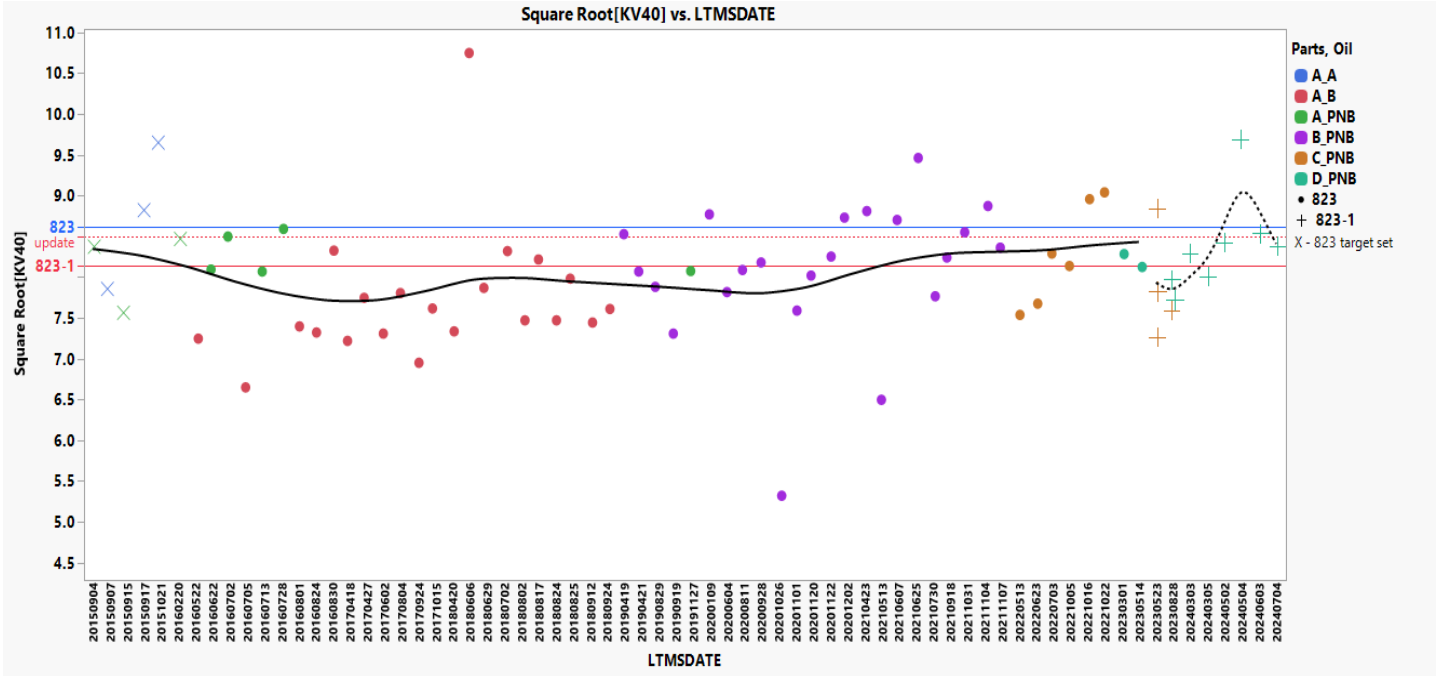
- The new mean target for RO 823-1 is 110.5 based on current data with n=12.
- The current standard deviation is still appropriate.
- No ICF for IRPH.

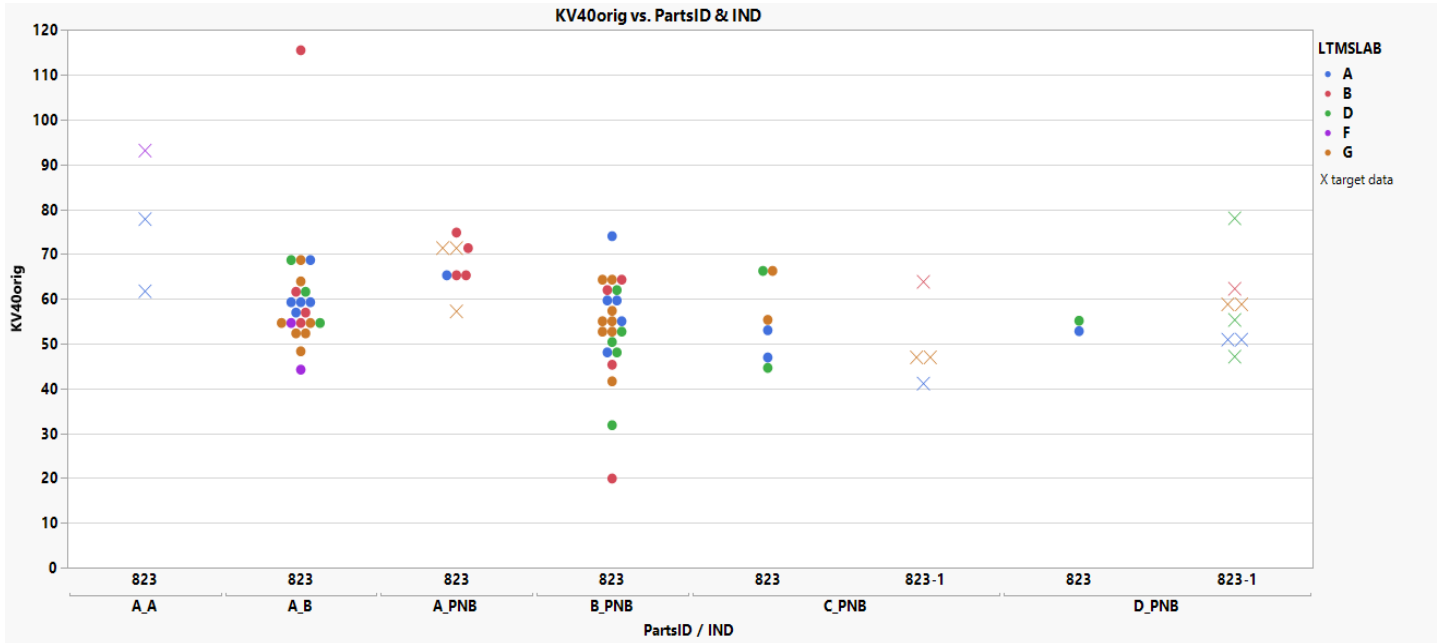
RO 823-1	Targets		ICF
	Mean	Standard Deviation (current)	
IRPH			
current (n=5)	109.3	11.1	None
update (n=12)	110.5	11.1	None

KV40

There is some evidence that 823-1 is lower than 823

- The difference between 823-1 C&D liners and 823/A liner is marginally significant
- The difference between oil re-blends (within C&D liners) is not statistically significant
- The difference between liners A and C&D combined (within oil 823) is not statistically significant





823-1 Targets and ICF (KV40)

- The new mean target for RO 823-1 is 8.50 and ICF=1.07 based on current data with n=12.
- ICF is to be applied for tests moving forward, not retroactive.
- The current standard deviation is still appropriate.

RO 823-1	Targets		ICF
	Mean	Standard Deviation (current)	
KV40 (sqrt)			
current (n=5)	8.139	0.929	0.857
update (n=12)	8.50	0.929	1.07

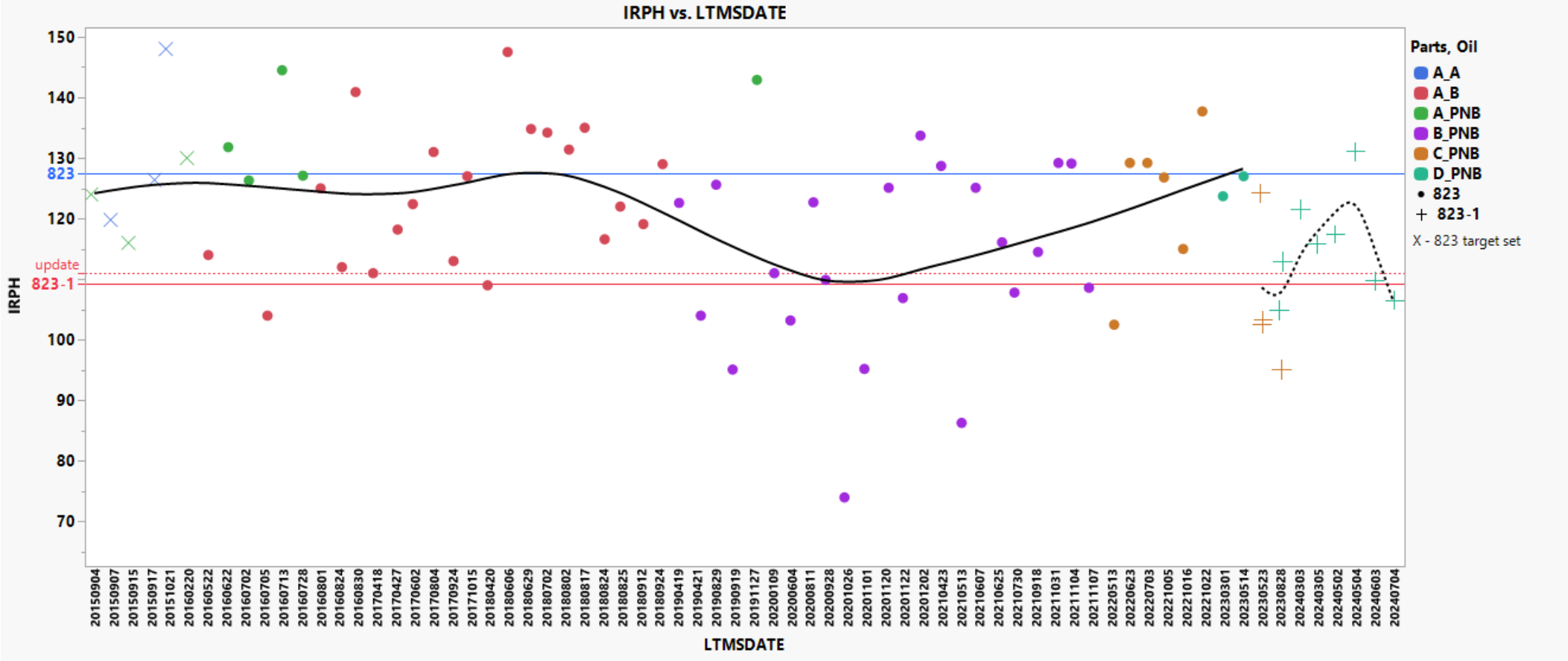
appendix

statistical analyses

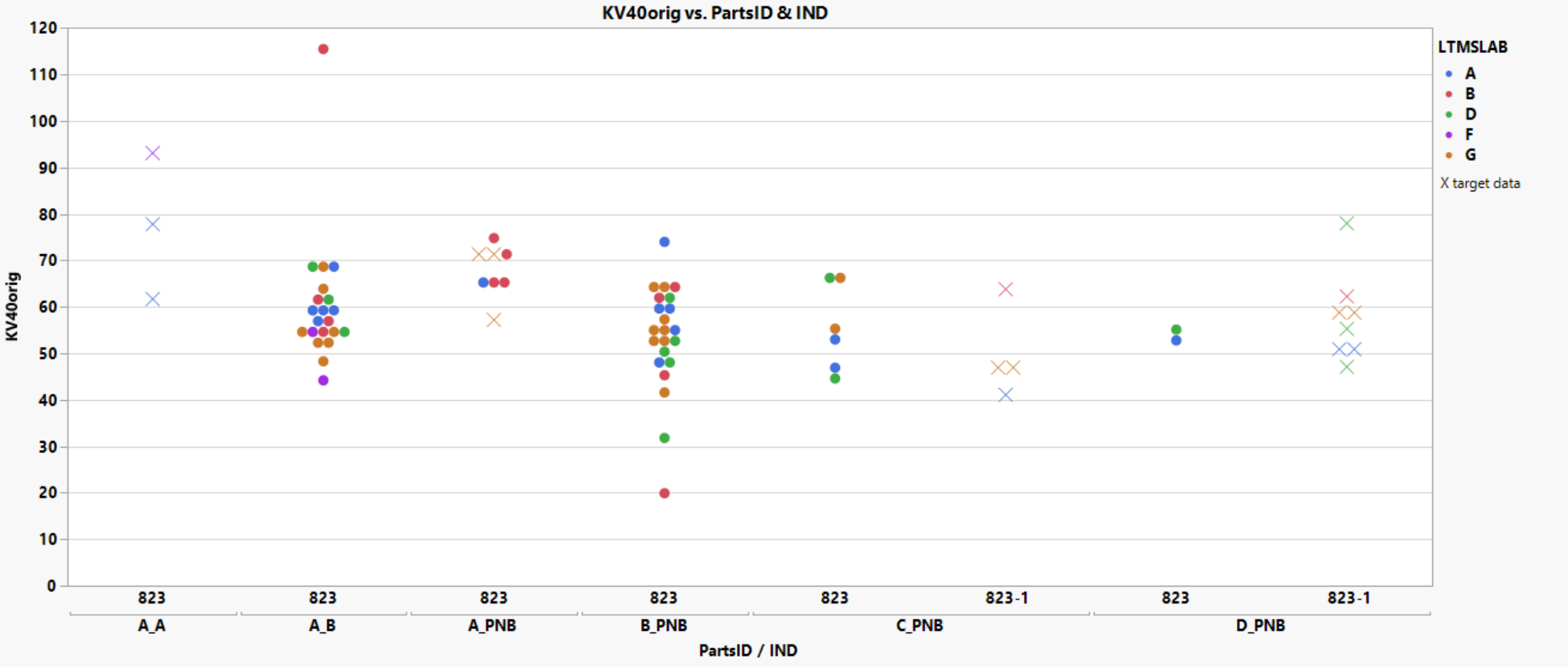
T-13 RO Target, ICF and OC Review

Jo Martinez
Chevron Oronite
July 17, 2024

IRPH data (n=74)



IRPH data (n=74)



Recommend new 823-1 target for IRPH

Summary of Fit

RSquare	0.413442
RSquare Adj	0.126148
Root Mean Square Error	13.0612
Mean of Response	119.5297
Observations (or Sum Wgts)	74

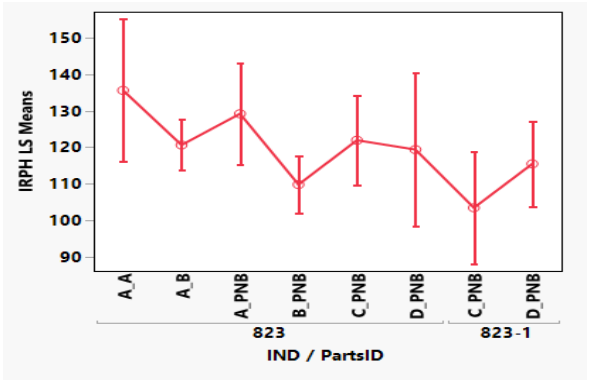
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	24	5892.040	245.502	1.4391
Error	49	8359.154	170.595	Prob > F
C. Total	73	14251.195		0.1389

Parameter Estimates

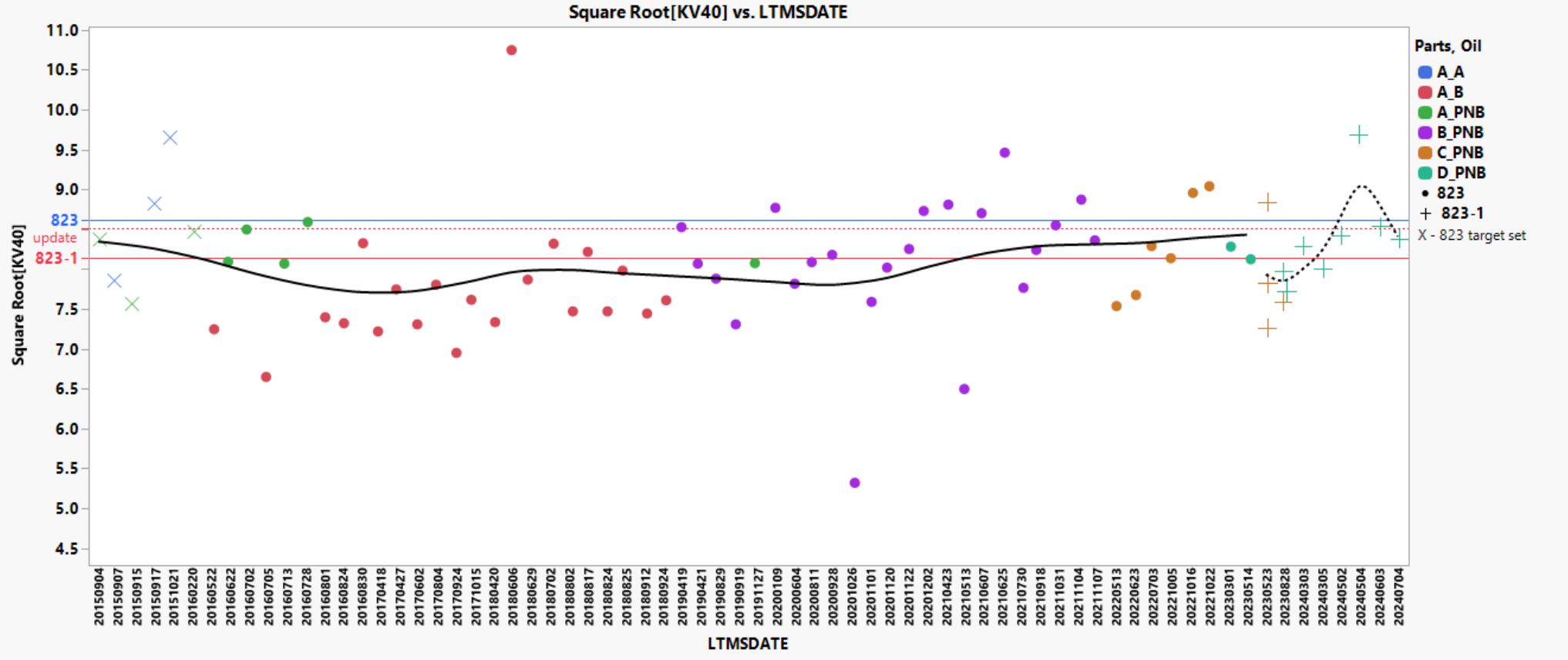
Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	4	4	353.4891	0.5180	0.7228
LTMSAPP[LTMSLAB]	13	13	1390.8249	0.6271	0.8195
IND	1	1	965.4172	5.6591	0.0213*
PartsID[IND]	6	6	2371.1455	2.3165	0.0477*

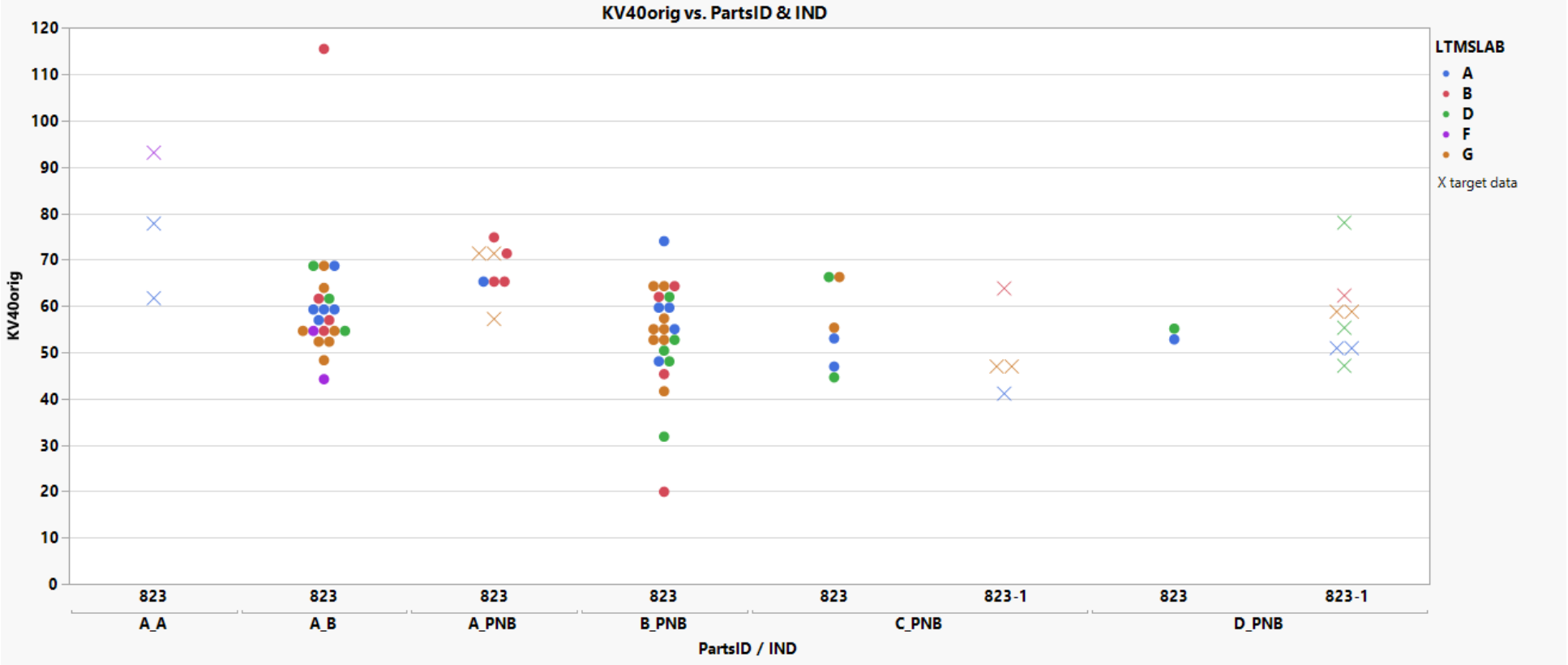


- Comparing 823 and 823-1 with liners C and D
  - difference is 11.2
  - p-value=0.14
- New target for 823-1: **110.5**
  - Based on the model with equal weights for labs A, B, D, G

KV40 data (n=74)



KV40 data (n=74)



Recommend new 823-1 target and ICF for KV40

Summary of Fit

RSquare	0.332081
RSquare Adj	0.004937
Root Mean Square Error	0.824175
Mean of Response	7.573931
Observations (or Sum Wgts)	74

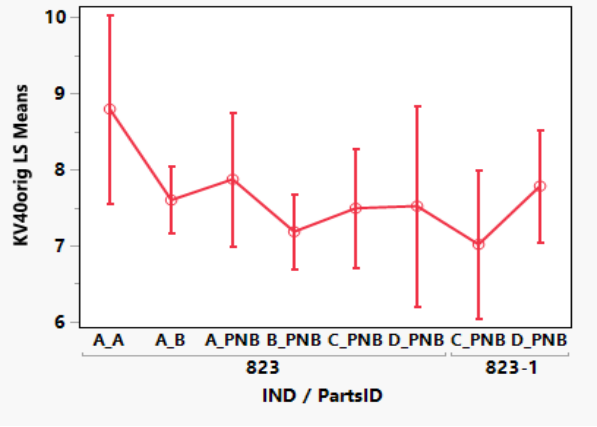
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	24	16.548366	0.689515	1.0151
Error	49	33.283937	0.679264	Prob > F
C. Total	73	49.832303		0.4671

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	4	4	0.8190657	0.3015	0.8756
LTMSAPP[LTMSLAB]	13	13	3.7204723	0.4213	0.9546
IND	1	1	0.6428705	0.9464	0.3354
PartsID[IND]	6	6	5.7015062	1.3989	0.2341

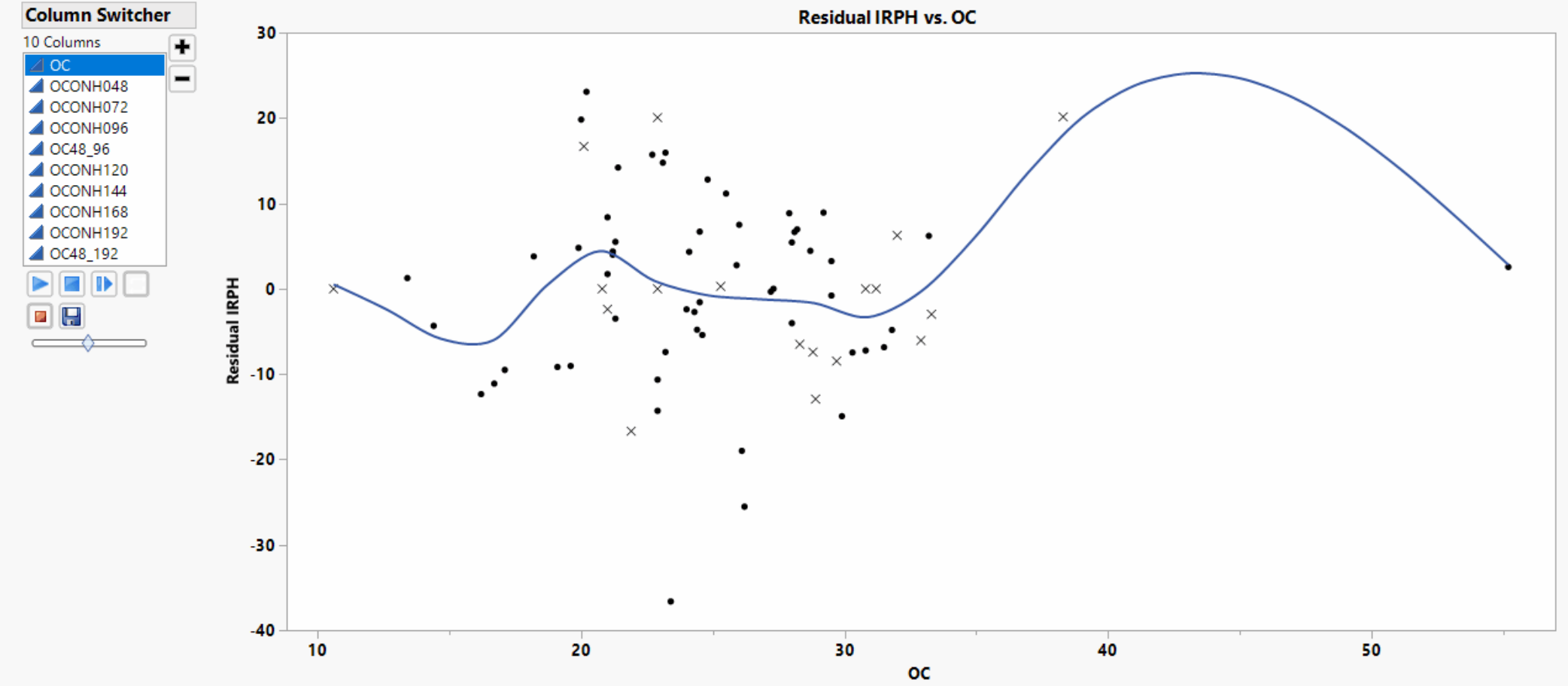


- Comparing 823 and 823-1 with liners C and D
  - difference = 0.11
  - P-value=0.82
- New target for 823-1: **8.50**
  - Current 8.61 - 0.11 = 8.50
- ICF for 823-1: **1.07**
  - Prediction for 823-1: **7.43**
    - Based on the model with equal weights for labs A, B, D, G
  - ICF: 8.50 – 7.43 = 1.07

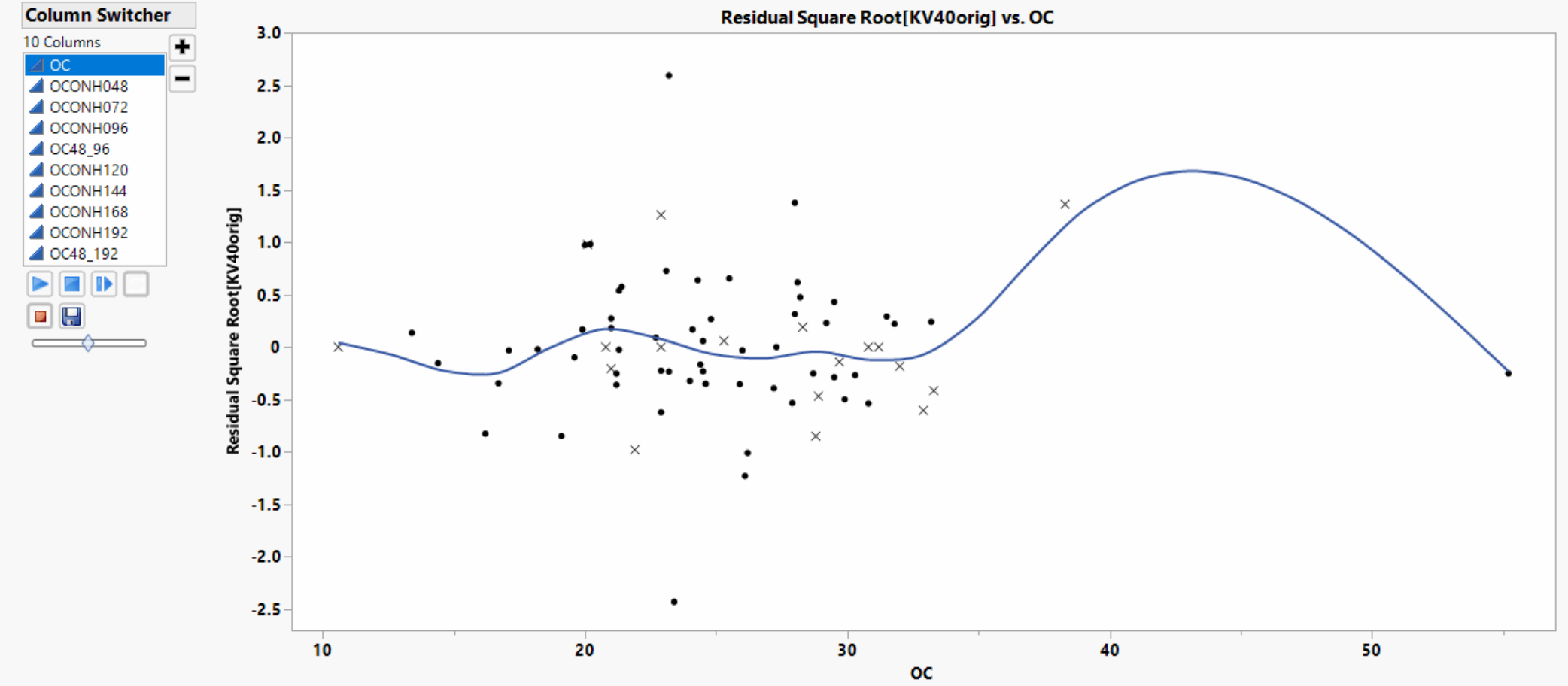
Targets Summary

T-13 targets	IRPH		KV40		
	Mean	s	Mean	ICF	s
823	127.4	11.1	8.61		0.929
823-1 (n=5)	109.3	11.1	8.139	0.857	0.929
823-1 (n=12)	110.5	10.4	8.50	1.07	0.642

IRPH residual plots by OC show no significant linear correlation



KV40 residual plots by OC show no significant linear correlation

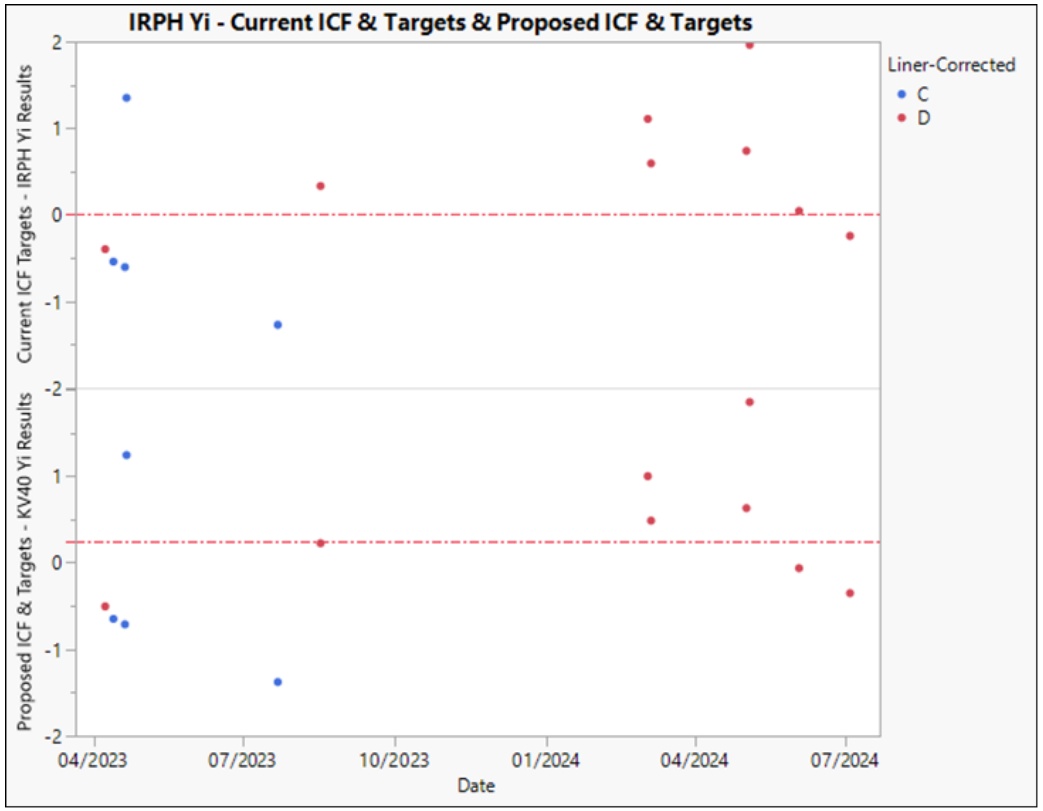


LTMS target evaluation

Todd Dvorak

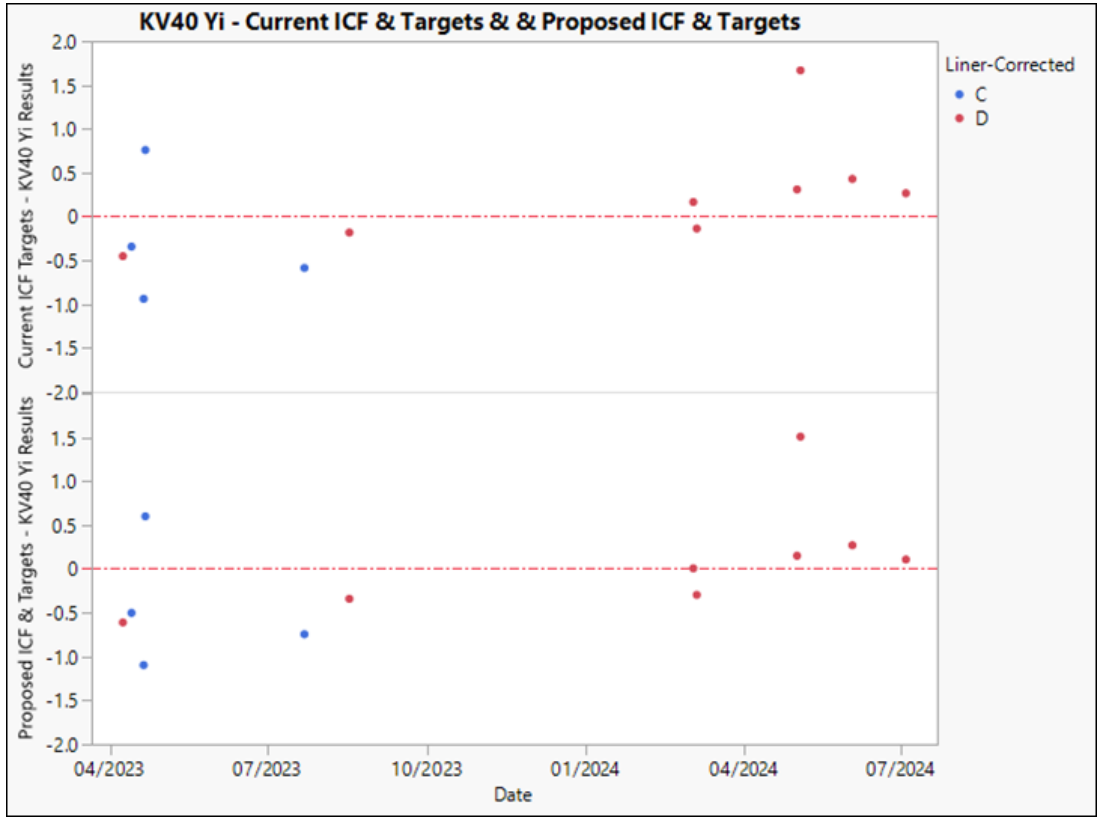
IRPH

Analysis Columns	Ref Oil	*Liner 'C' Yi Mean (n = 4)*	*Liner 'D' Yi Mean (n = 8)*	*Liner 'C' & 'D' Yi Mean (n = 12)*
Current ICF & Targets IRPH - Yi	823-1	-0.266	0.518	0.257
Proposed ICF & Targets IRPH - Yi	823-1	-0.374	0.410	0.149



KV40

Analysis Columns	Ref Oil	*Liner 'C' Yi Mean (n = 4)*	*Liner 'D' Yi Mean (n = 8)*	*Liner 'C' & 'D' Yi Mean (n = 12)*
Current ICF & Targets KV40 - Yi	823-1	-0.276	0.259	0.080
Proposed ICF & Targets KV40 - Yi	823-1	-0.436	0.100	-0.079



T-13: Exploring the Impact of High Oil Consumption on Oxidation and Viscosity increase before starting new reference oil testing

6/11/2024

Elisa Santos
Stats Group is reviewing

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Outline

- Plots
  - 11 tests: IRPH & sqrt(KV40) vs. OC (48-192 hr.) by Liner
  - 11 test results (823-1 limited data): Oxidation and Viscosity Increase vs. Time by Liner
  - Correlation between IRPH and OC
  - Correlation between KV40 and OC
- Modeling IRPH (11 tests) by Lab and OC (48-192 hr): ***OC (48-192 hr) is not statistically significant***
- Modeling Sqrt(KV40) (11 tests) by Lab and OC (48-192 hr): ***OC (48-192 hr) is not statistically significant***
- Comparing Oil consumption “before the recent increase” versus “recent 11 tests”
- sqrt(KV40) & IRPH: a few thoughts
  - Current 823-1 target is based on five tests: four tests on liner C and **one test on Liner D**
  - Recent data could (should?) be used to update the 823-1 target and standard deviation
  - However, most Liner D testing (5 out of 7) were done with parts associated with the recent increase in oil consumption
  - Parts are believed to be causing high OC
  - Correction factors should correct for parts change
- Appendix: looking into OC (48-96 hr)

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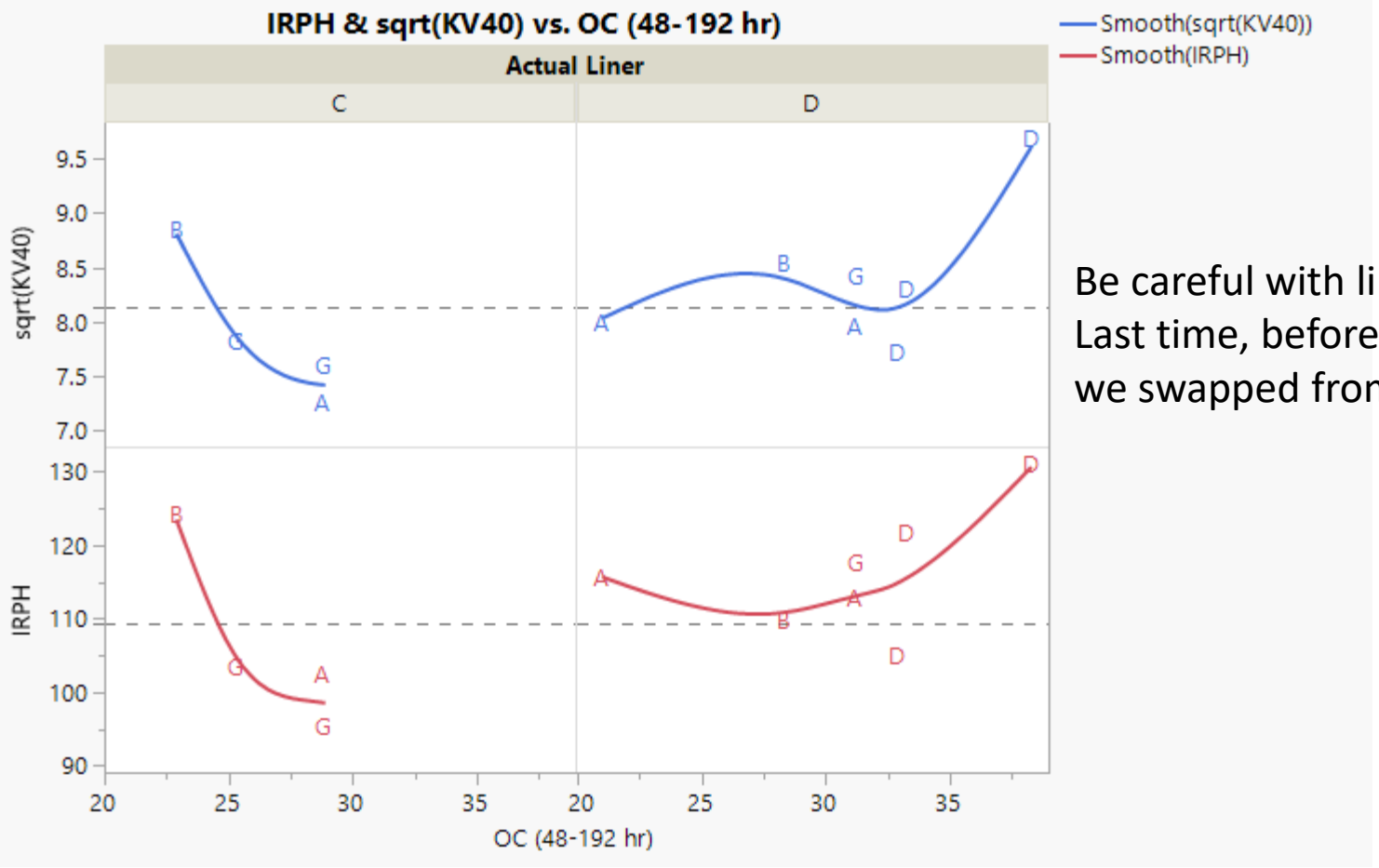
IRPH & sqrt(KV40) vs. OC (48-192 hr) by Liner



Be careful with liner labels
Last time, before tests were run, Liners we swapped from D to C

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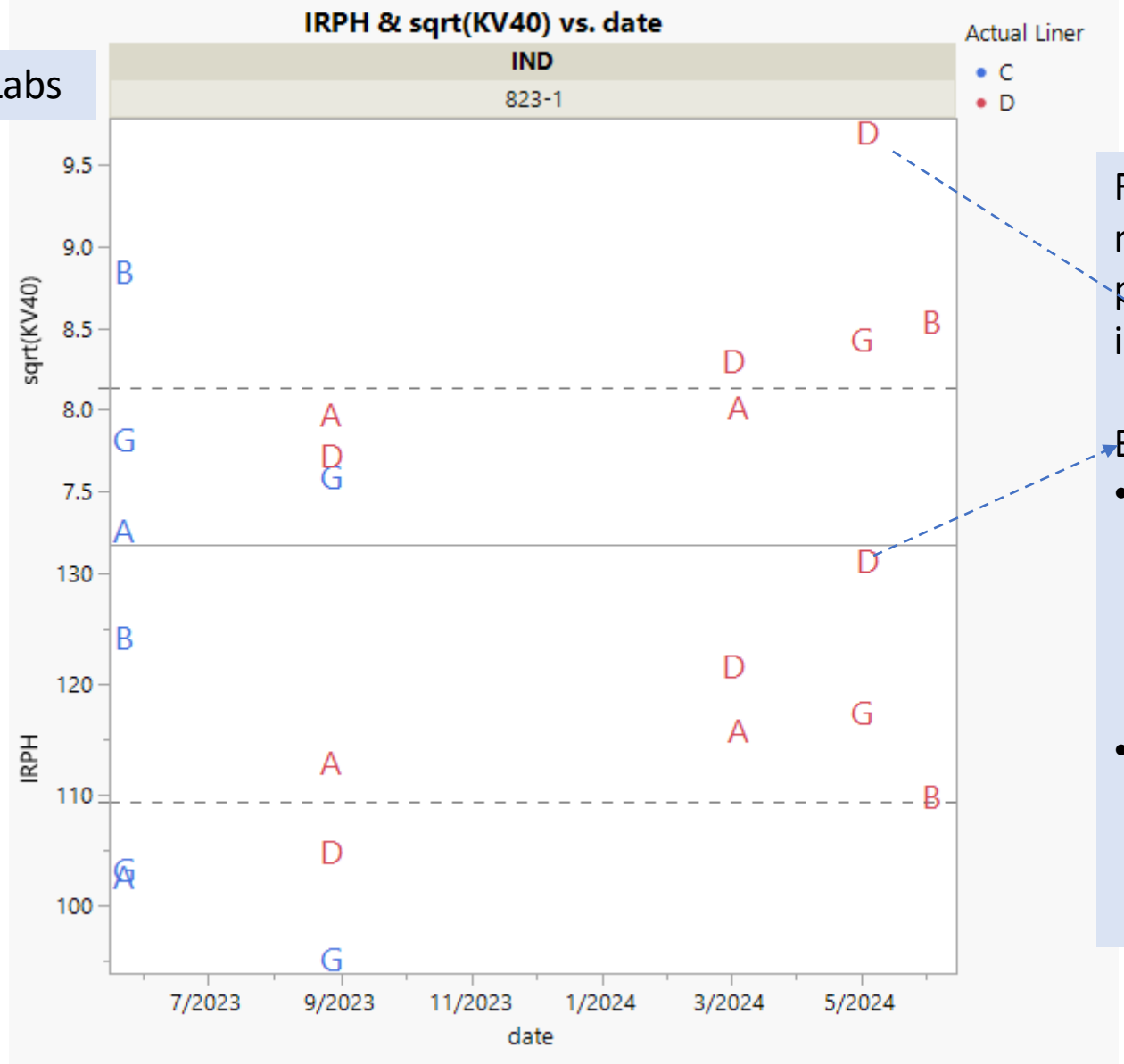
11 test results (***limited data***): Oxidation and Viscosity Increase vs. Time by Liner

Letters correspond to Labs

8.139 (target)

109.3 (target)



Fact: Most Liner D testing (red markers; 5 out of 7) were done with parts associated with the recent increase in oil consumption

Based on these 11 tests:

- except for one test from Lab D, the recent increase in OC does not seem to be associated with an ***alarming*** increase in IRPH or KV40
- However, recent testing has been ***on target*** *(one test)* ***or above target*** *(four tests)*

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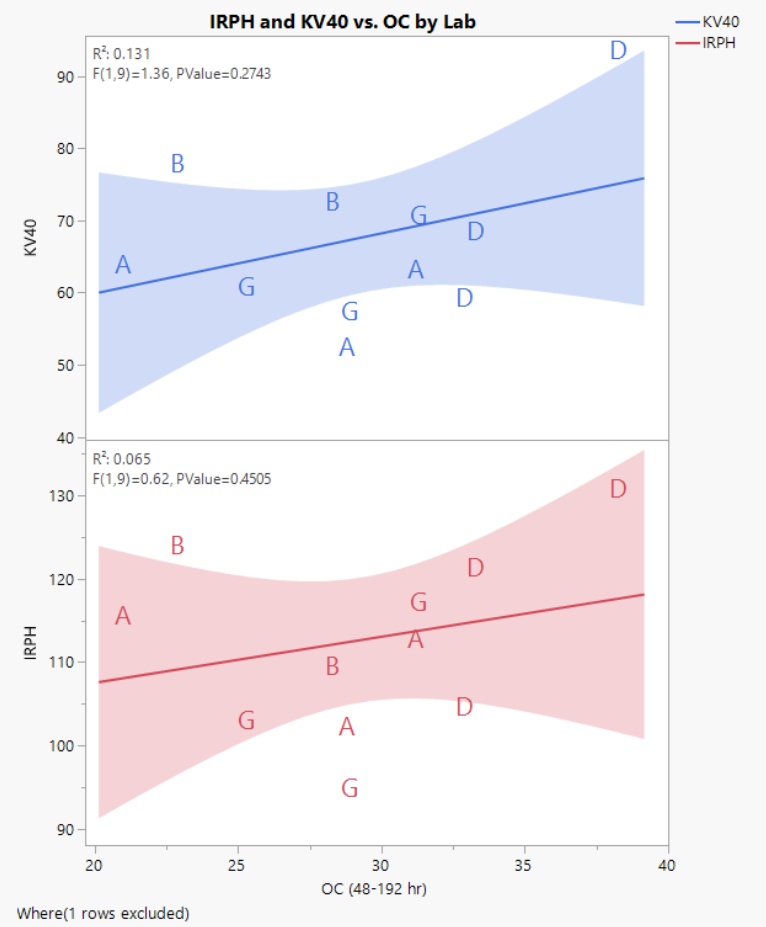
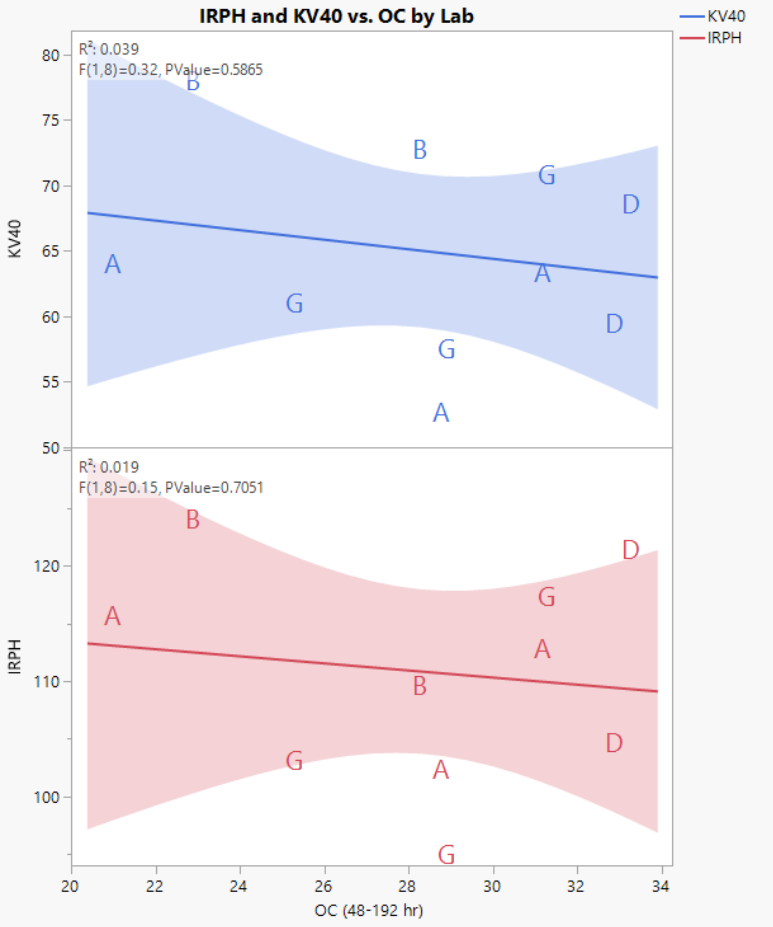
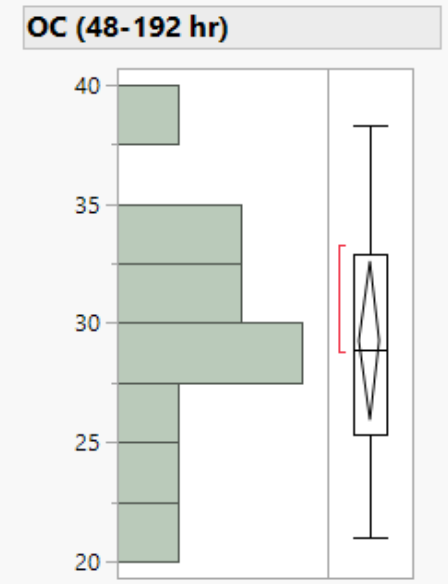
Correlation between IRPH and OC is very weak
Correlation between KV40 and OC is very weak

Including all tests (11)



Excluding test with high OC (186388) from Lab D





Quantiles

100.0%	maximum	38.3
99.5%		38.3
97.5%		38.3
90.0%		37.3
75.0%	quartile	32.9
50.0%	median	28.9
25.0%	quartile	25.3
10.0%		21.38
2.5%		21
0.5%		21
0.0%	minimum	21

Summary Statistics

Mean	29.290909
Std Dev	4.9480207
Std Err Mean	1.4918844
Upper 95% Mean	32.615035
Lower 95% Mean	25.966784
N	11
N Missing	0

Letters correspond to Labs

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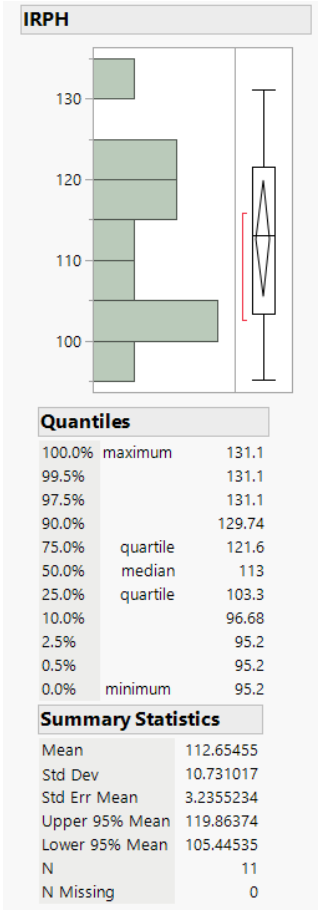
Modeling IRPH (11 tests) by Lab and OC (48-192 hr): *OC (48-192 hr) is not statistically significant*

We have reached similar conclusions when replacing OC (48-192 hr) by OC (48-96 hr)

IRPH distribution (823-1)



Quantiles

100.0%	maximum	131.1
99.5%		131.1
97.5%		131.1
90.0%		129.74
75.0%	quartile	121.6
50.0%	median	113
25.0%	quartile	103.3
10.0%		96.68
2.5%		95.2
0.5%		95.2
0.0%	minimum	95.2

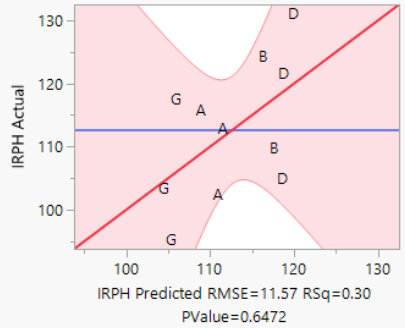
Summary Statistics

Mean	112.65455
Std Dev	10.731017
Std Err Mean	3.2355234
Upper 95% Mean	119.86374
Lower 95% Mean	105.44535
N	11
N Missing	0

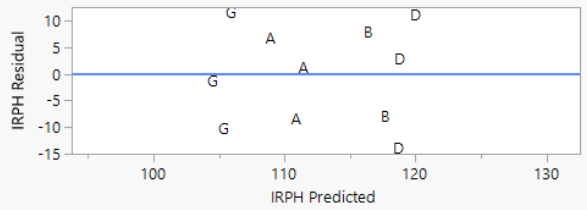
Response IRPH

Whole Model

Actual by Predicted Plot



Residual by Predicted Plot



Summary of Fit

RSquare	0.302545
RSquare Adj	-0.16243
Root Mean Square Error	11.56973
Mean of Response	112.6545
Observations (or Sum Wgts)	11

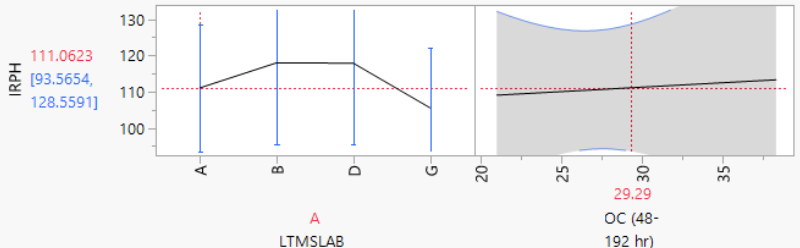
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	348.3948	87.099	0.6507
Error	6	803.1524	133.859	Prob > F
C. Total	10	1151.5473		0.6472

Effect Tests

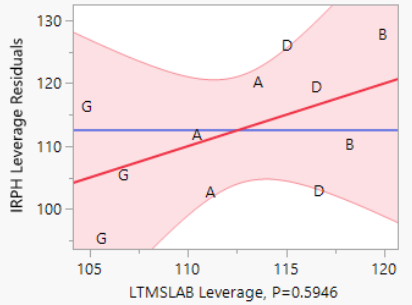
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	3	3	273.91605	0.6821	0.5946
OC (48-192 hr)	1	1	6.49924	0.0486	0.8329

Prediction Profiler



LTMSLAB

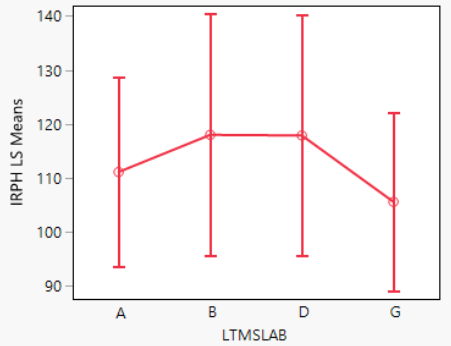
Leverage Plot



Least Squares Means Table

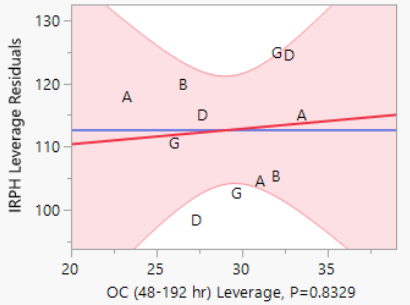
Level	Least Sq Mean	Std Error	Mean
A	111.06249	7.1509521	110.500
B	117.95624	9.1566482	117.050
D	117.83916	9.0973255	119.200
G	105.52753	6.7376762	105.333

Least Squares Means Plot



OC (48-192 hr)

Leverage Plot



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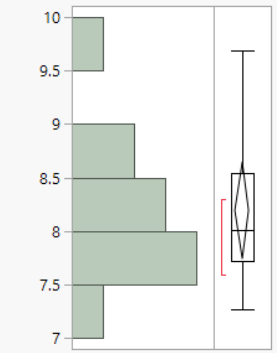
Modeling Sqrt(KV40) (11 tests) by Lab and OC (48-192 hr): *OC (48-192 hr) is not statistically significant*

We have reached similar conclusions when replacing OC (48-192 hr) by OC (48-96 hr)

Sqrt(KV40) distribution (823-1)

sqrt(KV40)



Quantiles

100.0%	maximum	9.69
99.5%		9.69
97.5%		9.69
90.0%		9.5206
75.0%	quartile	8.538
50.0%	median	8.012
25.0%	quartile	7.72
10.0%		7.332
2.5%		7.266
0.5%		7.266
0.0%	minimum	7.266

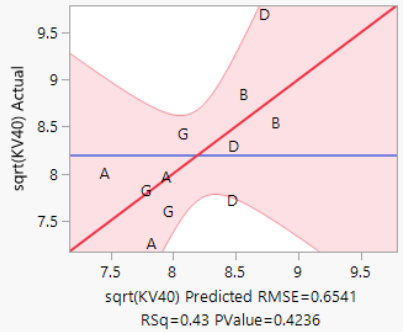
Summary Statistics

Mean	8.198
Std Dev	0.6712865
Std Err Mean	0.2024005
Upper 95% Mean	8.6489764
Lower 95% Mean	7.7470236
N	11
N Missing	0

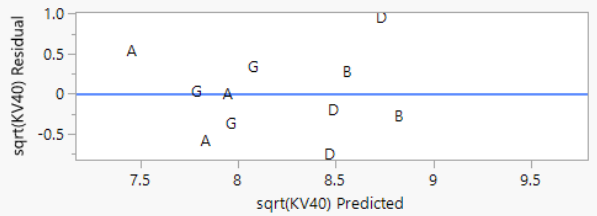
Response sqrt(KV40)

Whole Model

Actual by Predicted Plot



Residual by Predicted Plot



Summary of Fit

RSquare	0.430295
RSquare Adj	0.050491
Root Mean Square Error	0.65412
Mean of Response	8.198
Observations (or Sum Wgts)	11

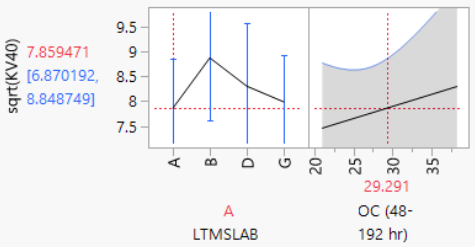
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	1.9390180	0.484754	1.1329
Error	6	2.5672380	0.427873	Prob > F
C. Total	10	4.5062560		0.4236

Effect Tests

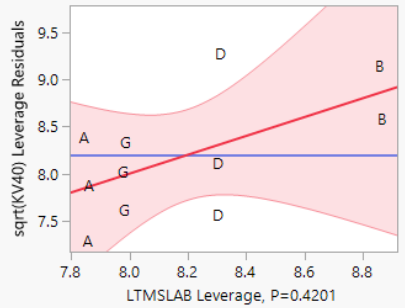
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	3	3	1.4083198	1.0971	0.4201
OC (48-192 hr)	1	1	0.2506618	0.5858	0.4731

Prediction Profiler



LTMSLAB

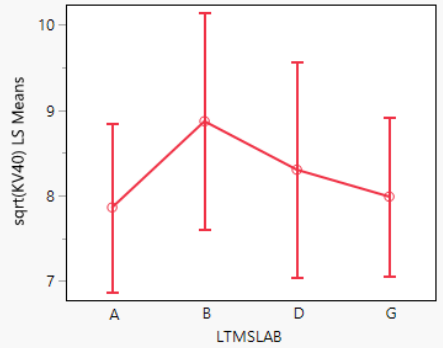
Leverage Plot



Least Squares Means Table

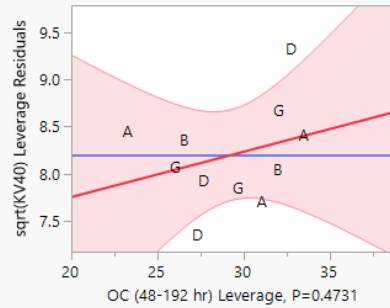
Level	Least Sq Mean	Std Error	Mean
A	7.8594661	0.40429461	7.74900
B	8.8684732	0.51769099	8.69050
D	8.3010813	0.51433705	8.56833
G	7.9864705	0.38092916	7.94833

Least Squares Means Plot



OC (48-192 hr)

Leverage Plot



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Comparing Oil consumption “before the recent increase” versus “recent 11 tests”

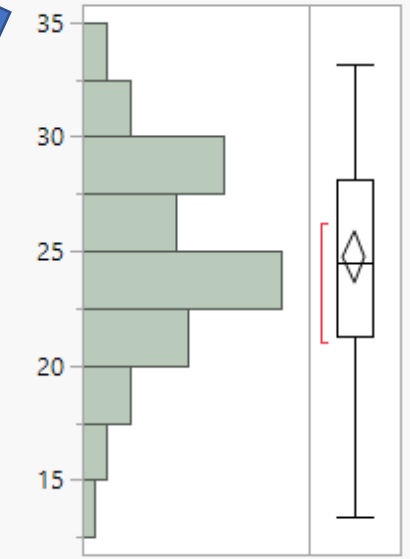
Oil consumption distributions (59 tests) after Fuel flow/ humidity control: 6 out of 59 tests with OC >30

- excluding two tests from lab F from 2016
- Excluding the most recent tests on 823-1 listed below

TESTKEY	OC(48-192 hr)
179972-T13	31.2
181571-T13	33.9
185298-T13	33.3
179973-T13	21
187293-T13	31.3
186388-T13	38.3
188349-T13	28.3

The analysis of “after fuel flow/ humidity control” T-13 subset has not revealed anything new about the impact of OC into IRPH or KV40

OC (48-192 hr) before OC increased



Quantiles

100.0%	maximum	33.2
99.5%		33.2
97.5%		33.05
90.0%		30.3
75.0%	quartile	28.1
50.0%	median	24.5
25.0%	quartile	21.3
10.0%		19.6
2.5%		15.05
0.5%		13.4
0.0%	minimum	13.4

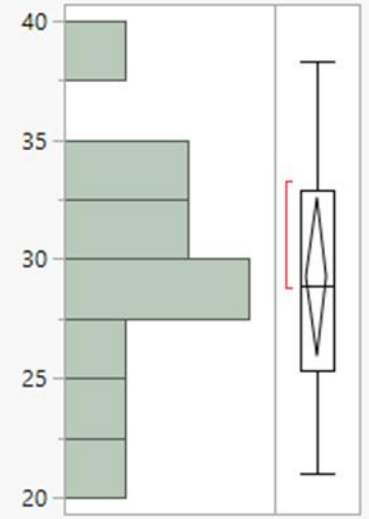
Summary Statistics

Mean	24.745763
Std Dev	4.2594043
Std Err Mean	0.5545272
Upper 95% Mean	25.85577
Lower 95% Mean	23.635756
N	59
N Missing	0

Recent 11 tests on 823-1

5 out of 11 tests with OC >30

OC (48-192 hr)



Quantiles

100.0%	maximum	38.3
99.5%		38.3
97.5%		38.3
90.0%		37.3
75.0%	quartile	32.9
50.0%	median	28.9
25.0%	quartile	25.3
10.0%		21.38
2.5%		21
0.5%		21
0.0%	minimum	21

Summary Statistics

Mean	29.290909
Std Dev	4.9480207
Std Err Mean	1.4918844
Upper 95% Mean	32.615035
Lower 95% Mean	25.966784
N	11
N Missing	0

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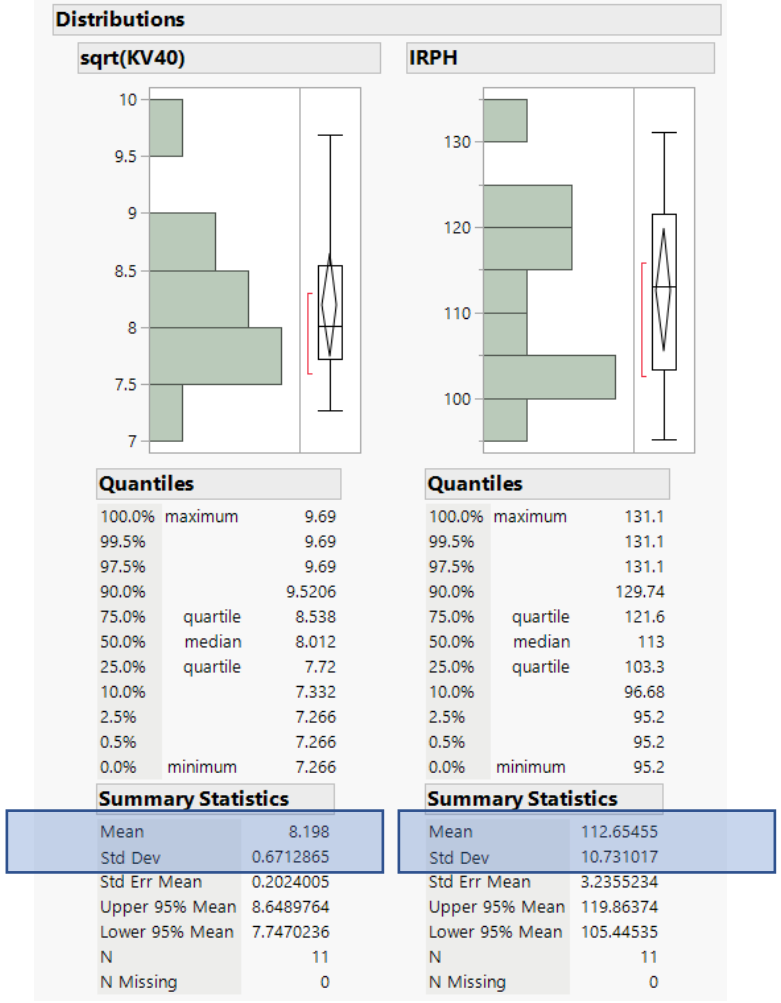
sqrt(KV40) & IRPH – Potential 823-1 Target & Standard Deviation

Mean and standard deviation (11 tests)



Quantiles

100.0%	maximum	9.69
99.5%		9.69
97.5%		9.69
90.0%		9.5206
75.0%	quartile	8.538
50.0%	median	8.012
25.0%	quartile	7.72
10.0%		7.332
2.5%		7.266
0.5%		7.266
0.0%	minimum	7.266

Summary Statistics

Mean	8.198
Std Dev	0.6712865
Std Err Mean	0.2024005
Upper 95% Mean	8.6489764
Lower 95% Mean	7.7470236
N	11
N Missing	0

Quantiles

100.0%	maximum	131.1
99.5%		131.1
97.5%		131.1
90.0%		129.74
75.0%	quartile	121.6
50.0%	median	113
25.0%	quartile	103.3
10.0%		96.68
2.5%		95.2
0.5%		95.2
0.0%	minimum	95.2

Summary Statistics

Mean	112.65455
Std Dev	10.731017
Std Err Mean	3.2355234
Upper 95% Mean	119.86374
Lower 95% Mean	105.44535
N	11
N Missing	0

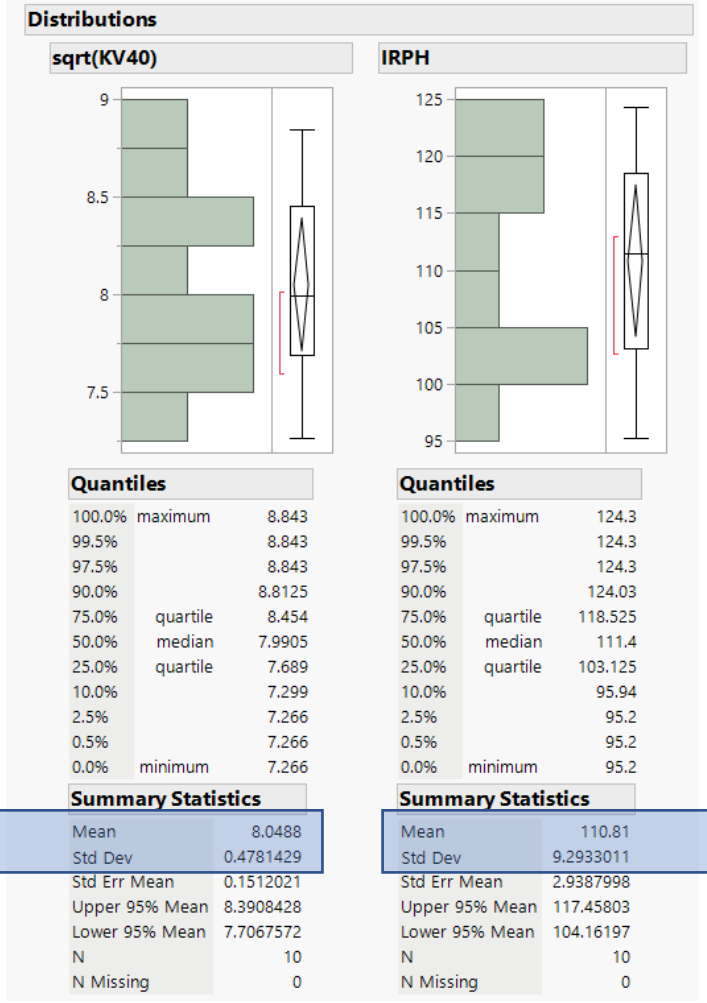
Currently, Parts are believed to be causing high OC

These are the available tests (confounded with liner D)

Correction factors should correct for parts change

Current target was based on only five tests

Mean and standard deviation (10 tests), excluding test 186388/ Lab D (OC (48-192 hr) =38.3)



Quantiles

100.0%	maximum	8.843
99.5%		8.843
97.5%		8.843
90.0%		8.8125
75.0%	quartile	8.454
50.0%	median	7.9905
25.0%	quartile	7.689
10.0%		7.299
2.5%		7.266
0.5%		7.266
0.0%	minimum	7.266

Summary Statistics

Mean	8.0488
Std Dev	0.4781429
Std Err Mean	0.1512021
Upper 95% Mean	8.3908428
Lower 95% Mean	7.7067572
N	10
N Missing	0

Quantiles

100.0%	maximum	124.3
99.5%		124.3
97.5%		124.3
90.0%		124.03
75.0%	quartile	118.525
50.0%	median	111.4
25.0%	quartile	103.125
10.0%		95.94
2.5%		95.2
0.5%		95.2
0.0%	minimum	95.2

Summary Statistics

Mean	110.81
Std Dev	9.2933011
Std Err Mean	2.9387998
Upper 95% Mean	117.45803
Lower 95% Mean	104.16197
N	10
N Missing	0

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sqrt(KV40) & IRPH

Current targets and standard deviations

T-13 FTIR Peak Height Oxidation
Unit of Measure: absorbance / cm

Reference Oil	Mean	Standard Deviation
823	127.4	11.1
823-1	109.3	11.1

Percent Increase in Viscosity at 40°C from 300 to 360 hour
Unit of Measure: SQRT(%)

Reference Oil	Mean	Standard Deviation
823	8.610	0.929
823-1	8.139	0.929

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Appendix

Modeling IRPH and sqrt(KV40) with and without Lab in the model ***replacing OC (48-192 hr) by*** **OC (48-96 hr)**

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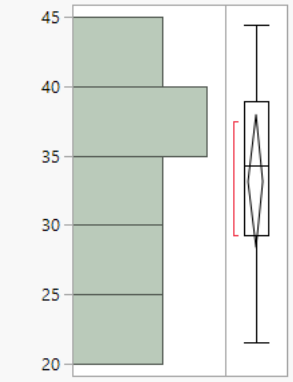
Modeling IRPH (11 tests) by Lab and OC (48-96 hr):

OC (48-96 hr) is not statistically significant

OC (48-96 hr)



Quantiles

100.0%	maximum	44.4
99.5%		44.4
97.5%		44.4
90.0%		43.54
75.0%	quartile	38.9
50.0%	median	34.3
25.0%	quartile	29.3
10.0%		21.9
2.5%		21.6
0.5%		21.6
0.0%	minimum	21.6

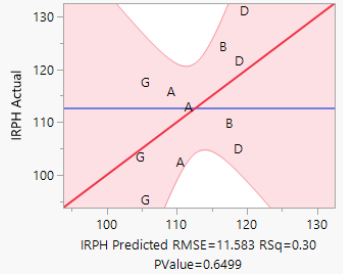
Summary Statistics

Mean	33.163636
Std Dev	7.073086
Std Err Mean	2.1326157
Upper 95% Mean	37.9154
Lower 95% Mean	28.411873
N	11
N Missing	0

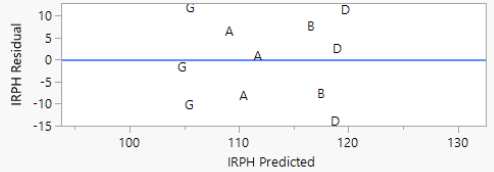
Response IRPH

Whole Model

Actual by Predicted Plot



Residual by Predicted Plot



Summary of Fit

RSquare	0.301004
RSquare Adj	-0.16499
Root Mean Square Error	11.58251
Mean of Response	112.6545
Observations (or Sum Wgts)	11

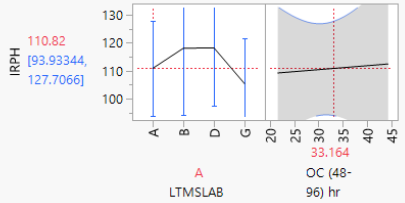
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	346.6201	86.655	0.6459
Error	6	804.9272	134.155	Prob > F
C. Total	10	1151.5473		0.6499

Effect Tests

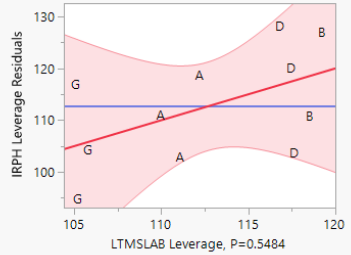
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	3	3	312.50499	0.7765	0.5484
OC (48-96) hr	1	1	4.72448	0.0352	0.8573

Prediction Profiler



LTMSLAB

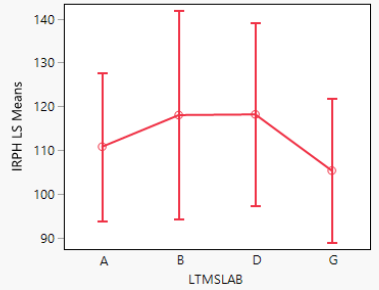
Leverage Plot



Least Squares Means Table

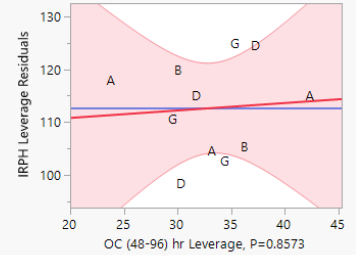
Level	Least Sq Mean	Std Error	Mean
A	110.81997	6.9011134	110.500
B	118.03433	9.7257336	117.050
D	118.19597	8.5640698	119.200
G	105.36118	6.6888107	105.333

Least Squares Means Plot



OC (48-96) hr

Leverage Plot



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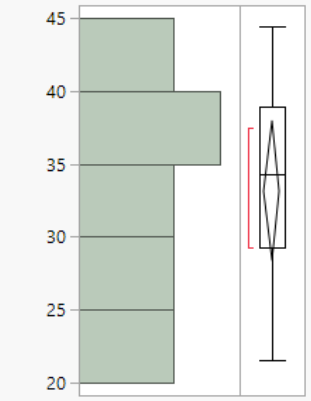
Modeling sqrt(KV40) (11 tests) by Lab and OC (48-96 hr):

OC (48-96 hr) is not statistically significant

OC (48-96) hr



Quantiles

100.0%	maximum	44.4
99.5%		44.4
97.5%		44.4
90.0%		43.54
75.0%	quartile	38.9
50.0%	median	34.3
25.0%	quartile	29.3
10.0%		21.9
2.5%		21.6
0.5%		21.6
0.0%	minimum	21.6

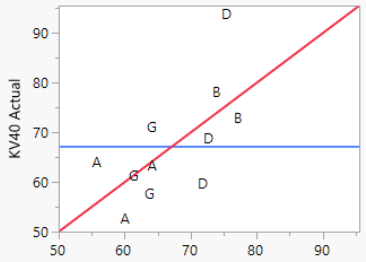
Summary Statistics

Mean	33.163636
Std Dev	7.073086
Std Err Mean	2.1326157
Upper 95% Mean	37.9154
Lower 95% Mean	28.411873
N	11
N Missing	0

Response Sqrt(KV40)

Whole Model

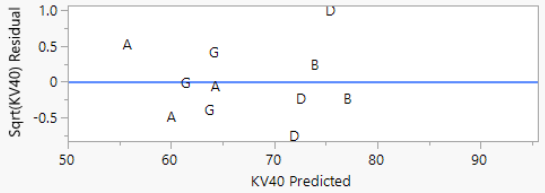
Actual by Predicted Plot



Effect Summary

Source	Logworth	PValue
LTMSLAB	0.432	0.36963
OC (48-96) hr	0.286	0.51722

Residual by Predicted Plot



Summary of Fit

RSquare	0.420292
RSquare Adj	0.03382
Root Mean Square Error	0.659829
Mean of Response	8.198081
Observations (or Sum Wgts)	11

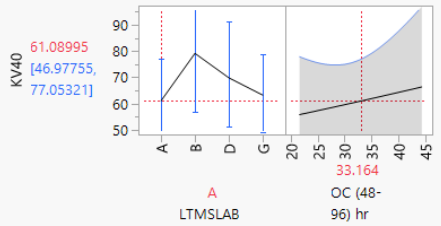
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	1.8938944	0.473474	1.0875
Error	6	2.6122435	0.435374	Prob > F
C. Total	10	4.5061378		0.4405

Effect Tests

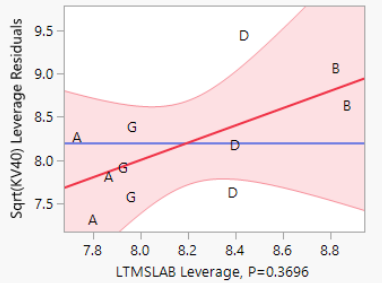
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	3	3	1.6429503	1.2579	0.3696
OC (48-96) hr	1	1	0.2060100	0.4732	0.5172

Prediction Profiler



LTMSLAB

Leverage Plot

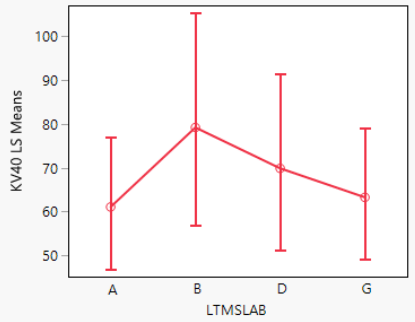


Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	61.089787	0.39314041	60.0498
B	79.141633	0.55405247	75.5268
D	69.866763	0.48787518	73.4157
G	63.269754	0.38104602	63.1773

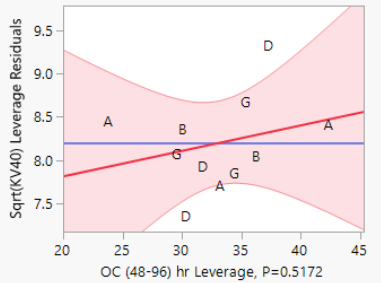
* Std Errors are on transformed Y's

Least Squares Means Plot



OC (48-96) hr

Leverage Plot



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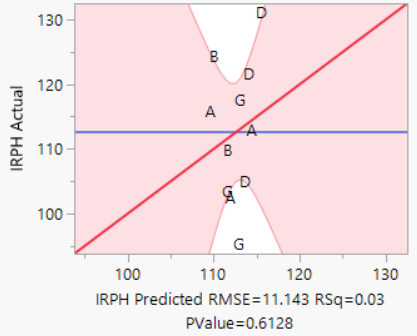
Replacing OC (48-192 hr) by OC (48-96) hr: same conclusion

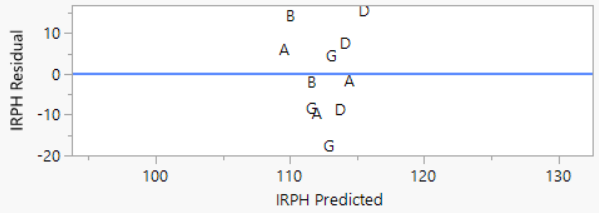
Response IRPH

Whole Model

Actual by Predicted Plot



Residual by Predicted Plot



Summary of Fit

RSquare	0.029625
RSquare Adj	-0.07819
Root Mean Square Error	11.14267
Mean of Response	112.6545
Observations (or Sum Wgts)	11

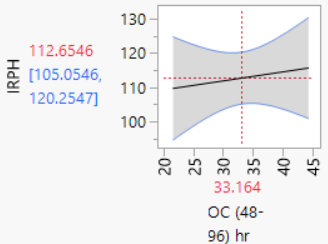
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	34.1151	34.115	0.2748
Error	9	1117.4322	124.159	Prob > F
C. Total	10	1151.5473		0.6128

Effect Tests

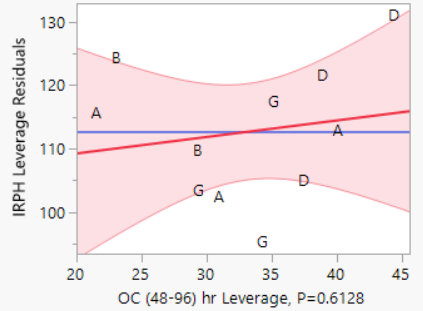
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
OC (48-96) hr	1	1	34.115093	0.2748	0.6128

Prediction Profiler



OC (48-96) hr

Leverage Plot



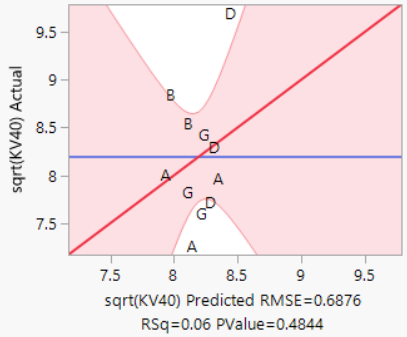
Classified as Confidential

Replacing OC (48-192 hr) by OC (48-96) hr: same conclusion

Response sqrt(KV40)

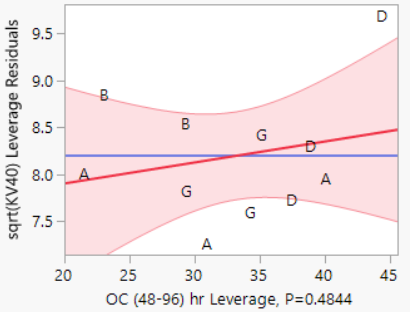
Whole Model

Actual by Predicted Plot

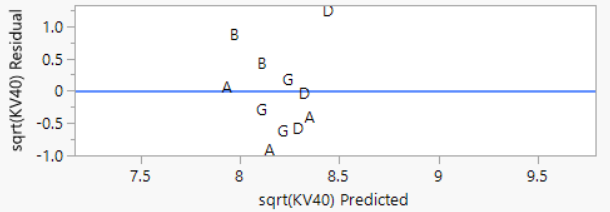


OC (48-96) hr

Leverage Plot



Residual by Predicted Plot



Summary of Fit

RSquare	0.055782
RSquare Adj	-0.04913
Root Mean Square Error	0.687579
Mean of Response	8.198
Observations (or Sum Wgts)	11

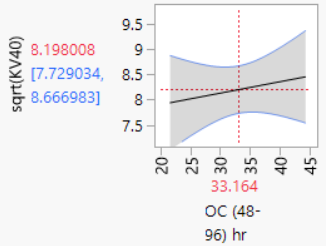
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.2513686	0.251369	0.5317
Error	9	4.2548874	0.472765	Prob > F
C. Total	10	4.5062560		0.4844

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
OC (48-96) hr	1	1	0.25136857	0.5317	0.4844

Prediction Profiler



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Parts Combinations

CMIR	Stand	Oil Consumption (48-192 hr)	Oil Consumption (48-96 hr)	Kit #	Liner Batch	Piston Date 1	Top Ring Stamping
172877*	A2	19.9	18.1	853	C	0522	5x 681k-808k, 1x 934k
179973	A2	21.0	21.6	917	D	0821, 0722, 3x 0822, 0922	1x 903k, 5x 939k
177777	B3	22.9	23.1	795	C	2x 0421, 4x 0521	
	G2		26.9	939/866	D	0123	1x 903k, 1x 914k, 4x 934k
188349	B3	28.3	29.3	976	D	5x 0119, 0619	6x 1017k
177774	G1	25.3	29.4	866	C	0822	1x 903k, 1x 914k, 4x 934k
177776	A4	28.8	31	860	C	0522	3x 903k, 3x 934k
180631	G2	28.9	34.3	907	C	0822, 5x 0922	
187293	G3	32.0	35.2	954	D	5x 0922, 0122	6x 1017k
177775	D2	32.9	37.5	856	D	0522	4x 914k, 2x 925k
185298	D1	33.3	38.9	929	D	3x 1022, 1x 1222, 2x 0223	6x 1000k
179972	A8	31.2	40.1	887	D	0922	5x 939k, 1x 968k
	G2		44.4 36.2 repeat	939	D	0123	6x 1017k
186388	D2	38.3	44.4	960	D	0423	6x 1017k

*RO823 < 30 30 ≤ x < 35 35 ≤ x 0922 and later >934k

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