T-13 RO 823-1 Targets and ICF

Statistics Group

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Statistics Group

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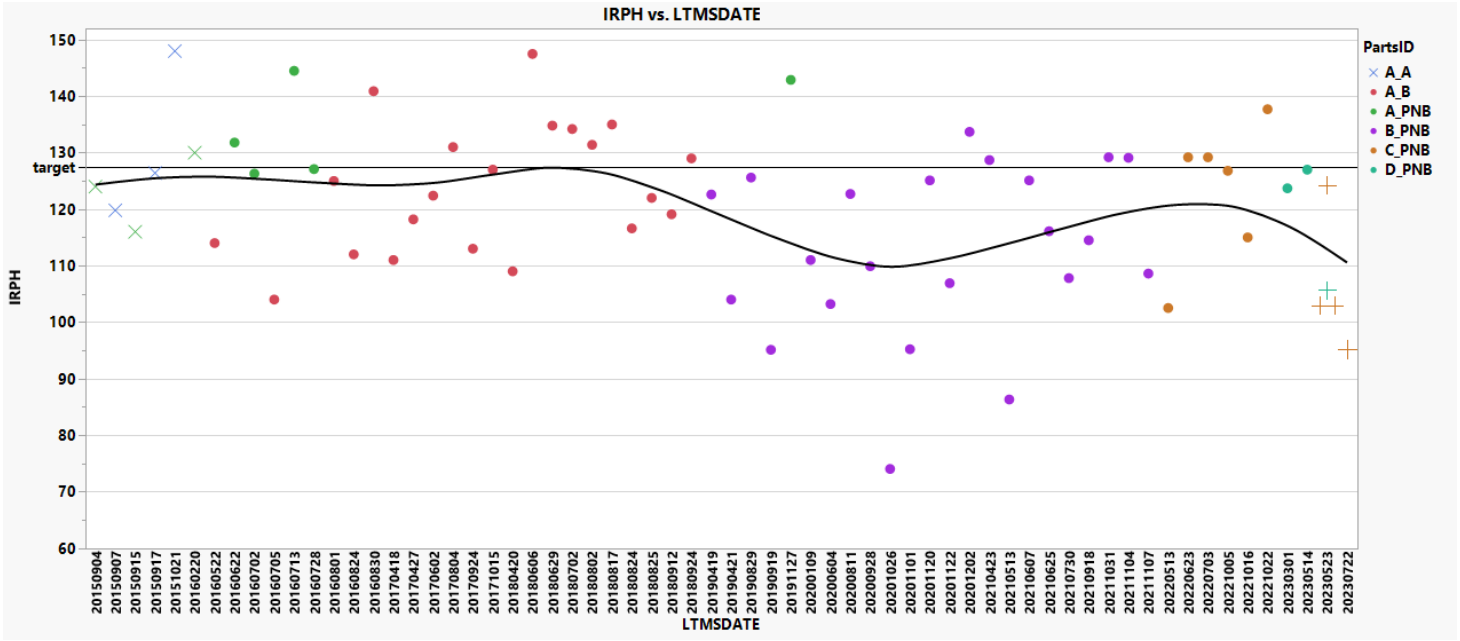
Data Analyses

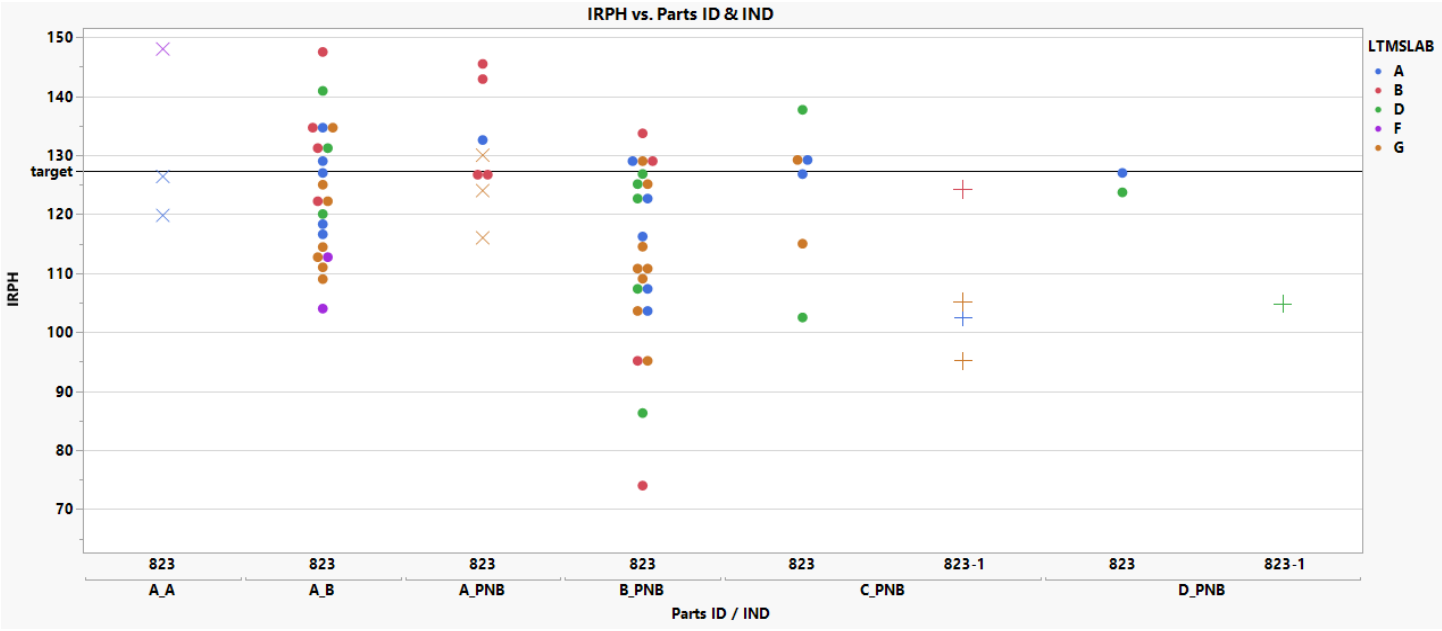
- Key is understanding whether the mean performance of 823-1 has changed and is different than 823. A change in the mean performance of an oil is different from a change in the engine test reflected in the oil performance. Determination of a change in performance is made through statistical analyses considering all possible covariates. If a change in performance is determined, the oil may be assigned new targets.
- Several analyses were discussed in making recommendations regarding 823-1 targets (See Appendix)
- Data sets analyzed
  - all oils from the target reset in 2015 (n=82)
  - 823 from target reset in 2015 (n=67)
  - 823 from humidity control without lab F and high data point from Lab B (n= 50)
- Additional methods were also considered for determining target means
  - Arithmetic mean of 823-1 results
  - Arithmetic mean of 823-1 severity adjusted results

IRPH

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

- The difference between oil re-blends (within liner C) is statistically 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





x - target set + 823-1

823-1 Targets and ICF (IRPH)

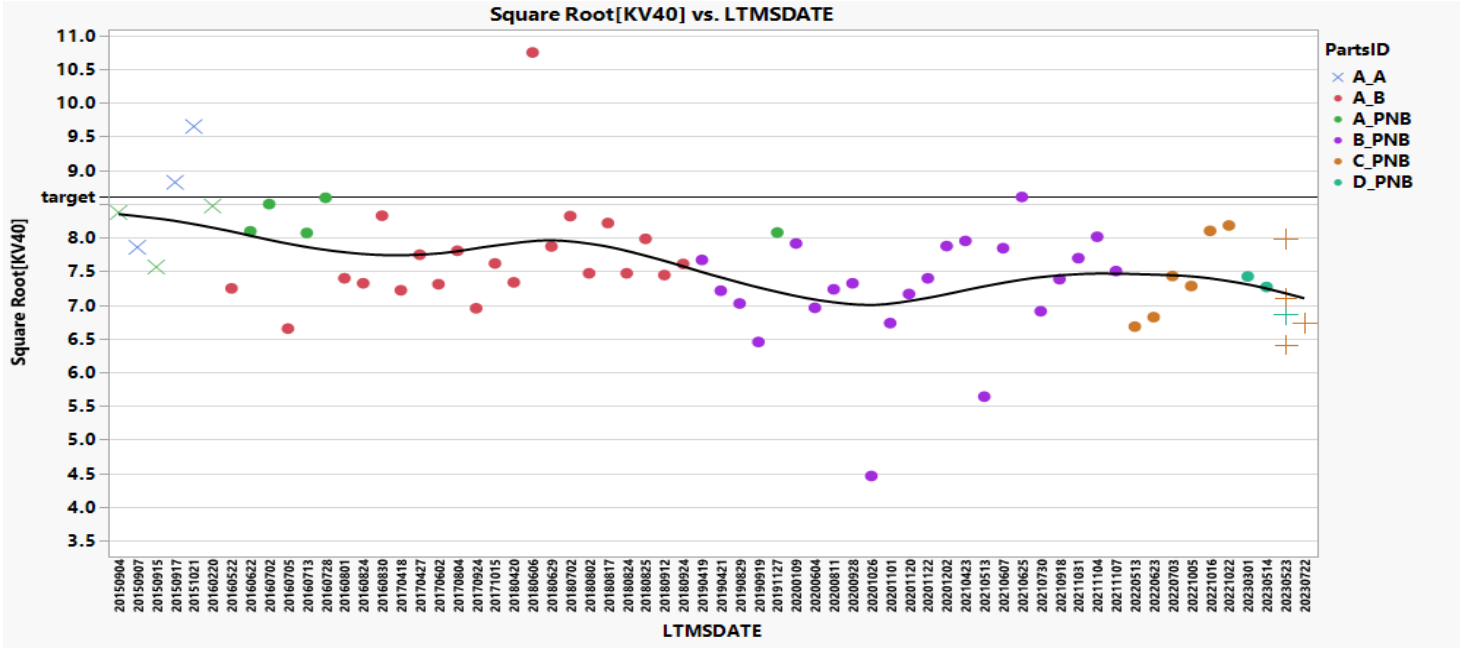
These targets and ICF should be reviewed again and updated if needed when more data is available with n=10.

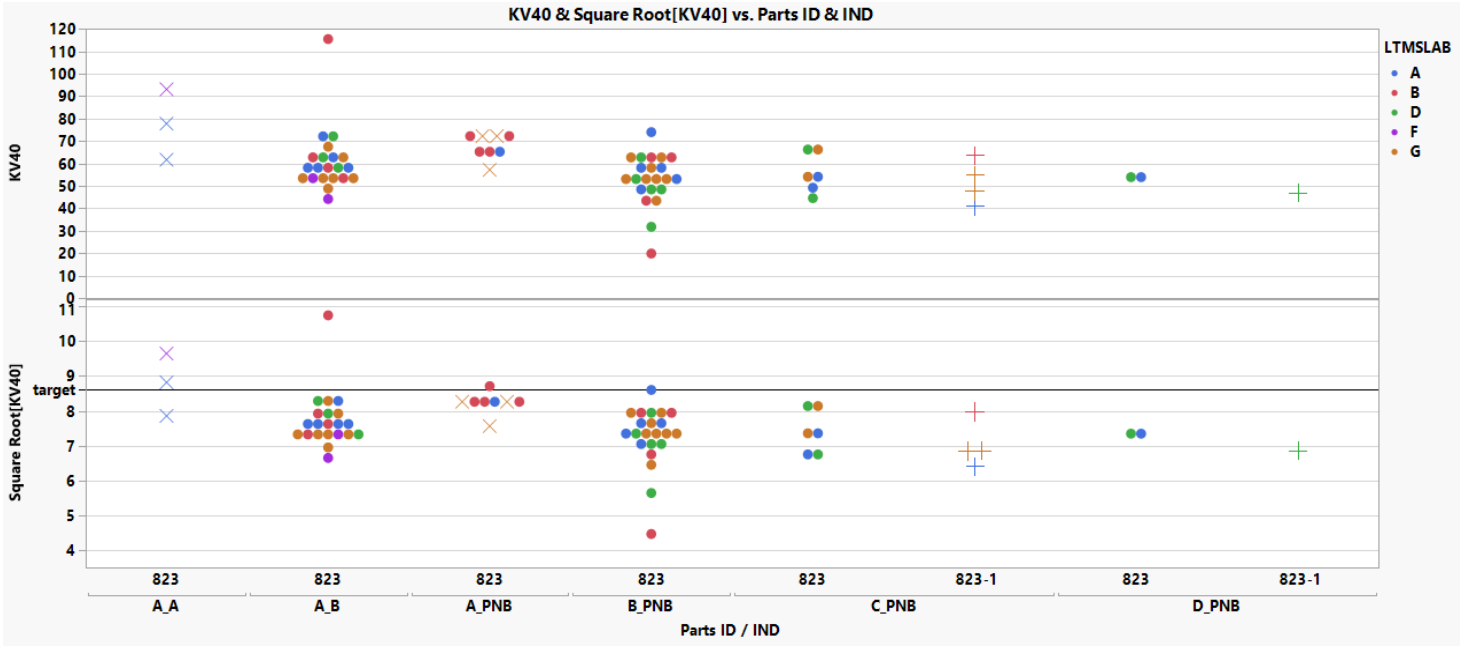
RO 823-1	Targets		ICF
	Mean	Standard Deviation (current)	
IRPH	109.3	11.1	None

KV40

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

- Some evidence that 823 target mean is off
- The difference between 823-1 C&D liners and 823/A liner is statistically 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





x - target set + 823-1

823-1 Targets and ICF (KV40)

These targets and ICF should be reviewed again and updated if needed when more data is available with n=10.

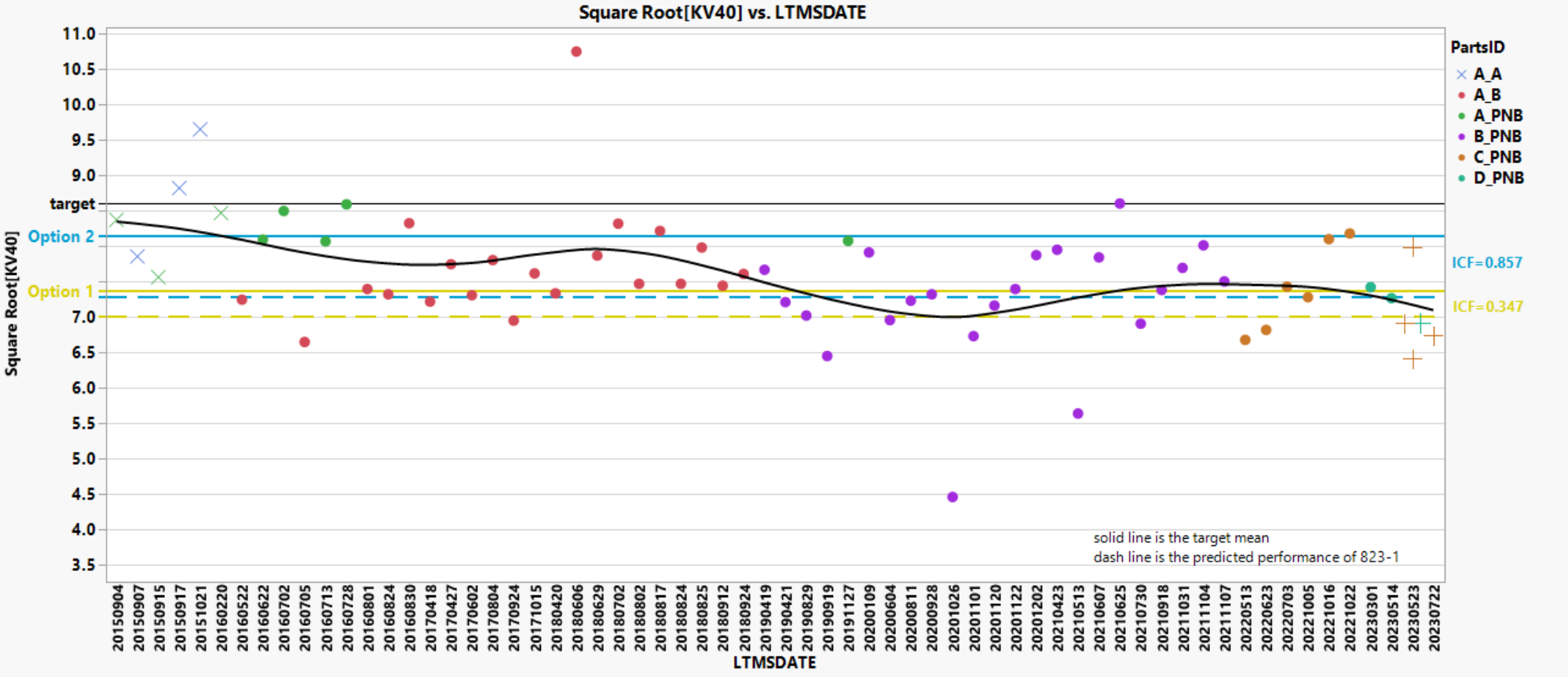
RO 823-1	Targets		ICF
	Mean	Standard Deviation (current)	
KV40 (sqrt)			
Option 1	7.357	0.929	0.347
Option 2	8.139	0.929	0.857

Option 1 is *assuming the new baseline severity is all runs on Liner Batch A*. For purposes of updating LTMS, ICF will be applied to liner batches C and D.

Option 2 is trying to adjust the test for past severity over multiple changes *assuming baseline severity of the current RO targets* in an attempt to avoid affecting future candidate performance. For purposes of updating LTMS, ICF will be applied from liner batch B forward.

823-1 Targets and ICF Options (KV40)

RO 823-1	Sqrt KV40 Targets		ICF	KV40	
	Mean	Standard Deviation		Mean	Mean-ICF
Current	8.610	0.929	None	74	74
Option 1	7.357	0.929	0.347	54	49
Option 2	8.139	0.929	0.857	66	53



appendix

statistical analyses

Volvo T-13 - IRPH Parameter

A proposal for 823-1 Target Update

August 2023

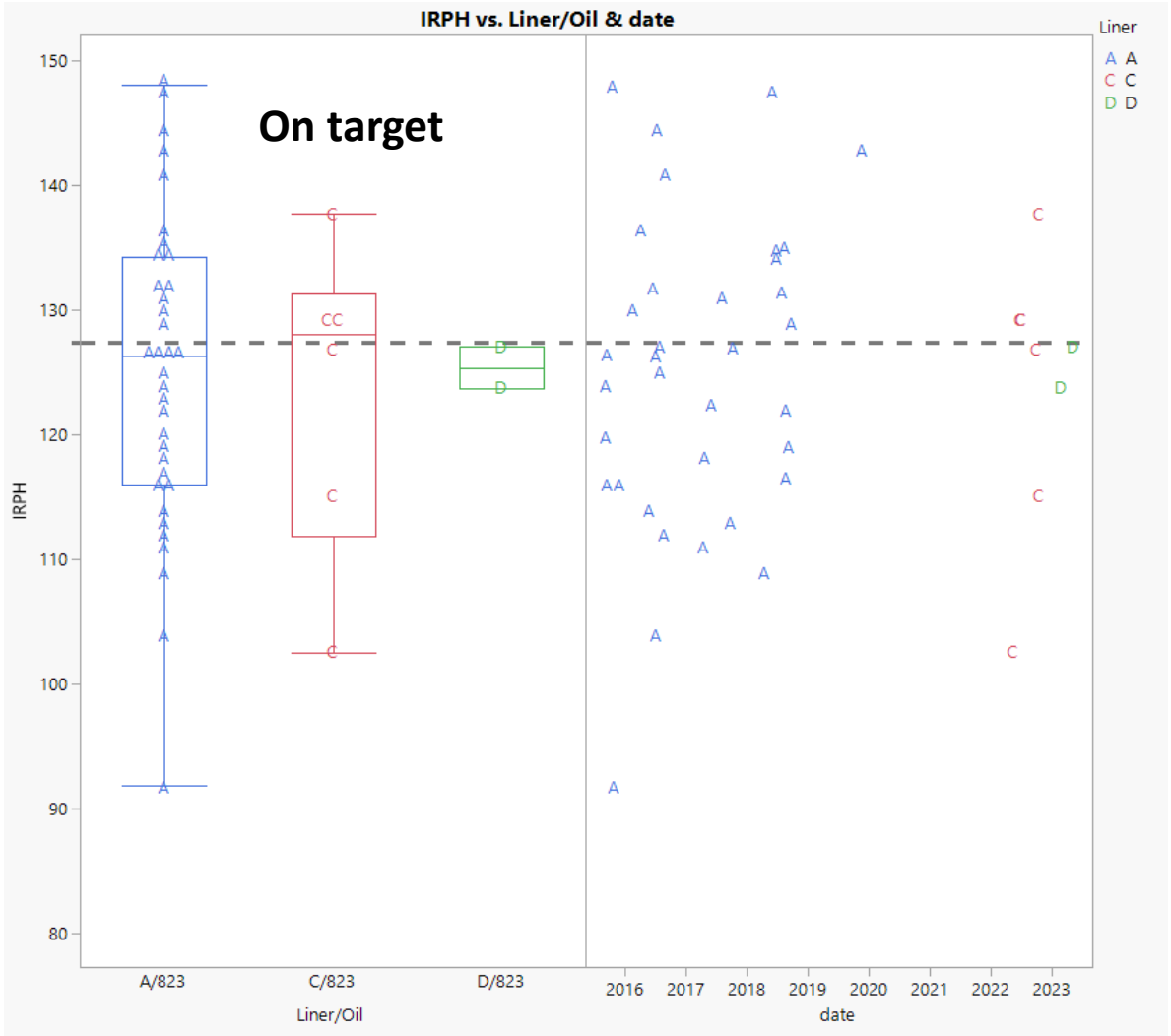
E. Santos & T. Dvorak

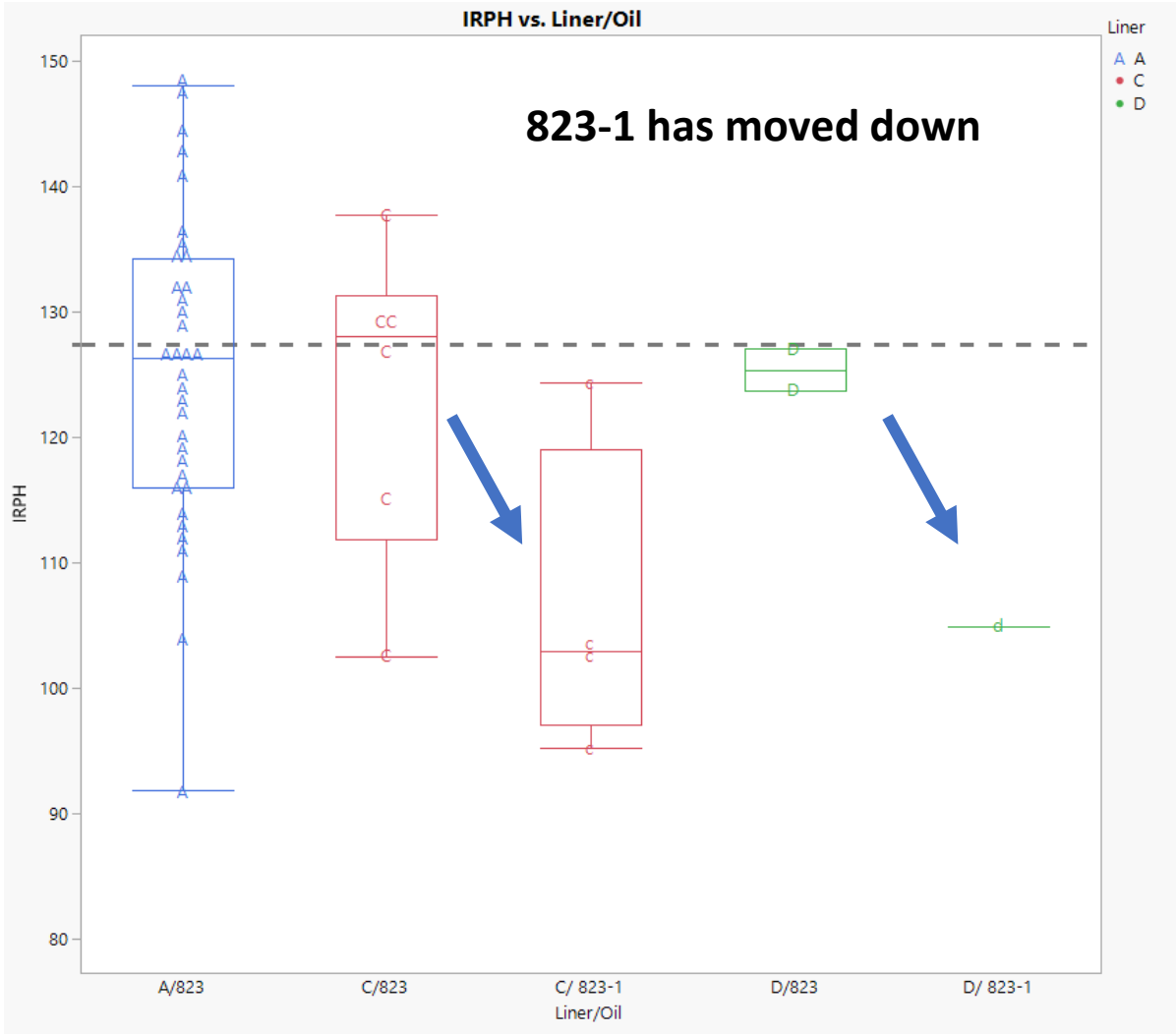
Proposal

- There is evidence that 823-1 is different from 823
- Update 823-1 target equal to 106
- No change for the standard deviation (11.1)
- Revise targets when there are ten 823-1 tests

Introducing current C & D liners: first, with oil **823**

Adding C & D liners: with oil **823-1**





No ICF required for liners C or D

There is evidence that 823-1 is lower than 823

Model details:

Model 1: Lab, Liner/Oil

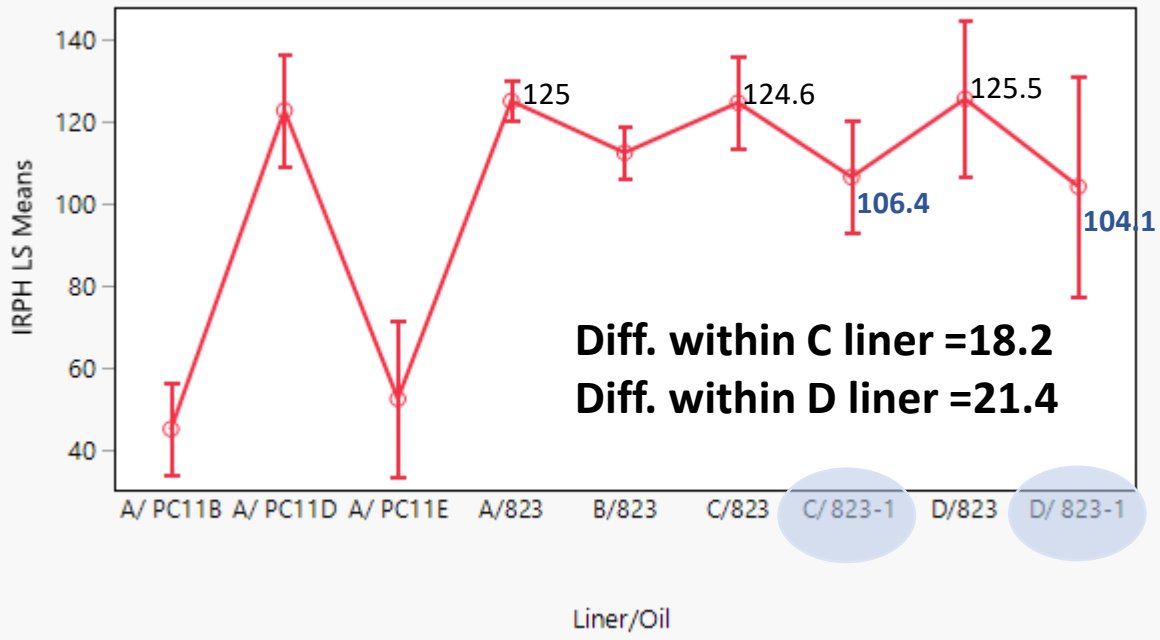
Summary of Fit

RSquare	0.777683
RSquare Adj	0.73902
Root Mean Square Error	13.05655
Mean of Response	112.7524
Observations (or Sum Wgts)	82

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	4	4	1180.314	1.7309	0.1531
Liner/Oil	8	8	40762.729	29.8893	<.0001*

Least Squares Means Plot: Liner/Oil



Least Squares Means Table: Liner/Oil

Level	Least Sq Mean	Std Error	Mean
A/ PC11B	44.88708	5.579025	46.533
A/ PC11D	122.69341	6.954473	121.000
A/ PC11E	52.26069	9.495980	54.300
A/823	125.01992	2.445977	125.089
B/823	112.41619	3.218195	112.473
C/823	124.62322	5.648080	123.400
C/ 823-1	106.44109	6.798652	106.350
D/823	125.54601	9.524158	125.350
D/ 823-1	104.12669	13.576045	104.900

Liner C/823-1 Predicted average from model (Lab, Liner/Oil) is equal to 106.44

Model 2: Lab, Liner/Oil, **Combining liners C & D**

Least Squares Means Table: Liner/Oil with C/D comb

Level	Least Sq Mean	Std Error	Mean
A/823	125.00021	2.4069034	125.089
A/ PC11B	44.87701	5.5008205	46.533
A/ PC11D	122.65784	6.8538000	121.000
A/ PC11E	52.22666	9.3577700	54.300
B/823	112.41895	3.1731831	112.473
C & D/823	124.88021	4.9285059	123.888
C & D/ 823-1	105.97685	5.9780244	106.060

Liner C&D /823-1 Predicted average value from model (Lab, Liner/Oil) is equal to 105.98

Test Detail

A/823	0
A/ PC11B	0
A/ PC11D	0
A/ PC11E	0
B/823	0
C & D/823	1
C & D/ 823-1	-1
Estimate	18.903
Std Error	7.4259
t Ratio	2.5456
Prob>|t|	0.0131
SS	1074
Lower 95%	4.0965
Upper 95%	33.71

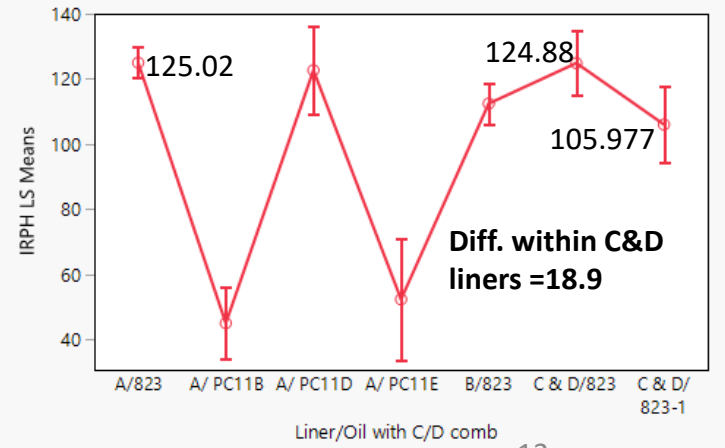
SS	NumDF	DenDF	F Ratio	Prob > F
1074	1	71	6.4801	0.0131*

Comparing 823 and 823-1 within C&D liners

C&D/823 (124.88) vs C&D/823-1 (105.977) = 18.903

statistically significant – p-value = 0.0131

Least Squares Means Plot: Liner/Oil with C/D comb



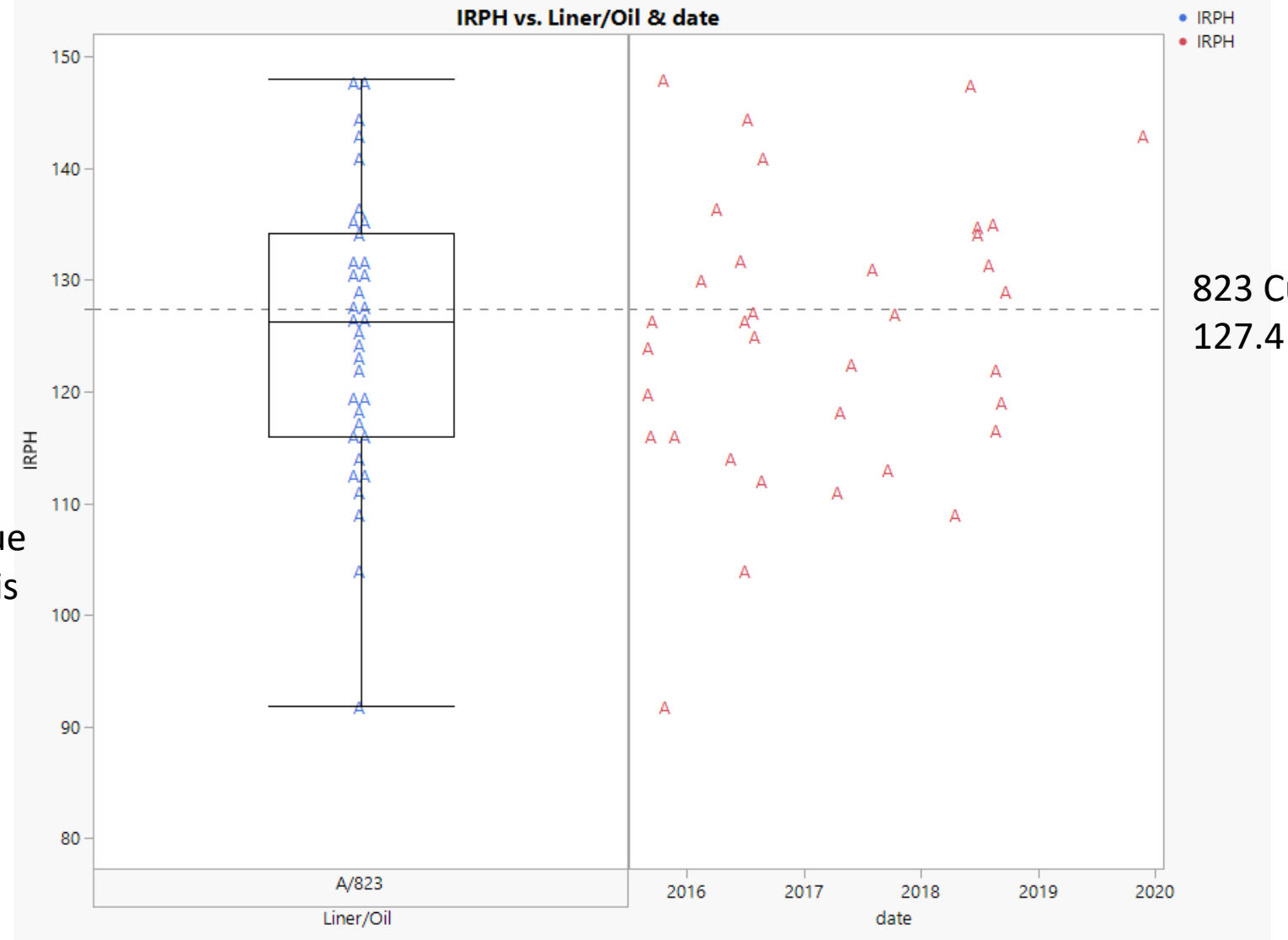
Data source - Appendix

- Currently, there are **82** T-13 engine tests after fuel flow was adopted. The whole data set was used in this analysis
  - ✓All but one test are Chart =yes, after T-13 target and standard deviation were updated (11/2015)
    - 111339-T13 validity = NG (donated test) Chart = N was included in the analysis because was part of target setting back in 2015
    - Lab F (three tests) is also included. These tests were part of the data set used to generate the updated target (11/2015)
    - I used liner A for 108334-T13 – this may change according Sean's feedback
    - Exclusions: VGRA tests are Chart = N. (8 tests – PC11 KK, PC11 LL, PC11 Y, PC11 G)

Appendix: Liner A (47 tests; 4 oils)

Simple average = 125.089

Liner A/ oil 823 Predicted average value from model (Lab, Oil) is equal to 125.620 – details are on the appendix



823 Current target: 127.4

Appendix: Liner A (47 tests - 35 tests for 823 and 12 tests other oils; 4 oils)

Summary of Fit

RSquare	0.89171
RSquare Adj	0.872273
Root Mean Square Error	11.22531
Mean of Response	111.7
Observations (or Sum Wgts)	47

Least Squares Means Table: LTMSLAB

Level	Least Sq Mean	Std Error	Mean
A	82.735893	3.6703890	110.653
B	97.193171	4.0111791	114.518
D	90.142498	6.2028529	108.675
F	82.593526	7.1754489	121.333
G	81.735852	3.7201615	109.407

Liner/Oil

Least Squares Means Table: Liner/Oil

Level	Least Sq Mean	Std Error	Mean
A/ PC11B	44.79077	4.8106474	46.533
A/ PC11D	125.39430	6.1614101	121.000
A/ PC11E	51.71568	8.2640464	54.300
A/823	125.62000	2.1867697	125.089

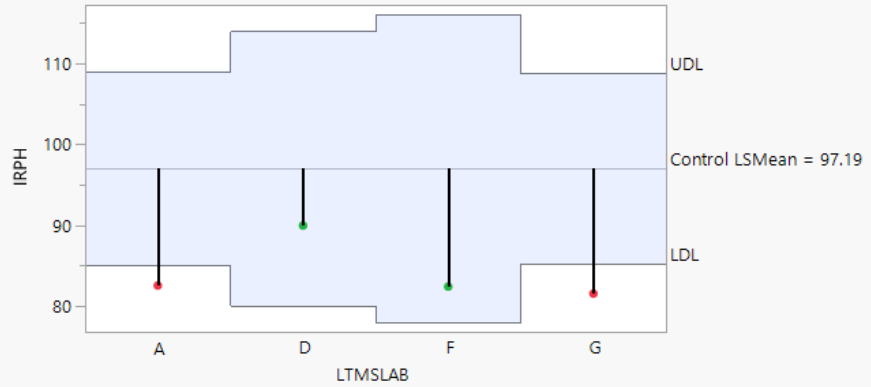
*Lab B is higher than Lab A and Lab G

LSMeans Differences Dunnett

α= 0.050 Q= 2.56876 Control= B Adjustment = Dunnett-Hsu

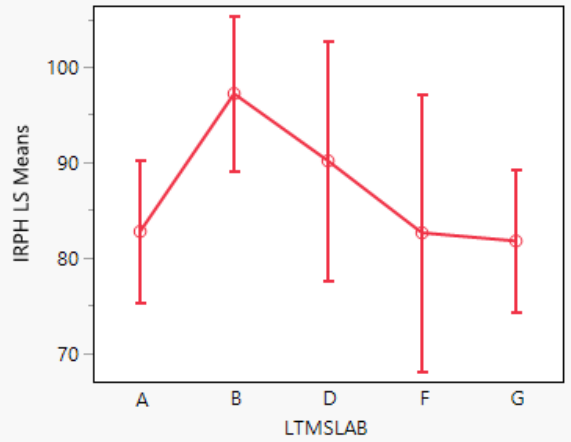
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
A	B	-14.4573	4.681016	-26.4817	-2.43287	0.0137*
D	B	-7.0507	6.603163	-24.0126	9.91127	0.6932
F	B	-14.5996	7.415704	-33.6488	4.44952	0.1811
G	B	-15.4573	4.576092	-27.2122	-3.70243	0.0063*

Control Differences Comparing the labs to lab B – the highest



α = 0.05 , Control = B

Least Squares Means PlotL LTMSLAB



823/liner A average and standard deviation

N Rows	Mean(Column 1)	Std Dev(Column 1)
35	125.08857142857	12.5580949152

* Similar conclusion for sqrt(KV40)

823-1

N Rows	Mean(IRPH)	Std Dev(IRPH)	Mean(sqrt(KV40))	Std Dev(sqrt(KV40))
5	106.06	10.8578542999...	6.9926	0.5936171325

Lab	sqrt(kv40)
D2	6.863
G1	6.964
A4	6.411
B3	7.987
G2	6.738
average	6.993

Volvo T-13 - KV40 Parameter

A proposal for 823-1 Target Update

August 2023

E. Santos & T. Dvorak

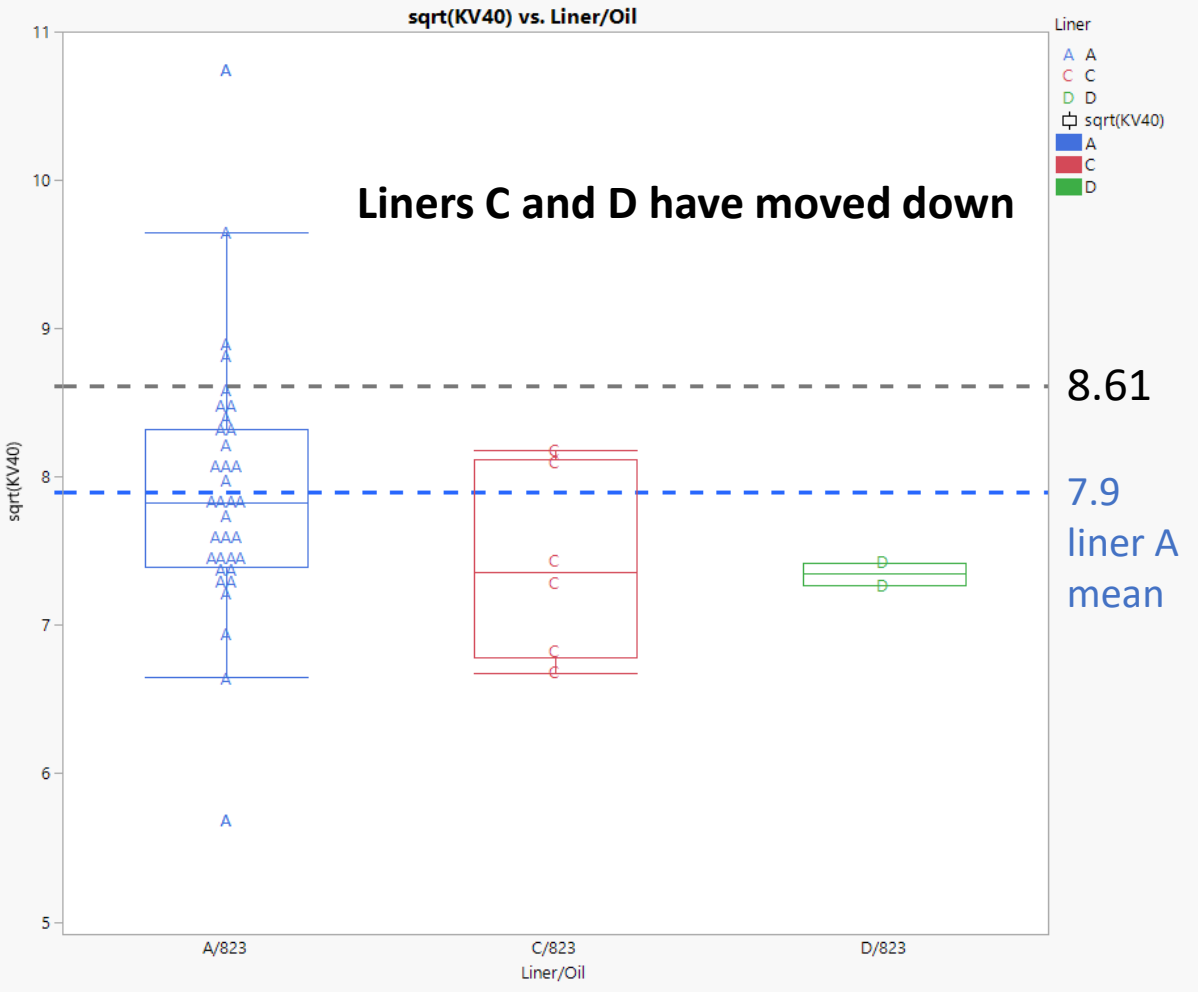
Option 1

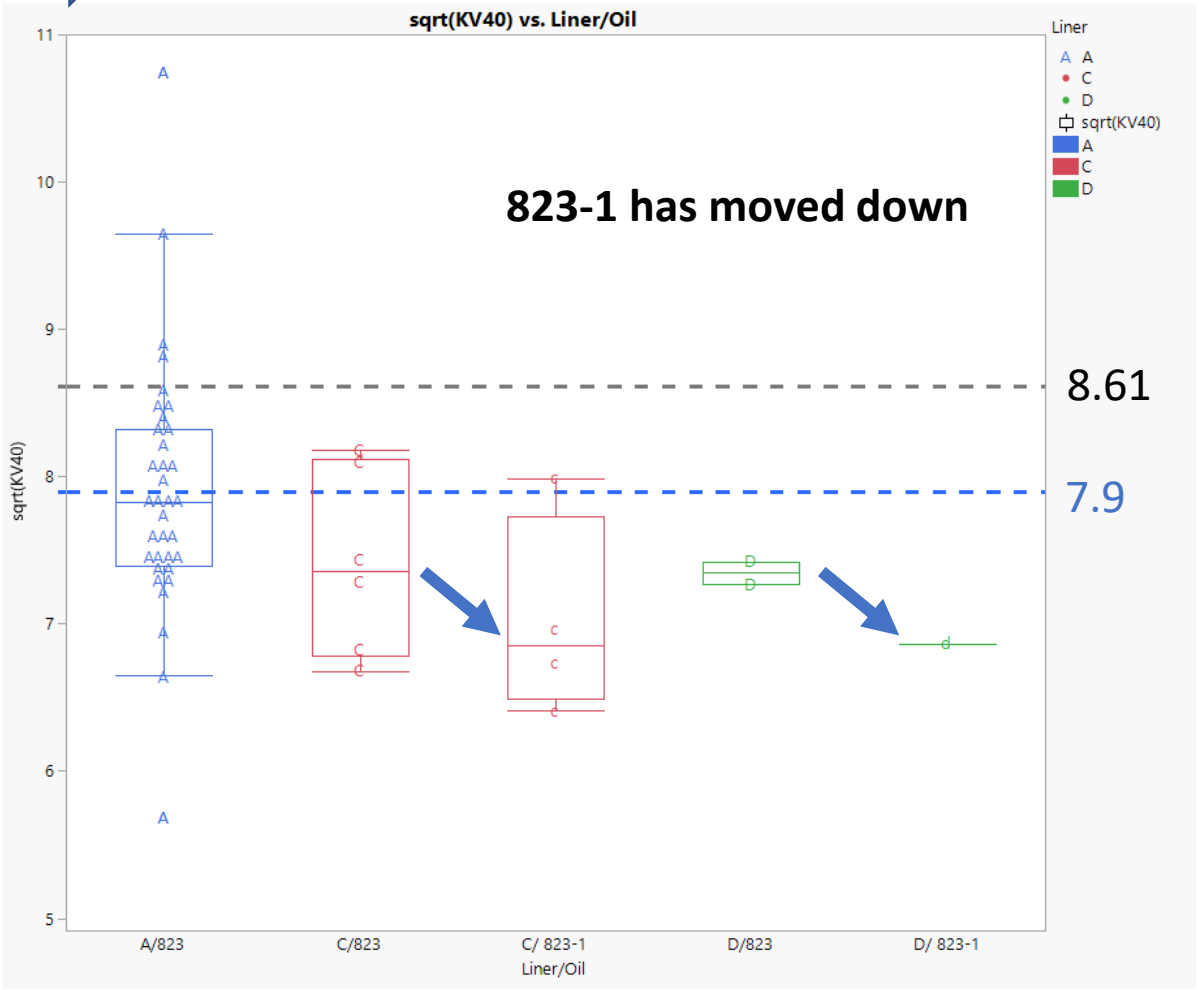
- 823-1 Target Update equal to 7.357
- ICF for C and D liners equal to 0.347
- No change for the standard deviation
- Update target when there are ten 823-1 tests

All the data after fuel flow control (N=82) – all available data (since 03/2015)

Introducing current C & D liners: first, with oil **823**

Adding oil **823-1… target seems to have changed**



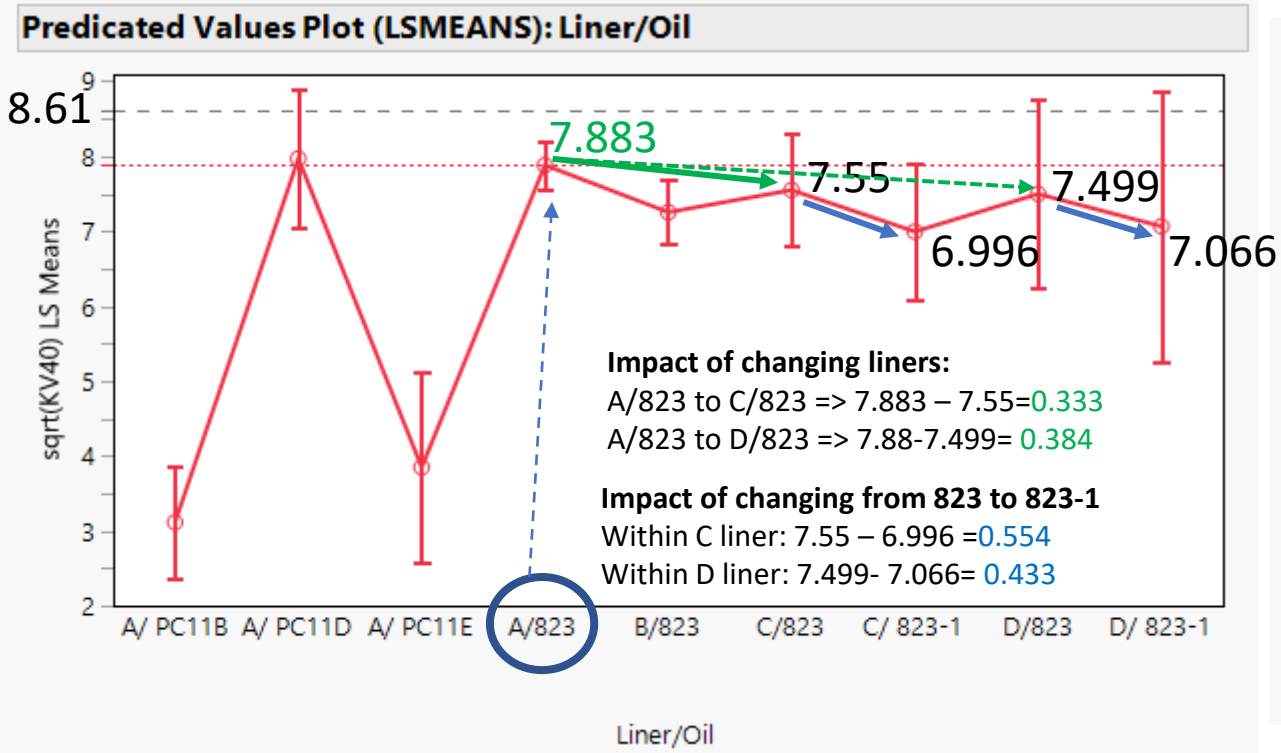


The impact of changing from A to C&D liners, within oil 823, is shown in the next slide

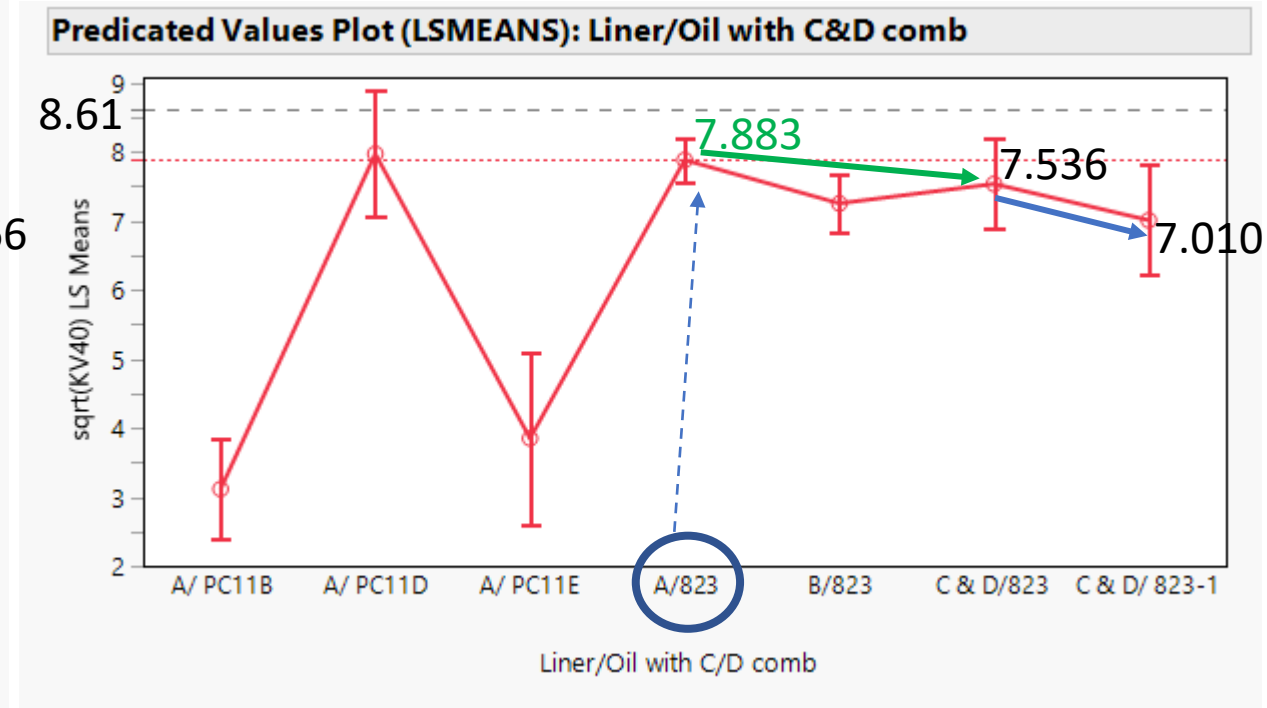
The impact of changing from 823 to 823-1, within C&D liners, is shown in the next slide

What are the sources of change seen in the data? How much is due to the oil re-blend?
How much is due to the liners?

C and D liners are separated



Combining C&D liners – *moving forward combining liners*



Impact of overestimated target, an example:
Compare **C/823** (7.55) to **current 823 target (8.61)**
=> 8.61 – 7.55 is **1.06** (but the data says that only **0.333** is due to parts). Note that the oil has not changed yet…

Impact of changing liners:
A to C&D/823 => 7.883 – 7.536 =0.347 → C&D liners ICF

Impact of changing from 823 to 823-1
Within C&D liner: 7.536 – 7.01 =0.526 → Target update

*The values added to the left side plot (from model 1/ table 1, slide 6) are estimated values from model 1 (Lab, Liner/Oil). It shows **C and D liners are separated**
-Option 1 combines liners C&D (model 2/table 2, slide 6), right side plot

All the data after fuel flow control (N=82) – all available data

Based on the **actual Liner A/823 severity => 7.883**	
Option 1	**823-1 Target Update equal to 7.357** **ICF for C&D liners equal to 0.347** **No change for std deviation** **Update target when there are ten 823-1 tests**

Liner change within 823		**Oil Change within liner**	
A to C	A to C&D	C	C&D combined
0.333	**ICF= 0.347**	0.554	**target update =0.526**
Predicted value for C&D/823-1			7.01
New Target for 823-1 (C&D liners)			7.883-0.526=**7.357** or 7.010+0.347=**7.357**

Based on **current target => 8.61**			
Liner change within 823		**Oil Change within liner**	
A to C	A to C&D	C	C&D combined
0.333	**0.347**	0.554	**0.526**
Current target:			8.61
New Target for 823-1			8.61-0.526 = **8.084**
Predicted value for C&D/823-1			7.01
Difference between New Target for 823-1 and predicted value for C&D/823-1 =**1.074**			8.084 - 7.01= 1.074 **but only 0.347 is due to parts change**
Bias: NOT due to C&D liner or re-blend changes			1.074-0.347=**0.727**

- The change in the T-13 reference oil provides an opportunity to discuss different views about updating targets, in the presence of large bias
- Change in parts are corrected by ICFs
- Change in reference oil re-blends are corrected by updating targets
- Where does the bias, in this case 0.727, belong to?
  - Option 1 proposes eliminating the bias

- The bias is equal to 0.727 (transformed scale)
- 8.61- 0.727 = **7.883 (62.1 original scale)** is the **actual Liner A/823 severity**
- **0.727 is equivalent to 12 (original scale) at 8.61 (74.1 original scale)**

Model details:

Model 1: Lab, Liner/Oil

C and D liners are separated

Summary of Fit

RSquare	0.728437
RSquare Adj	0.681208
Root Mean Square Error	0.871872
Mean of Response	7.171012
Observations (or Sum Wgts)	82

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	4	4	3.49287	1.1487	0.3411
Liner/Oil	8	8	138.36901	22.7532	<.0001*

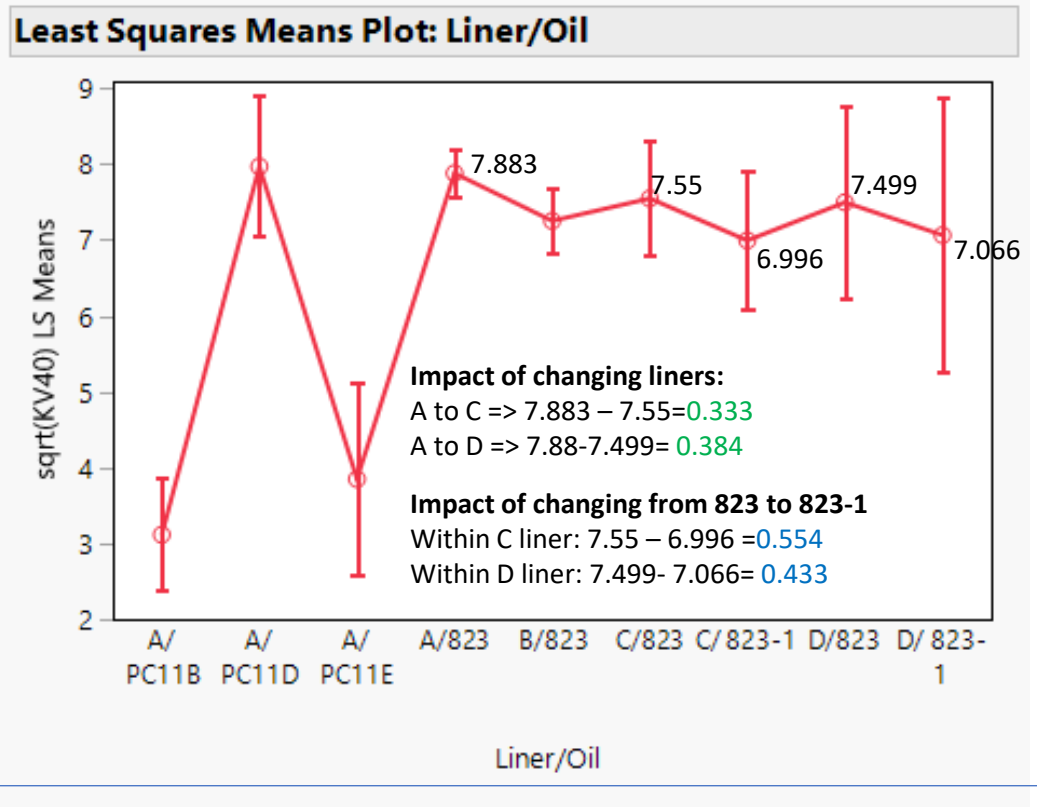


Table 1

Least Squares Means Table: Liner/Oil

Level	Least Sq Mean	Std Error	Mean
A/ PC11B	3.1158744	0.37254827	3.16933
A/ PC11D	7.9708078	0.46439602	7.86675
A/ PC11E	3.8497795	0.63410920	4.00950
A/823	7.8827426	0.16333398	7.89877
B/823	7.2539092	0.21490008	7.22395
C/823	7.5497835	0.37715955	7.41417
C/ 823-1	6.9960732	0.45399083	7.02500
D/823	7.4991825	0.63599078	7.34450
D/ 823-1	7.0661165	0.90656200	6.86300

Model 2: Lab, Liner/Oil,

Combining liners C & D

Comparing 823 and 823-1 within C&D liners

C&D/823 (7.536) vs C&D/823-1 (7.01) = **0.526**

Not statistically significant

Contrast

Test Detail	
A/823	0
A/ PC11B	0
A/ PC11D	0
A/ PC11E	0
B/823	0
C & D/823	1
C & D/ 823-1	-1
Estimate	0.5264
Std Error	0.4958
t Ratio	1.0617
Prob>|t|	0.292
SS	0.8329
Lower 95%	-0.462
Upper 95%	1.515

SS	NumDF	DenDF	F Ratio	Prob > F
0.833	1	71	1.1273	0.2920

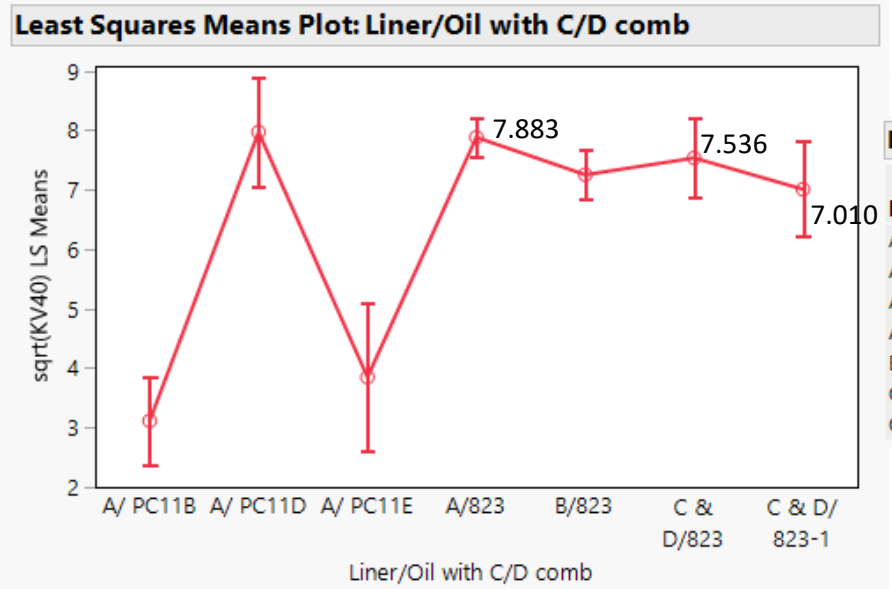


Table 2

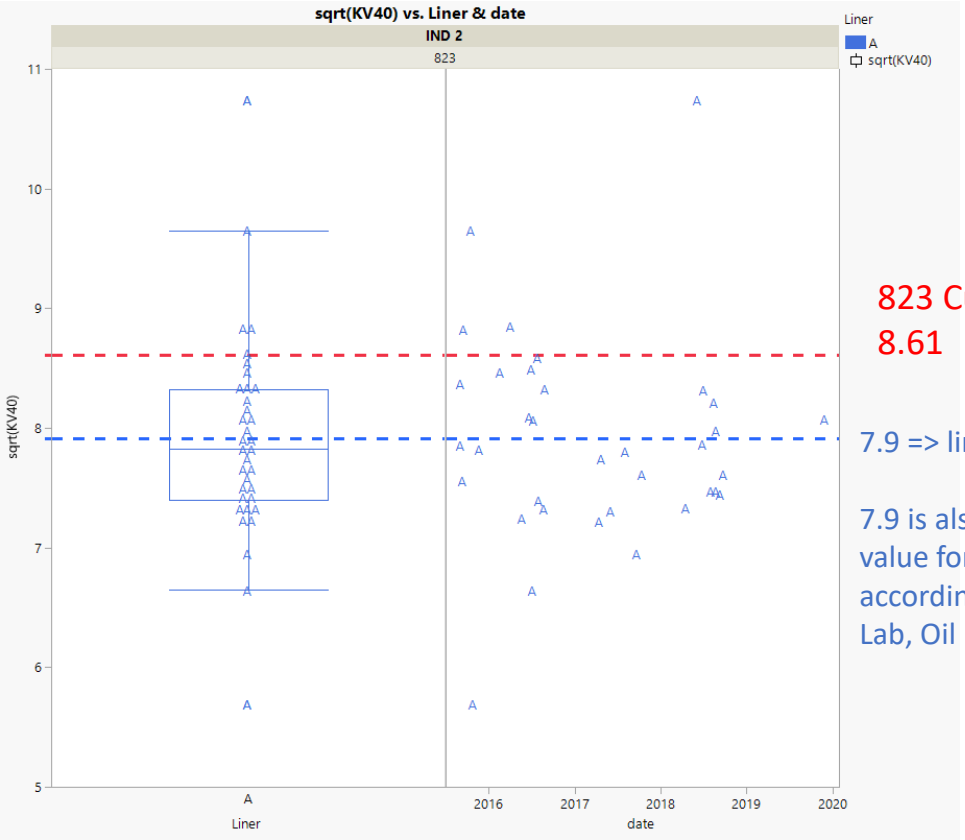
Least Squares Means Table: Liner/Oil with C/D comb

Level	Least Sq Mean	Std Error	Mean
A/823	7.8832603	0.16070020	7.89877
A/ PC11B	3.1162165	0.36726981	3.16933
A/ PC11D	7.9719217	0.45760334	7.86675
A/ PC11E	3.8505308	0.62478432	4.00950
B/823	7.2537802	0.21186191	7.22395
C & D/823	7.5364540	0.32905844	7.39675
C & D/ 823-1	7.0100410	0.39913098	6.99260

Appendix: Option 1

T-13 sqrt(kv40) has been off target from the beginning

1. Below is all batch A liner tests: Only 4 tests out of 35 are higher than the current 823 target (8.610)
2. The simple average of Liner A/823 is **7.899 ~7.9**
3. The predicted value for Liner A/823 from model (Lab, Liner/Oil) is **7.883 ~7.9**

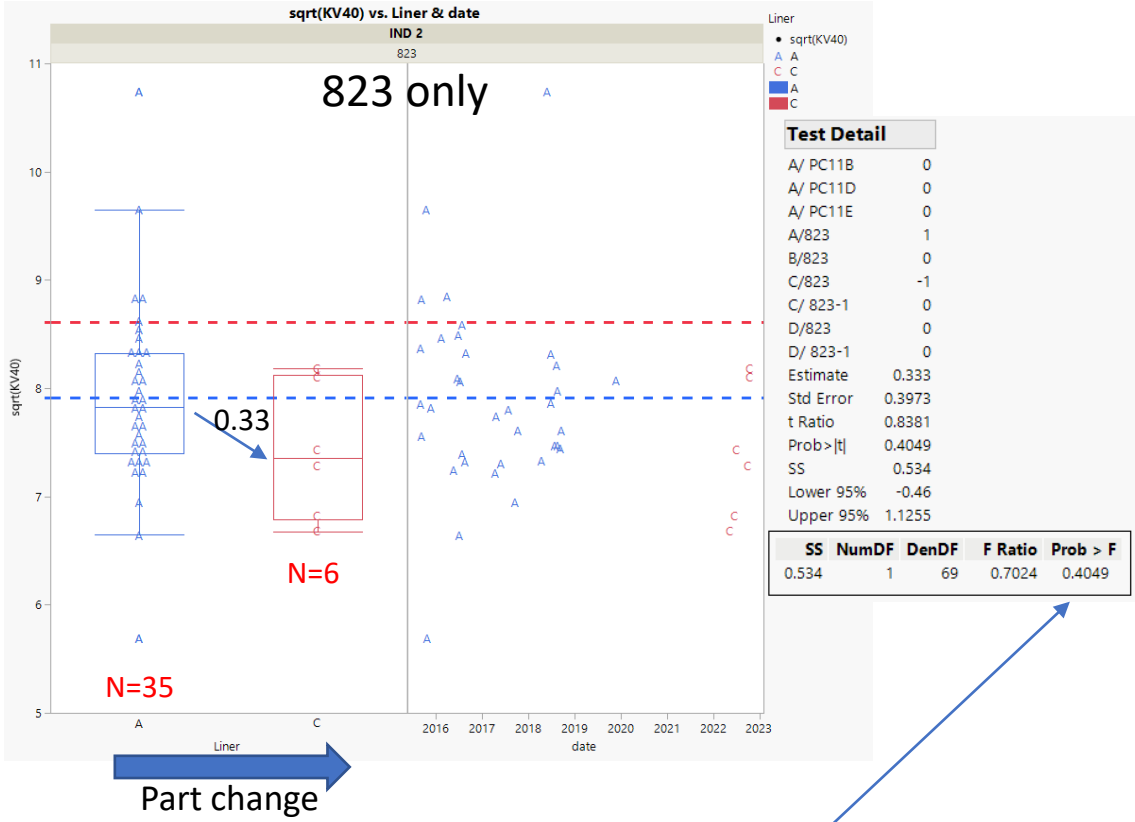


823 Current target 8.61

7.9 => liner A mean

7.9 is also the predicted value for 823/ Liner A according to the model Lab, Oil

4. Why bring up 823/ Liner A target?

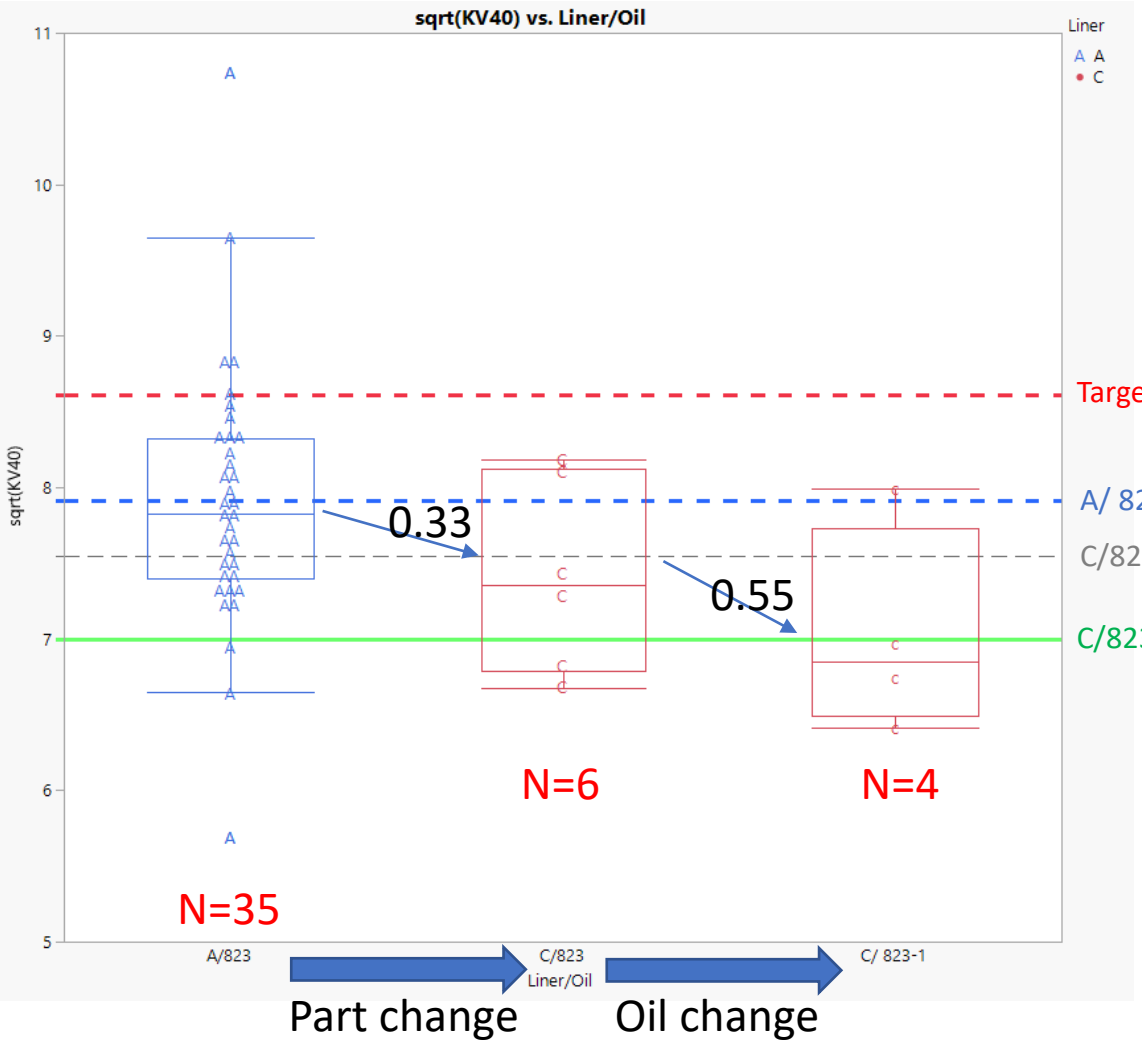


Part change

5. The difference due to change in liners: A/823 (7.883) and C/823 (7.55) is equal to 0.333 –The difference is not statistically significant - p-value =0.40

5. Comparing C/823 equal to 7.55 to current 823 target (8.61), the difference will be 1.06 (but the data says that only 0.333 is due to parts) and the oil has not changed…

6. How about 823-1? The predicted value for **Liner C/823-1** from model (Lab, Liner/Oil) is **6.996 ~7**



Parts change ONLY
A/823 (7.9) vs **C**/823 (7.55) = **0.333**
not statistically significant

Contrast

Test Detail	
A/ PC11B	0
A/ PC11D	0
A/ PC11E	0
A/823	1
B/823	0
C/823	-1
C/ 823-1	0
D/823	0
D/ 823-1	0
Estimate	0.333
Std Error	0.3973
t Ratio	0.8381
Prob>|t|	0.4049
SS	0.534
Lower 95%	-0.46
Upper 95%	1.1255

SS	NumDF	DenDF	F Ratio	Prob > F
0.534	1	69	0.7024	0.4049

Parts & oil change
A/823 (7.9) vs C/823-1 (6.996) = 0.8867

Contrast

Test Detail	
A/ PC11B	0
A/ PC11D	0
A/ PC11E	0
A/823	1
B/823	0
C/823	0
C/ 823-1	-1
D/823	0
D/ 823-1	0
Estimate	0.8867
Std Error	0.464
t Ratio	1.9109
Prob>|t|	0.0602
SS	2.7758
Lower 95%	-0.039
Upper 95%	1.8123

SS	NumDF	DenDF	F Ratio	Prob > F
2.776	1	69	3.6516	0.0602

Oil change
C/**823** (7.55) vs C/**823-1** (6.996) = 0.5537
not statistically significant

Contrast

Test Detail	
A/ PC11B	0
A/ PC11D	0
A/ PC11E	0
A/823	0
B/823	0
C/823	1
C/ 823-1	-1
D/823	0
D/ 823-1	0
Estimate	0.5537
Std Error	0.5737
t Ratio	0.9652
Prob>|t|	0.3378
SS	0.7081
Lower 95%	-0.591
Upper 95%	1.6982

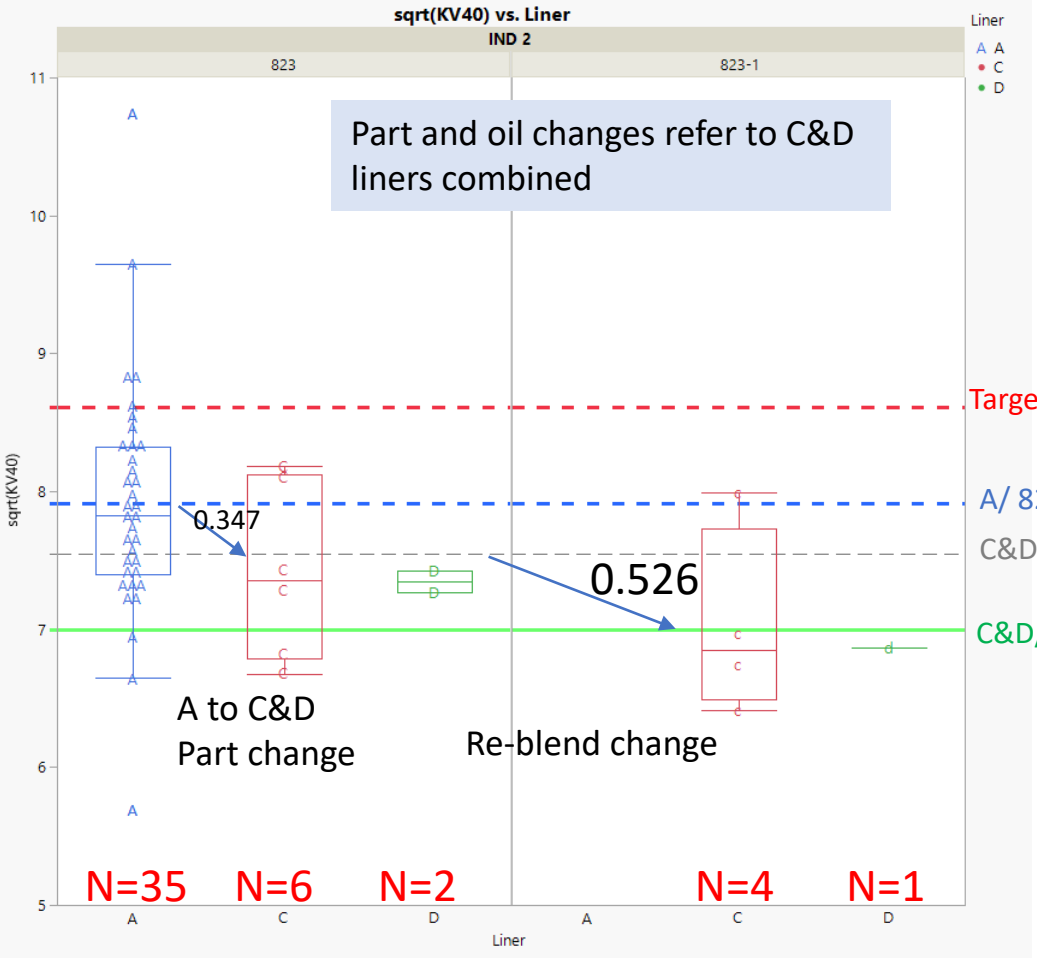
SS	NumDF	DenDF	F Ratio	Prob > F
0.708	1	69	0.9316	0.3378

Adding meaning to how large 0.55 is: The difference between Liner A (35 tests) and liner B (22 tests) which seems of practical and statistical significance is equal to 0.6288. (***p-value of 0.0125***) – not shown here.

The difference between C/823 (7.55) vs C/823-1 (6.996) is equal to 0.5537, away from 0.6288 by 0.0751.

The smaller sample size associated to liner C (6 tests for 823 and 4 for 823-1) causes power (probability of detecting a difference when there is one) to be low.

7. The plot below, **adds D liner** tests to the previous plot. The changes from previous slides are small.



Oil change combining C&D liners
C&D/823 (7.536) vs C&D/823-1 (7.01) = 0.526
not statistically significant

Summary of Fit

RSquare	0.728398
RSquare Adj	0.690144
Root Mean Square Error	0.859566
Mean of Response	7.171012
Observations (or Sum Wgts)	82

Contrast

Test Detail

A/823	0
A/ PC11B	0
A/ PC11D	0
A/ PC11E	0
B/823	0
C & D/823	1
C & D/ 823-1	-1
Estimate	0.5264
Std Error	0.4958
t Ratio	1.0617
Prob>|t|	0.292
SS	0.8329
Lower 95%	-0.462
Upper 95%	1.515

SS	NumDF	DenDF	F Ratio	Prob > F
0.833	1	71	1.1273	0.2920

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	4	4	3.51359	1.1889	0.3232
Liner/Oil with C/D comb	6	6	138.36145	31.2108	<.0001*

Least Squares Means Table: Liners C and D combined

Level	Least Sq Mean	Std Error	Mean
A/823	7.8832603	0.16070020	7.89877
A/ PC11B	3.1162165	0.36726981	3.16933
A/ PC11D	7.9719217	0.45760334	7.86675
A/ PC11E	3.8505308	0.62478432	4.00950
B/823	7.2537802	0.21186191	7.22395
C & D/823	7.5364540	0.32905844	7.39675
C & D/ 823-1	7.0100410	0.39913098	6.99260

8. When analyzing IRPH data, there is strong evidence that 823-1 has changed. For kv40 the evidence is weaker, but there is a clear trend.

9. **Option 1:** Update 823-1 target to 7.357 by adding the predicted value for C&D/823-1 (7.01) and the difference between A and C&D liners (0.347). Add an ICF for C and D liners equal to 0.347. Keep current standard deviation. Update target when there are ten 823-1 tests

Data source - Appendix

- Currently, there are 82 T-13 engine tests after fuel flow was adopted. The whole data set was used in this analysis (all available data since 03/2015)
  - ✓All but one test are Chart =yes, after T-13 target and standard deviation were updated (11/2015)
    - 111339-T13 validity = NG (donated test) Chart = N was included in the analysis because was part of target setting back in 2015
    - Lab F (three tests) is also included. These tests were part of the data set used to generate the updated target (11/2015)
    - I used liner A for 108334-T13 – this may change according Sean's feedback
    - Exclusions: VGRA tests are Chart = N. (8 tests – PC11 KK, PC11 LL, PC11 Y, PC11 G)

823-1

N Rows	Mean(IRPH)	Std Dev(IRPH)	Mean(sqrt(KV40))	Std Dev(sqrt(KV40))
5	106.06	10.8578542999...	6.9926	0.5936171325

Lab	sqrt(kv40)
D2	6.863
G1	6.964
A4	6.411
B3	7.987
G2	6.738
average	6.993

Model 2: Lab, Liner/Oil – additional comparison

Parts & oil change combined

A/823 (7.8832) vs C & D/ 823-1 (7.01) = 0.8732

Contrast: Test Detail

A/ PC11B	0
A/ PC11D	0
A/ PC11E	0
A/823	1
B/823	0
C & D/823	0
C & D/ 823-1	-1
Estimate	**0.8732**
Std Error	0.415
t Ratio	2.1044
Prob>|t|	0.0389
SS	3.272
Lower 95%	0.0458
Upper 95%	1.7006

SS	NumDF	DenDF	F Ratio	Prob > F
3.272	1	71	4.4284	0.0389*

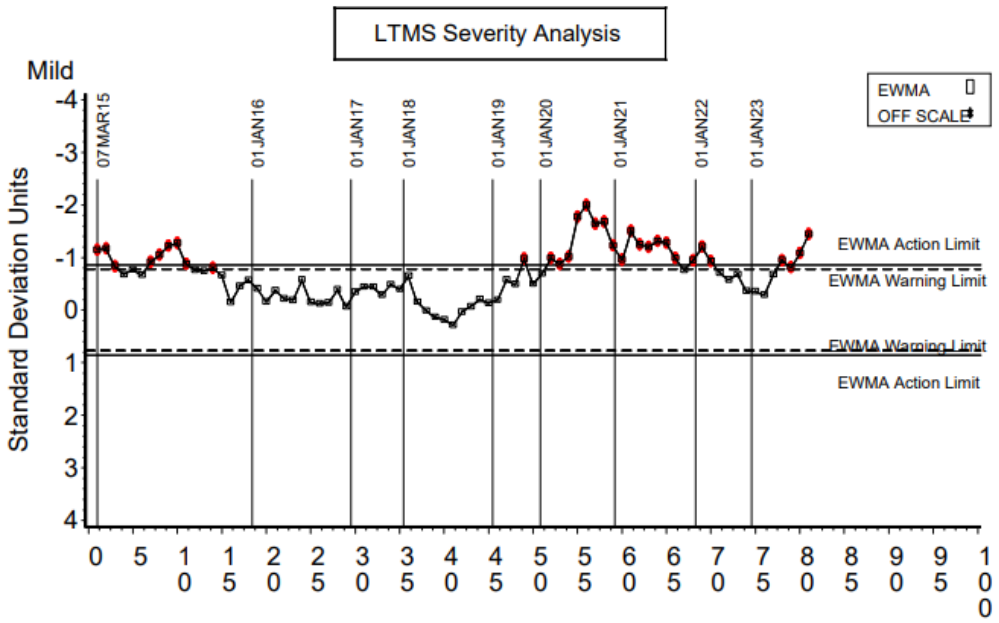
T-13 Severity Review by Travis Kostan

SOUTHWEST RESEARCH INSTITUTE®

Industry Control Charts

Both parameters are in an action alarm on the mild side.

Peak Height IR



KV40 % Increase

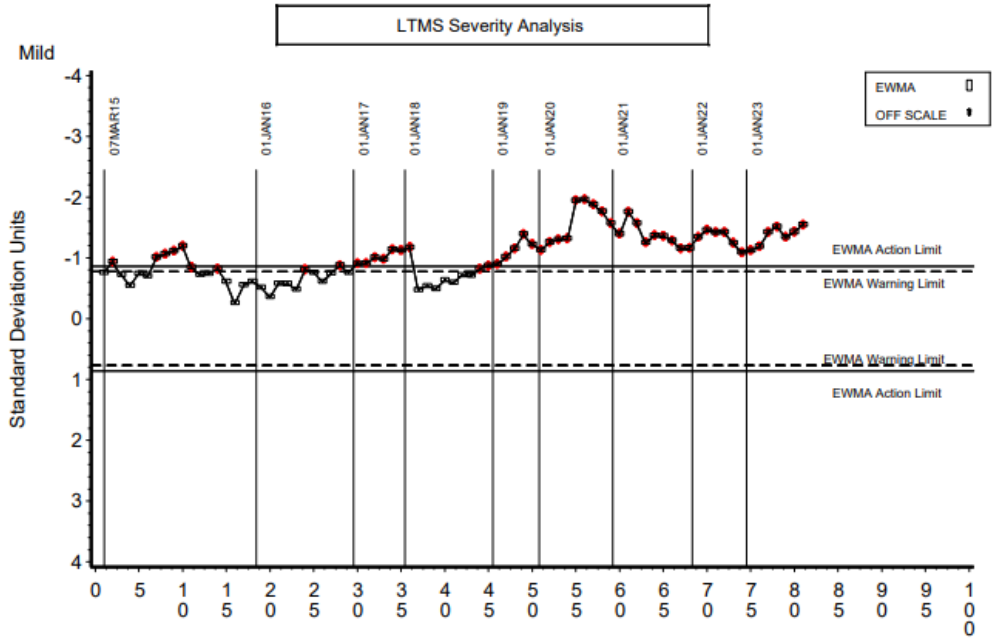


*Chart as of 08/02/2023

Early Target Change

Targets were changed for both parameters six months into the test life after evaluating new data on fuel flow control tests in November 2015, and have been in place since (approximately 8 years).

T-13 Reference Oil Targets							
		Effective Dates		IR Oxidation Peak Height absorbance / cm		% Increase in Viscosity at 40°C from 300 to 360 hour[2]	
Oil	n	From[1]	To[2]	$\bar{X}$	s	$\bar{X}$	s
PC11A	6	10-01-2014	11-24-2015	142.7	12.4	9.303	1.212
PC11A	6	11-25-2015	***	127.4	11.1	8.610	0.929
PC11B	3	10-01-2014	***	59.7	12.4	4.690	1.212
PC11C	4	10-01-2014	***	121.1	12.4	8.146	1.212
PC11D	7	10-01-2014	***	133.5	12.4	8.676	1.212
PC11E	7	10-01-2014	***	59.2	12.4	4.606	1.212
PC11F	4	10-01-2014	***	123.6	12.4	9.044	1.212
823(PC11A)	-	05-01-2015	11-24-2015	142.7	12.4	9.303	1.212
823(PC11A)	-	11-25-2015	***	127.4	11.1	8.610	0.929

1 Effective for all tests completed on or after this date.
2 *** = currently in effect
3 SQRT Transformation adopted 20151019

General Statement

Changing reference oil targets for any reason that is not **unique to the reference oil alone** (typically reference oil re-blend) will change candidate pass/fail probability. Therefore, to change targets for 823 by any amount or for 823-1 by an amount other than the difference between an 823 and an 823-1 test **run today on the same hardware** will treat candidates differently moving forward than they have been treated for the past 8 years.

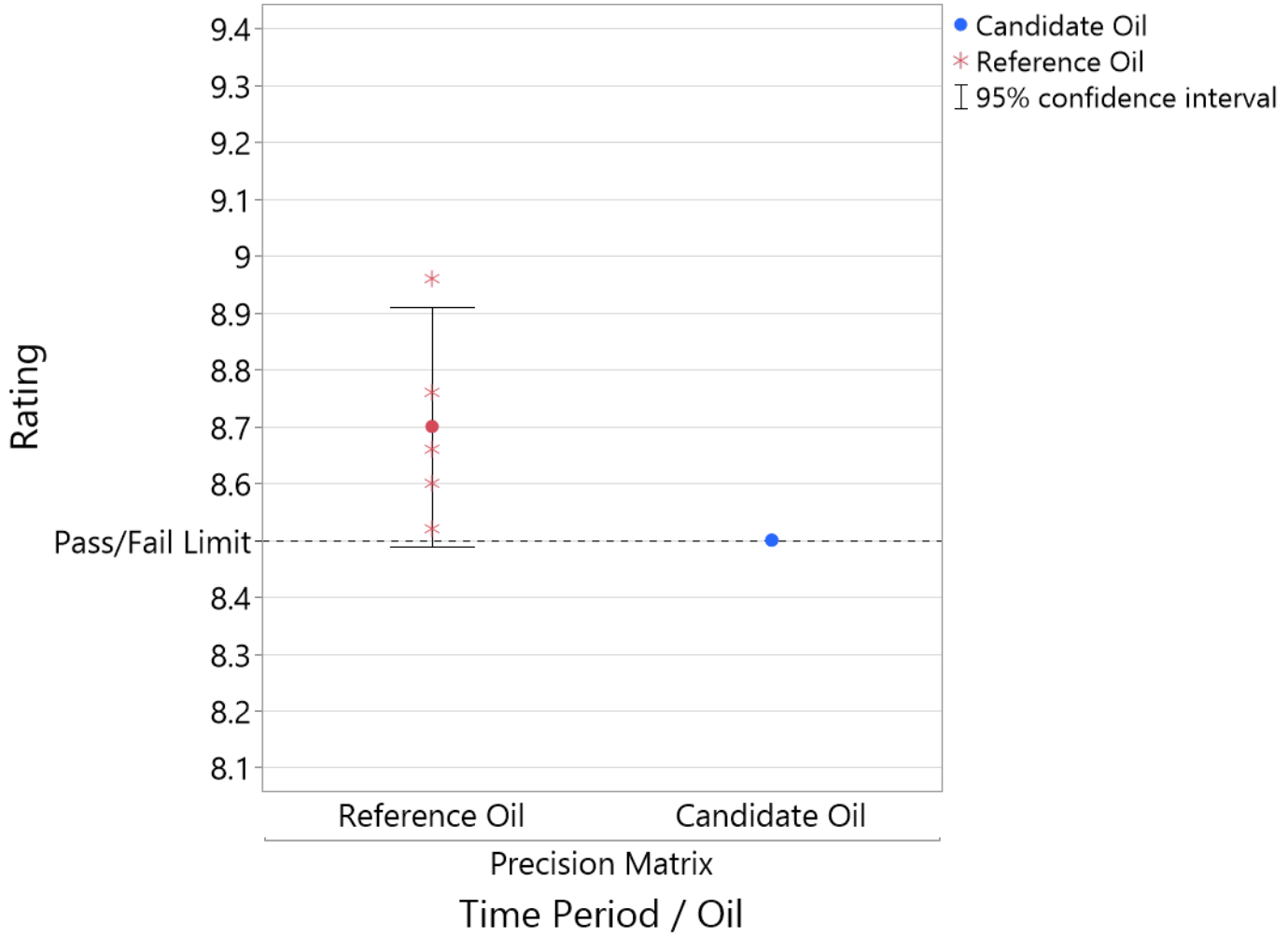
In the following slides we explore 3 cases of issues which may affect severity:

- Incorrect precision matrix targets.
- A change to the test procedure of critical hardware component.
- A reference oil re-blend.

A Hypothetical Case…

Consider a test with the following characteristics:

- A critical rating parameter with a pass/fail limit of 8.5 merits.
- There is some candidate oil right at the pass/fail limit (50% probability of pass).
- We observed reference oil data during the precision matrix near the pass/fail limit which gets an LTMS target mean of 8.7.

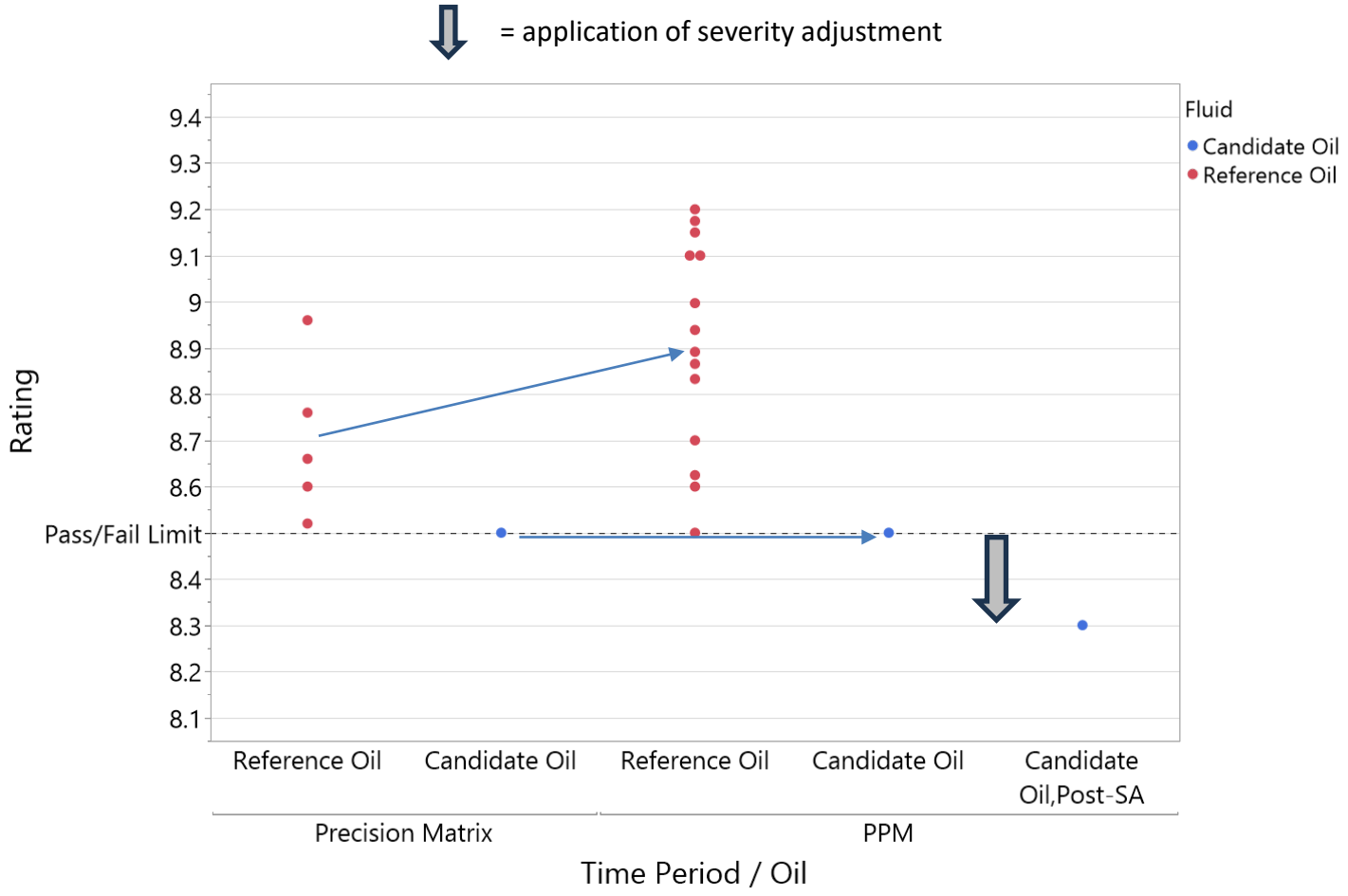


Case 1: Impact of Incorrect PM Target Setting

There is often error in estimation in PM targets due to small sample sizes. What if the true mean of the reference oil was in fact 8.9 and not 8.7?

- Average severity adjustment will be -0.2 merits.
- Assuming nothing about the test has changed and the error was only due to estimation error caused by limited data on the reference oil, the candidate oil would still have the same performance level.
- This means all candidates will now on average be adjusted downward incorrectly by 0.2 merits, making it harder to pass the test. The reverse is also true. If the true mean is on the severe side of the PM target, candidates would more easily pass the test.

This highlights the importance of revisiting the PM target early on. A MAJOR assumption is that nothing about the test severity has changed, and that the difference in reference oil performance is due to estimation error only.



PPM = Post Precision Matrix

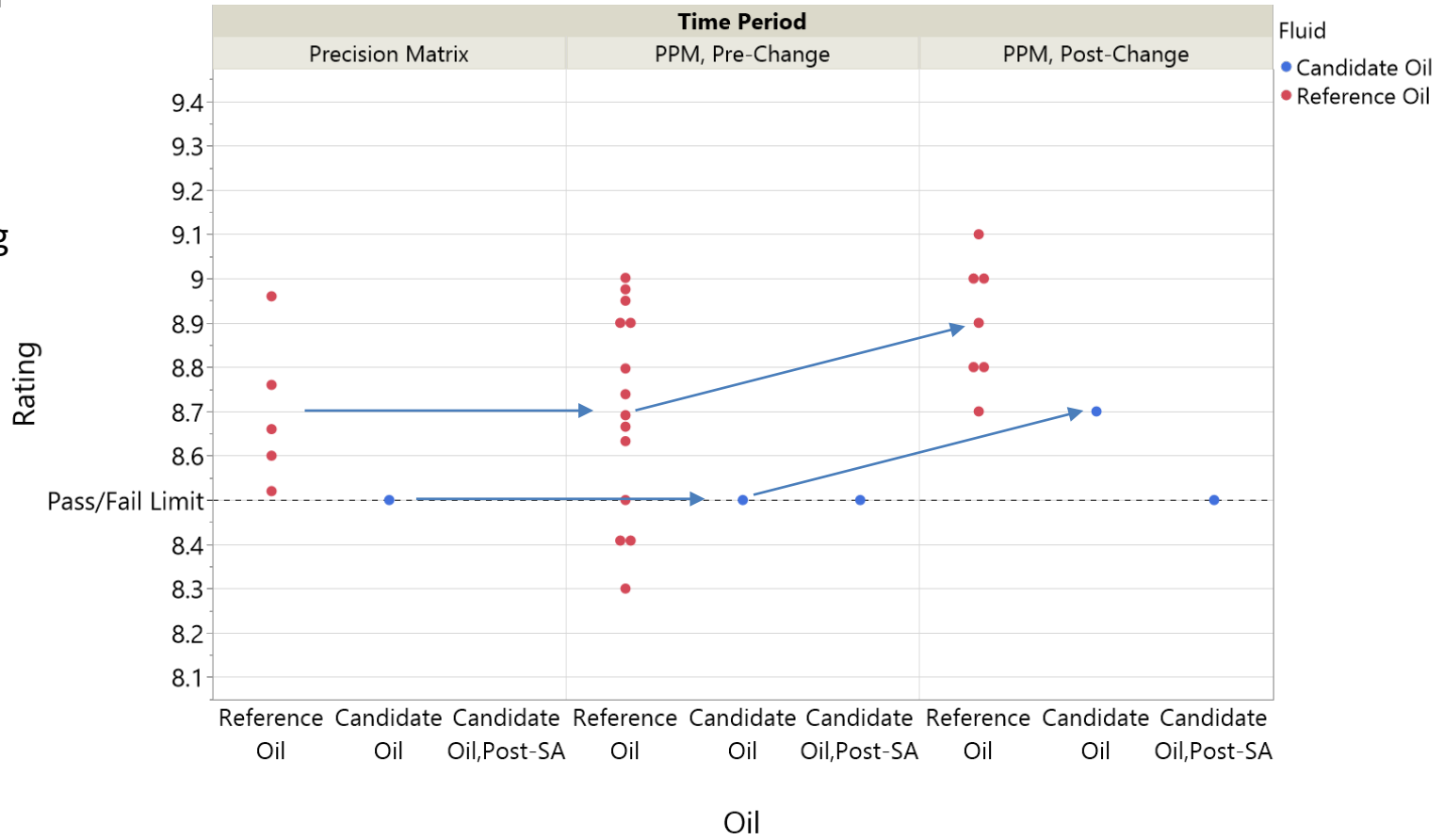
Case 2: A Change to the Test Procedure or Critical Hardware

If there is a change to the test procedure or critical hardware component that causes the reference oil performance to change, we expect candidate performance to change by the same amount.

Below are 3 options one might consider for dealing with this situation.

1. Do nothing and let it be handled with severity adjustments.
2. Apply an industry correction factor to reference oil results and candidate results.
3. Update the reference oil targets to match the new performance of the reference oil.

Only the following slides we explore the impact of making each of these choices.

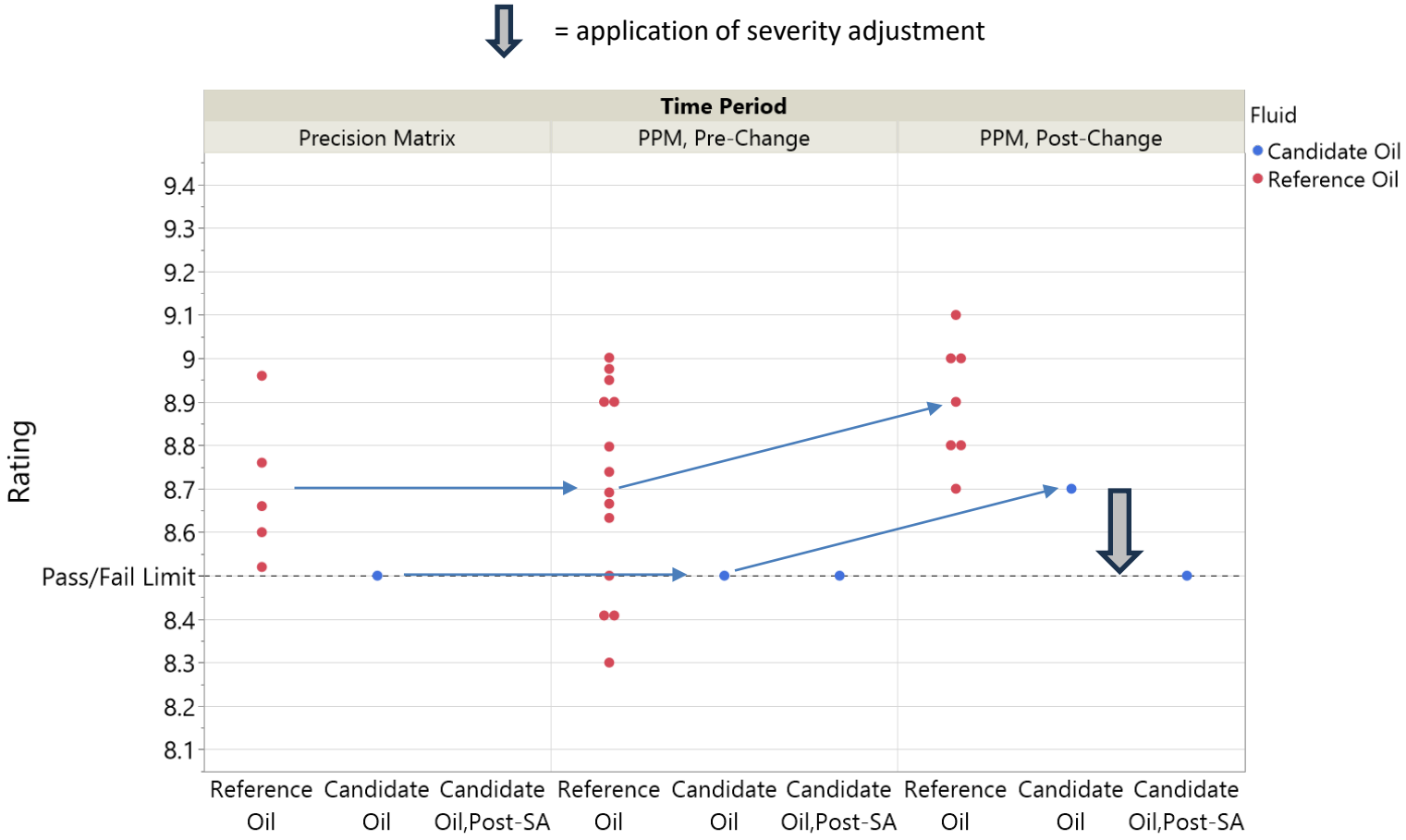


Case 2: A Change to the Test Procedure or Critical Hardware

Solution #1: Do nothing and let it be handled with severity adjustments.

- Eventually keeps the test in parity for candidates but may take a long time for severity adjustments to catch up (see below).
- May cause labs to struggle with calibration if the shift is too far away from the original targets.

Time Period	Yi Result	Lab Zi
Pre-Change	0	0.00
Post-Change	1	0.30
Post-Change	1	0.51
Post-Change	1	0.66
Post-Change	1	0.76
Post-Change	1	0.83
Post-Change	1	0.88



Severity Adjustment Standard Deviations

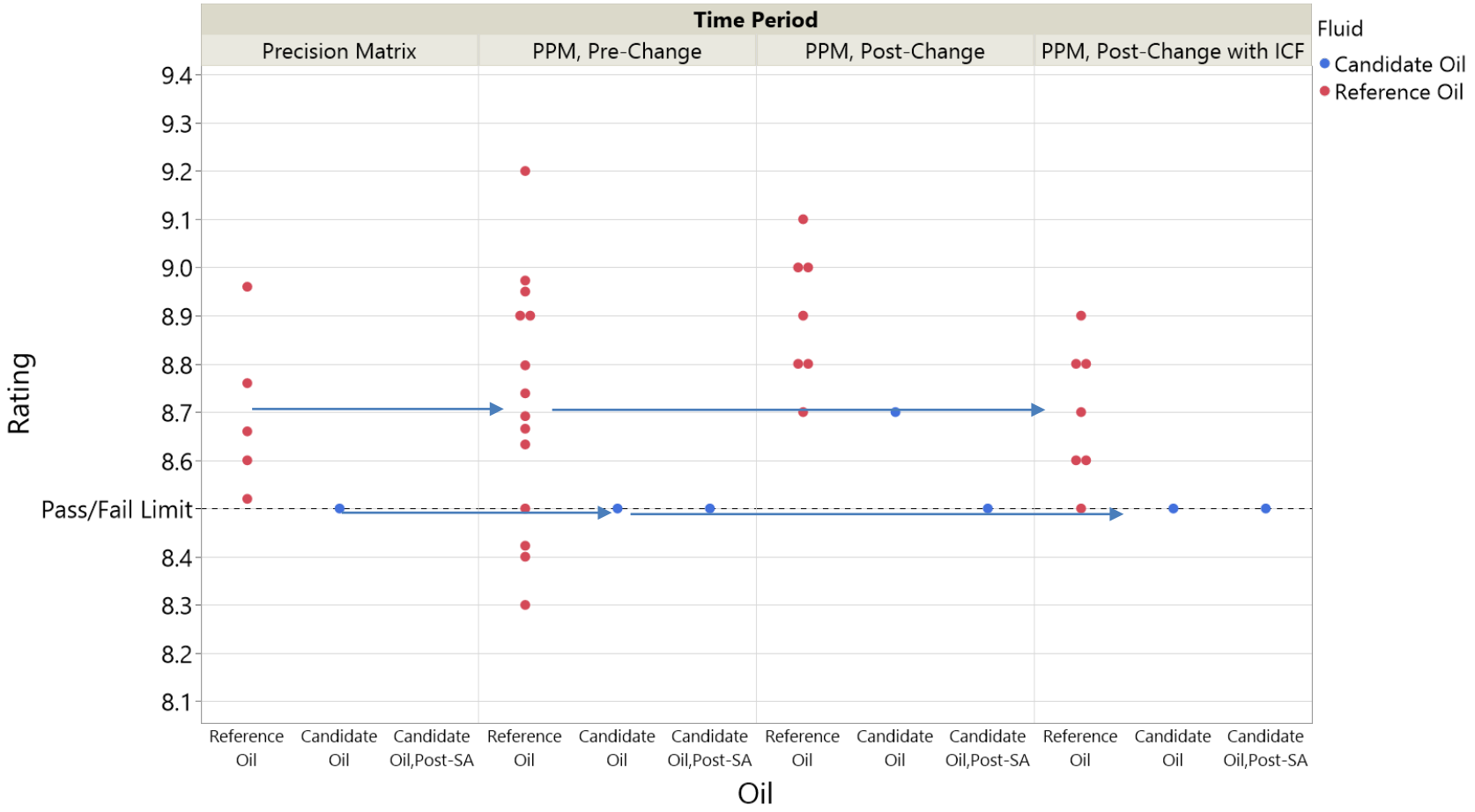
T-13 FTIR Peak Height Oxidation: $SA = (-Z_i) \times (11.1)$

Percent Increase in Viscosity at 40°C from 300 to 360 hour: $SA = (-Z_i) \times (0.929)$

Case 2: A Change to the Test Procedure or Critical Hardware

Solution #2: Apply an Industry Correction Factor (ICF).

- Keeps the test in parity for candidates immediately without a time lag.
- Helps return labs to proper calibration success probability.
- Should be monitored to ensure reference oil is still in a range to appropriate represent candidate performance.



Case 2: A Change to the Test Procedure or Critical Hardware

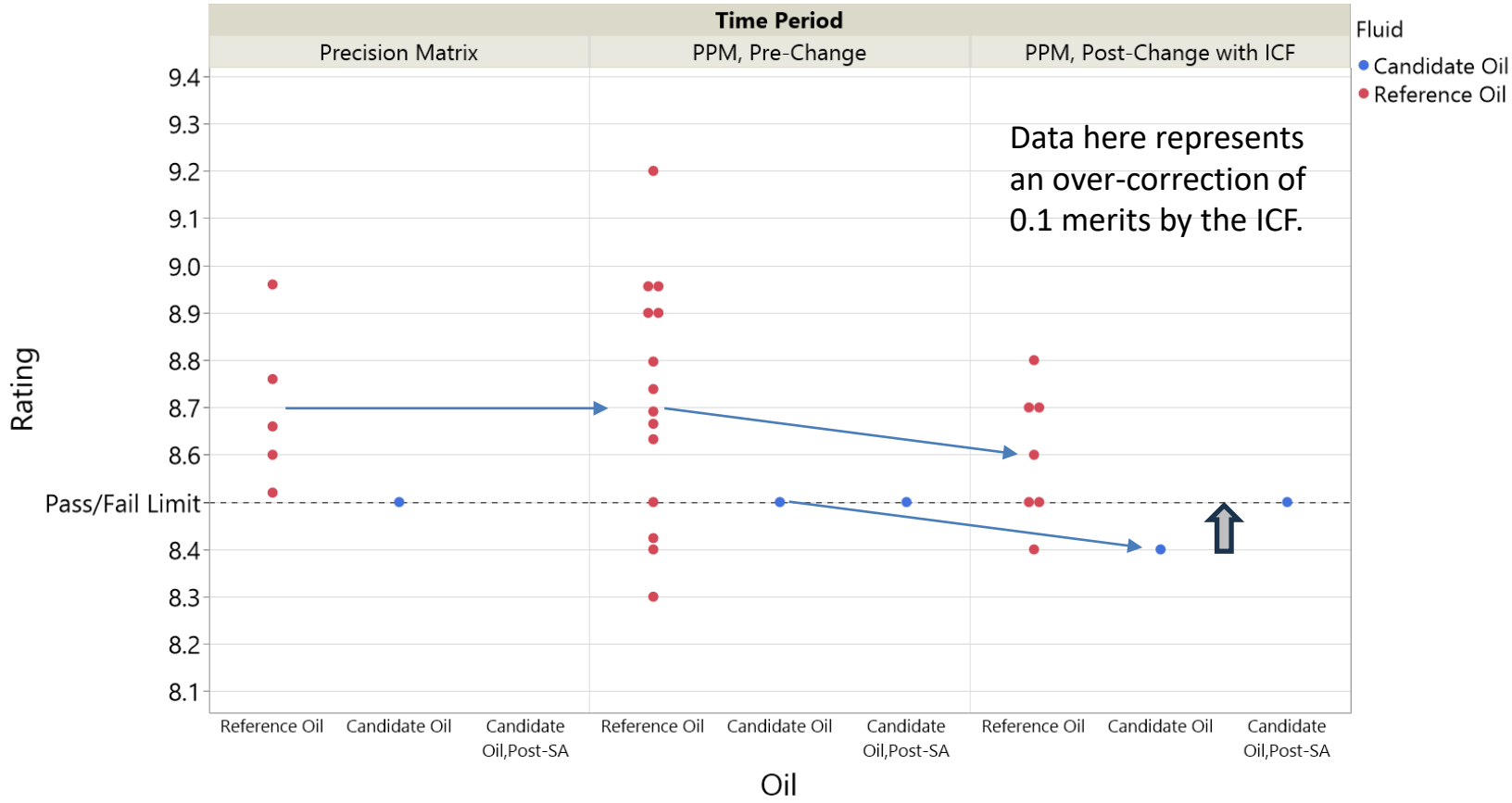
Solution #2: Apply an Industry Correction Factor (ICF).

Question: What if we don't have enough data and our calculated ICF is slightly off, or we associated it with the wrong test factor?

Answer: Almost no practical impact!

- Small miscalculations will cause minor changes in lab calibration pass/fail probabilities.
- Since ICFs are applied to references and candidates, the error will be seen in both, so severity adjustments will make up the difference. Larger errors would have some lag time, but as long as estimation with ICF is better than doing nothing, this method will be better than SA's alone.

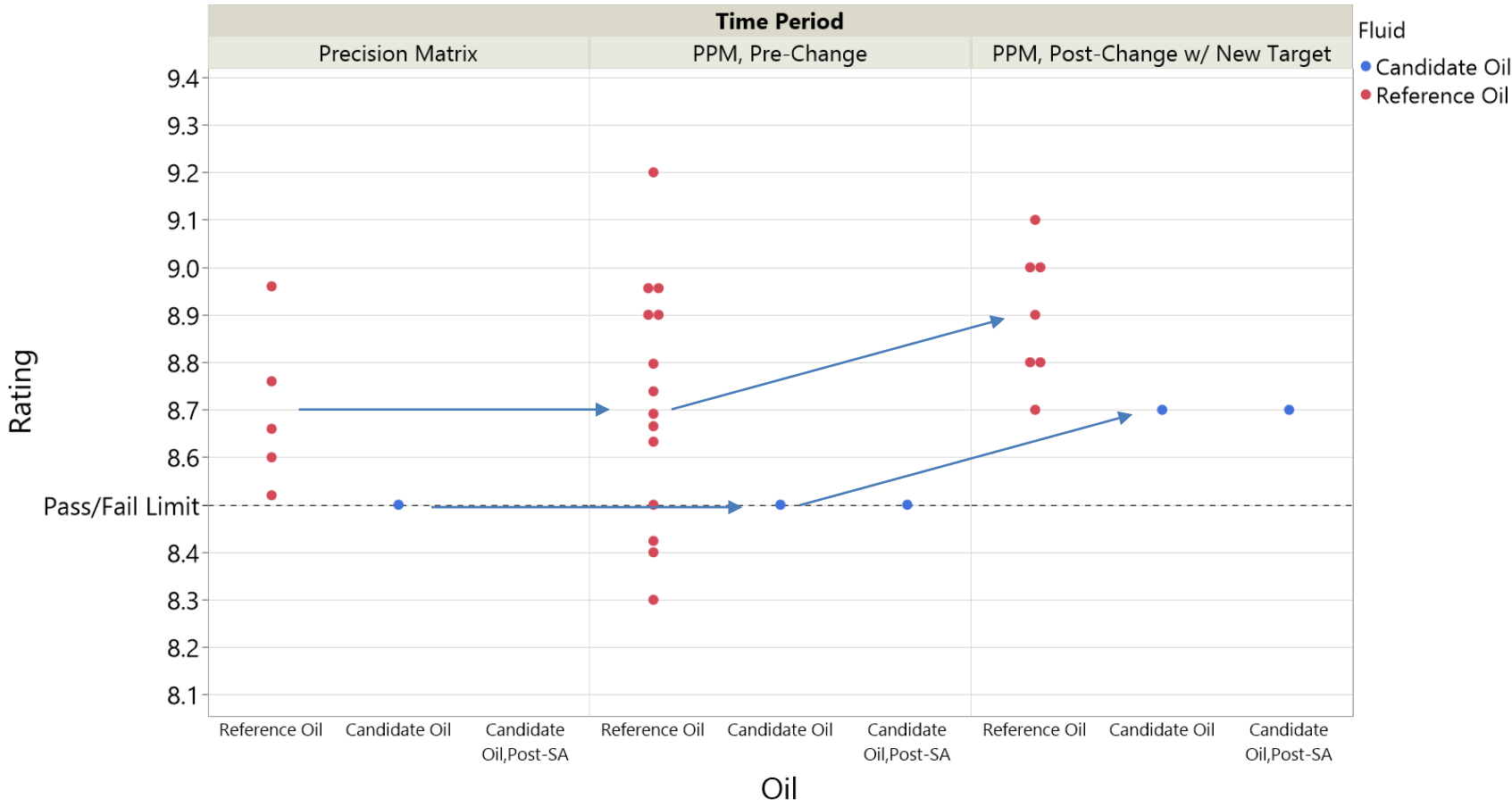
⇧ = application of severity adjustment



Case 2: A Change to the Test Procedure or Critical Hardware

Solution #3: Update the reference oil targets.

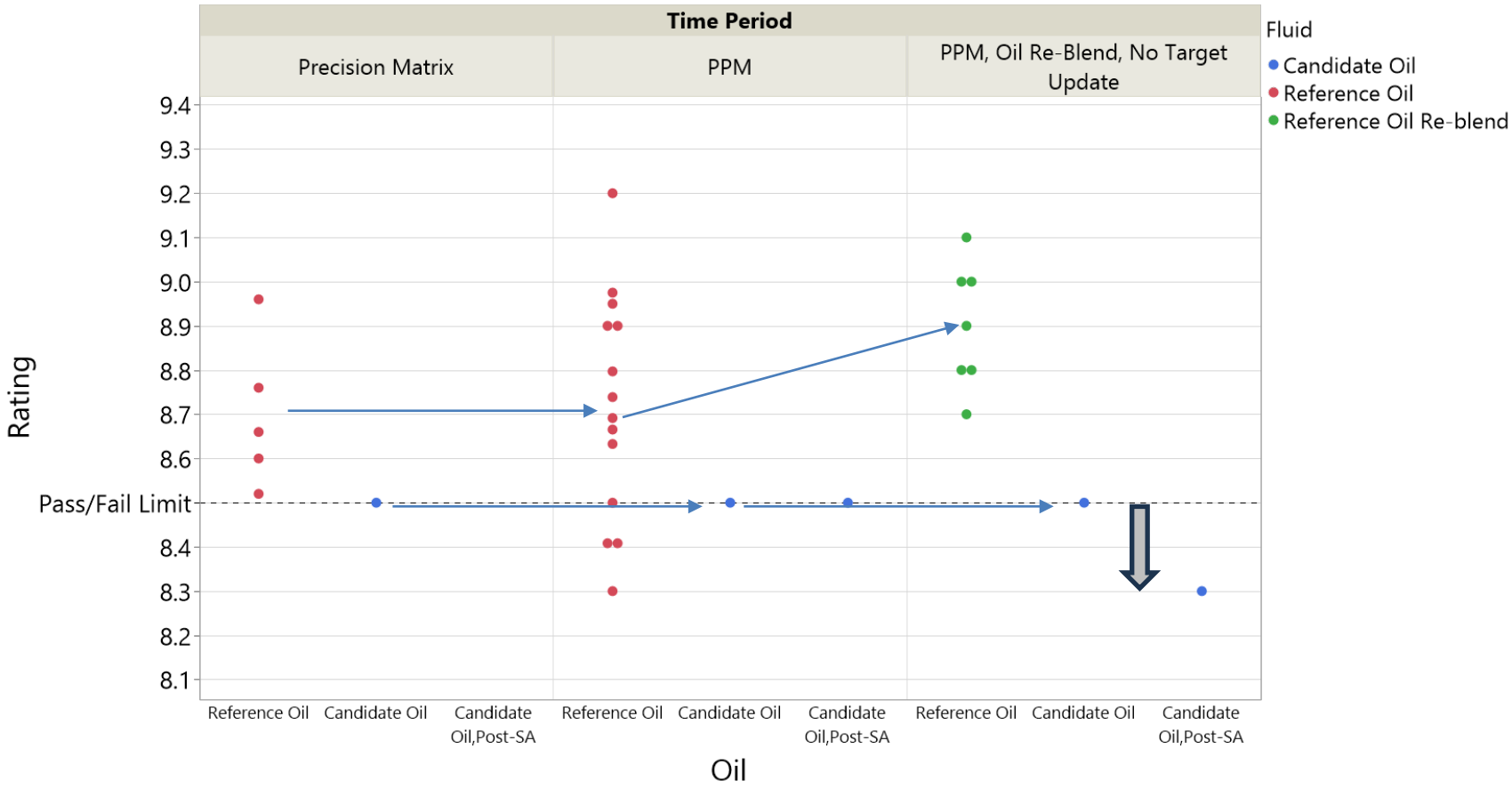
- This option ignores the fact that the candidate data is expected to move similar to the reference data.
- Once we update the reference oil target, the change in performance of the candidate oil will no longer receive proper severity adjustments.
- This will make the test either harder or easier for candidates, depending on the direction.



Case 3: A Reference Oil Re-blend

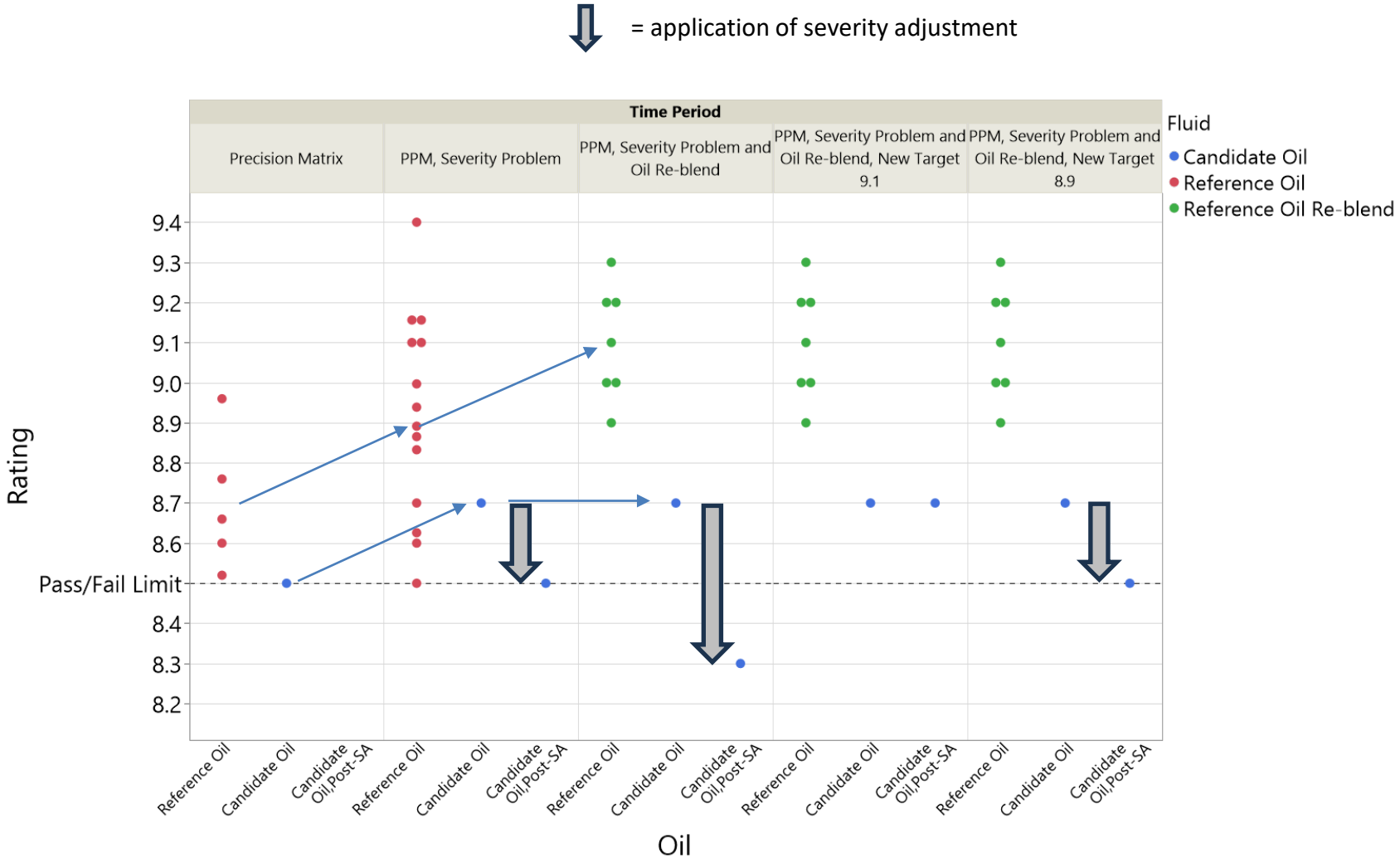
= application of severity adjustment

A change seen due to a reference oil re-blend would not change candidate performance. Therefore, in this situation, one should update the targets, but only for the difference due to the re-blend itself. Failure to do so would also change candidate pass/fail probability.



Case 3: A Reference Oil Re-blend

A case similar to the T-13 is that there is both a severity issue and a reference oil re-blend. One should not attempt to fix both problems with a target update.



Turning to T-13 Data…

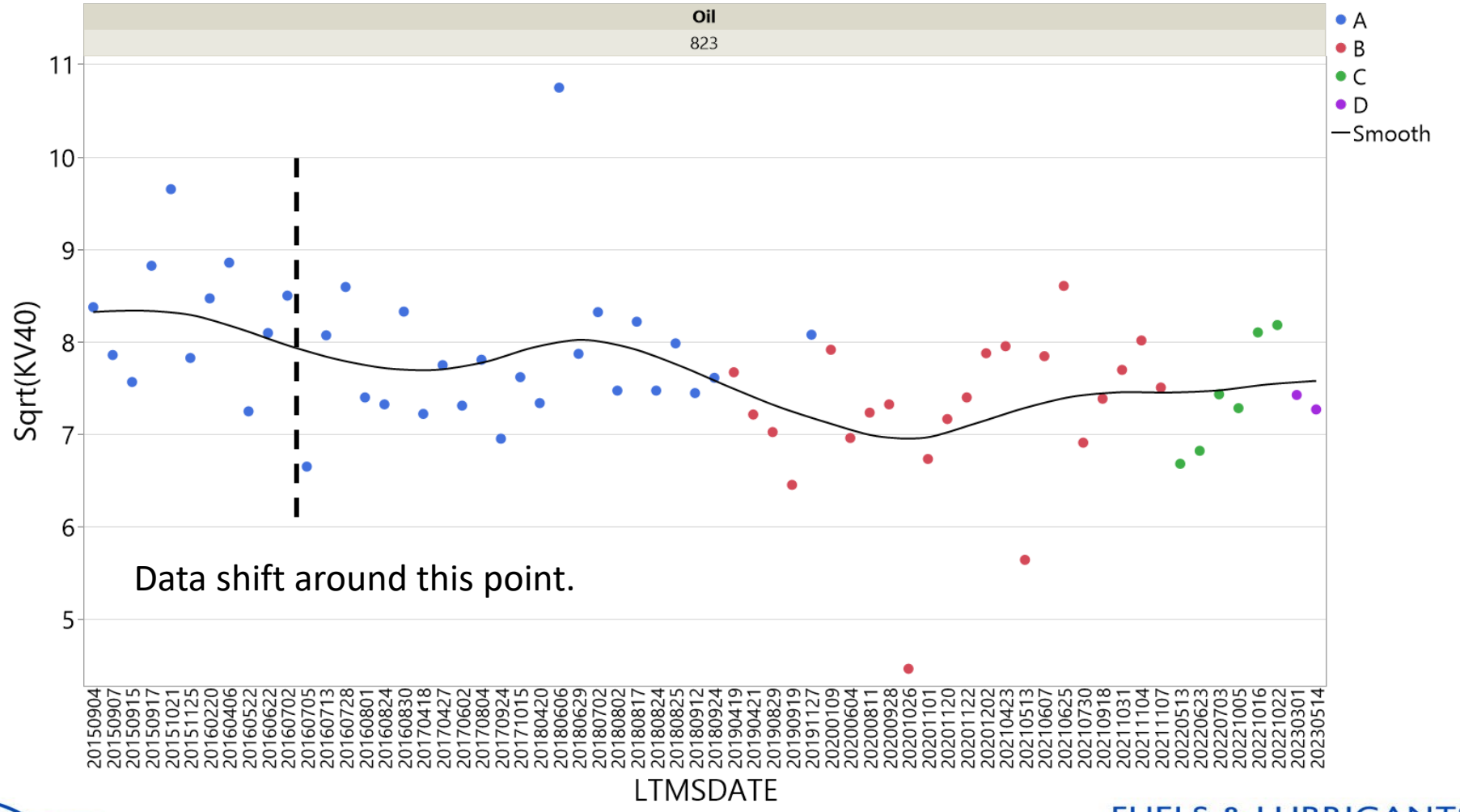
Analysis Begins with Fuel Flow Control Adoption

The change to fuel flow control from torque control is not expected to have only impacted the reference oil, but also candidates. Therefore, a correction factor may have been more appropriate than a target update if there was any intention to keep candidate results in parity with data prior to the change. However, we skip over this change due the number of confounding factors trying to estimate how a candidate may change over that time period.

KV40

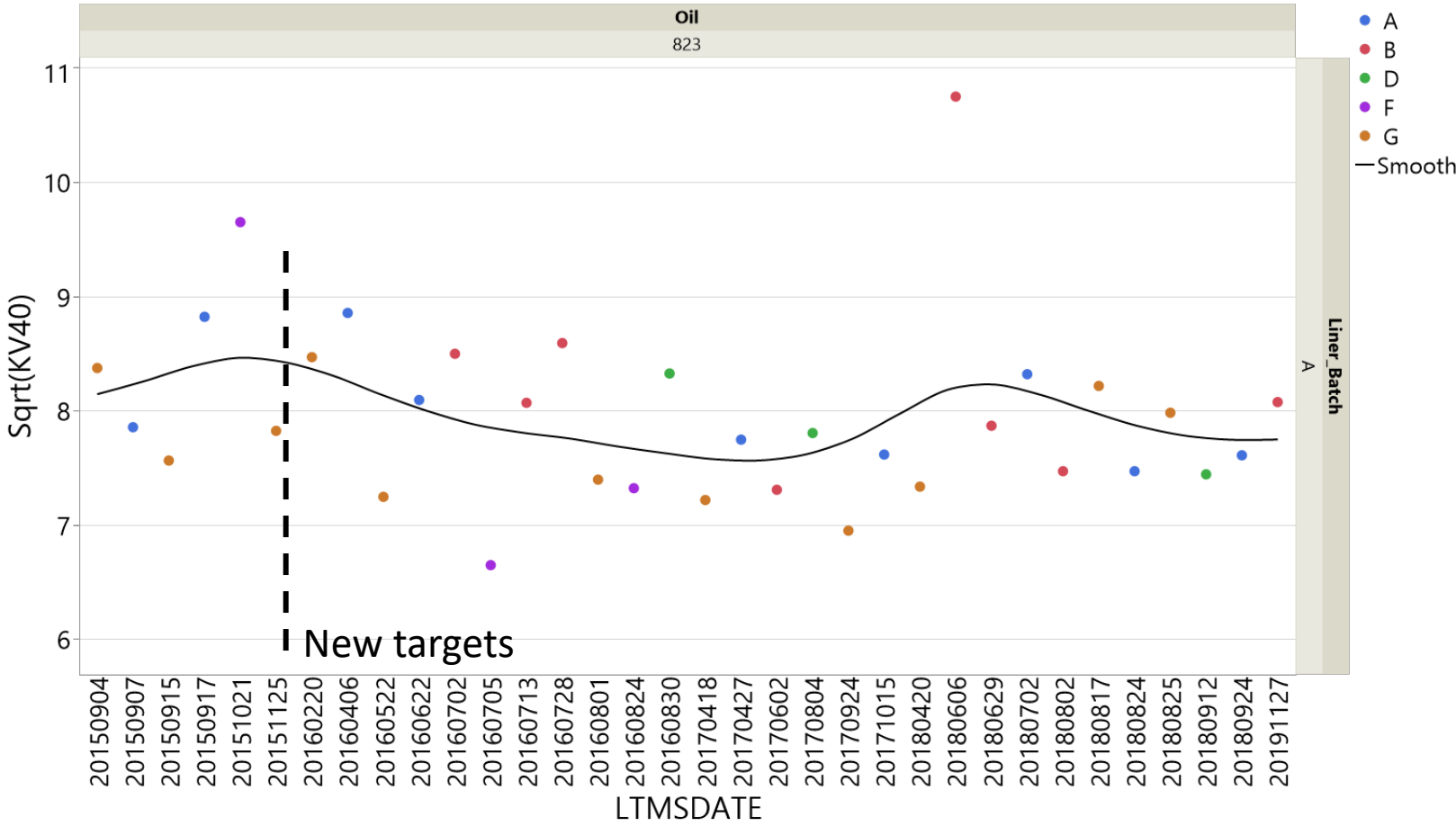
Analysis Begins with Fuel Flow Control Adoption

A quick inspection reveals that there appears to have been a shift in the middle of the Batch A liners



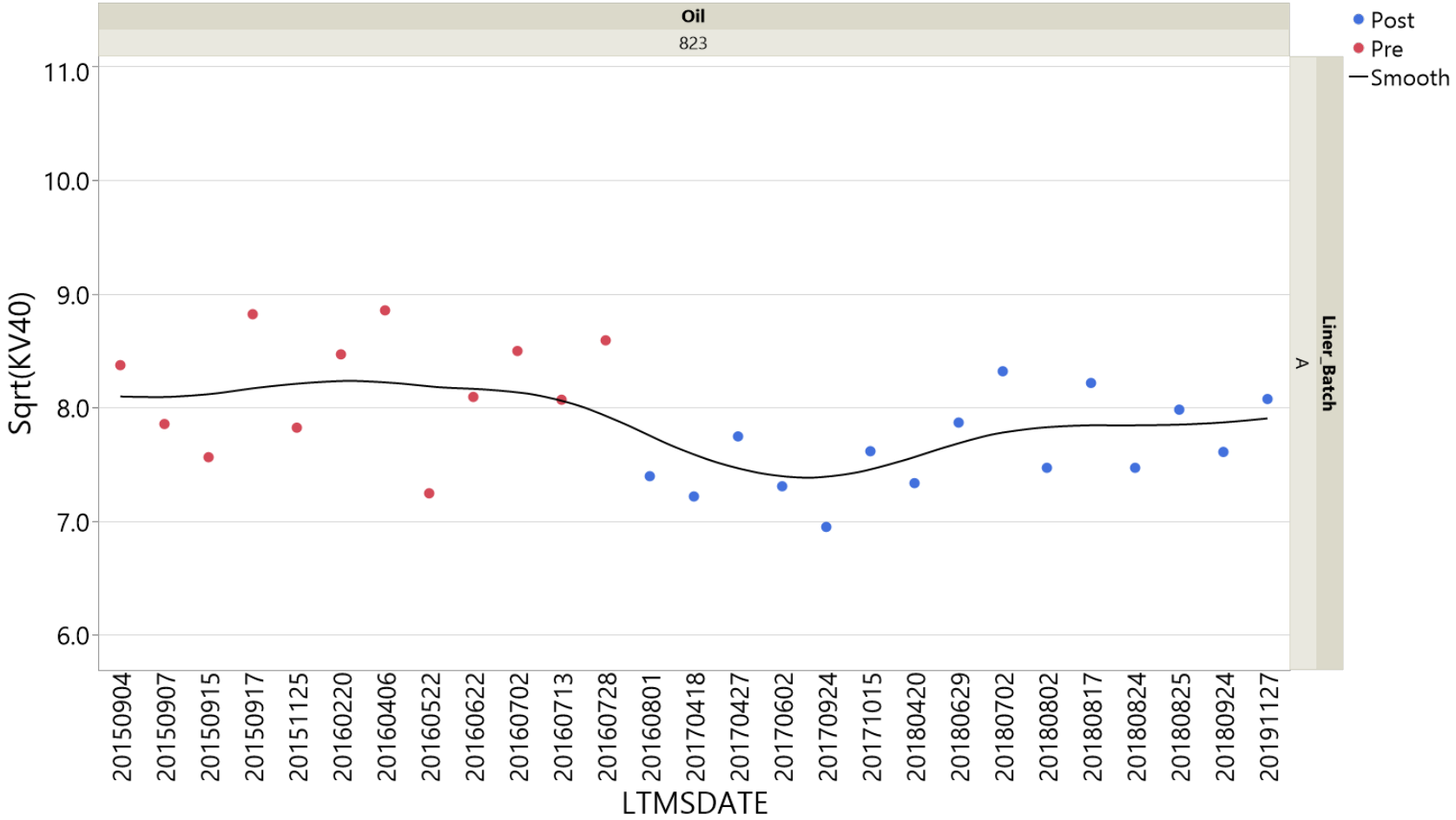
Analysis Begins with Fuel Flow Control Adoption

- Removed Lab F (3 data points, high variability), along with high data point from Lab B.
- Removed Lab D (1/3 of data during severity transition).



Analysis Begins with Fuel Flow Control Adoption

The following data was used to determine initial performance of 823 during batch A liners prior to the shift.



Batch A Model

The Lab effect was not significant in the model, so it was removed and re-run. In either case, the expected performance of Batch A prior to the shift is either 8.21 or 8.19 (vs. a target of 8.61). The impact of this mis-estimation for 823 targets would have been an expected disadvantage to candidates by 0.40.

- A candidate at the CK-4 pass/fail limit of 75 would be expected to be adjusted upward to 82.1%.
- This also means the effective limit would be 68.2%.

Model with Lab

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	2	2	0.7533243	2.0905	0.1465
Pre/Post	1	1	2.0481984	11.3678	0.0026*

Least Squares Means Table

Level	Least Sq Mean	Lower 95%	Upper 95%
Post	7.659	7.430	7.887
Pre	8.213	7.957	8.469

Model without Lab

Effect Tests

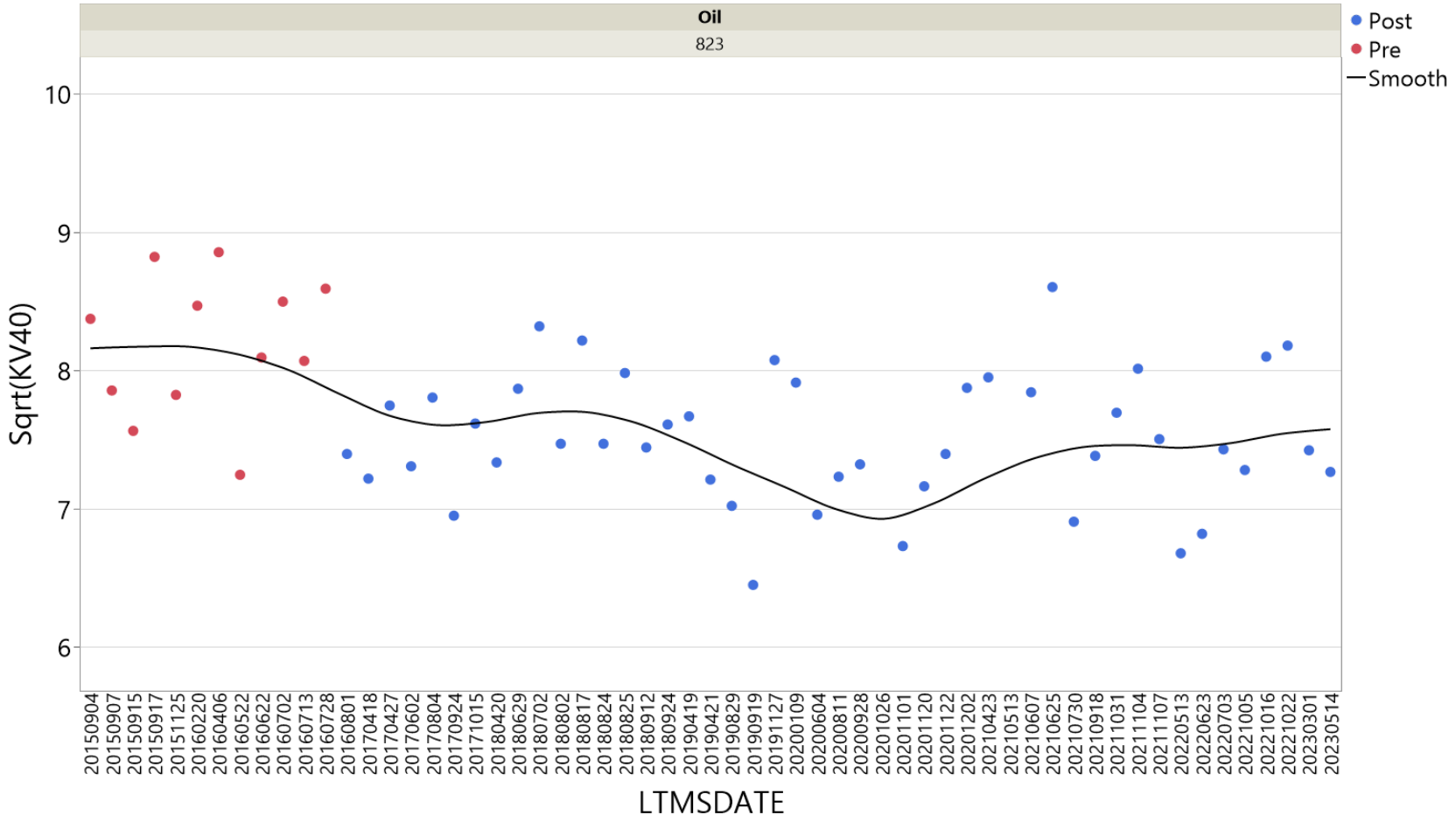
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Pre/Post	1	1	2.0112282	10.2669	0.0037*

Least Squares Means Table

Level	Least Sq Mean	Lower 95%	Upper 95%
Post	7.638	7.403	7.874
Pre	8.188	7.924	8.451

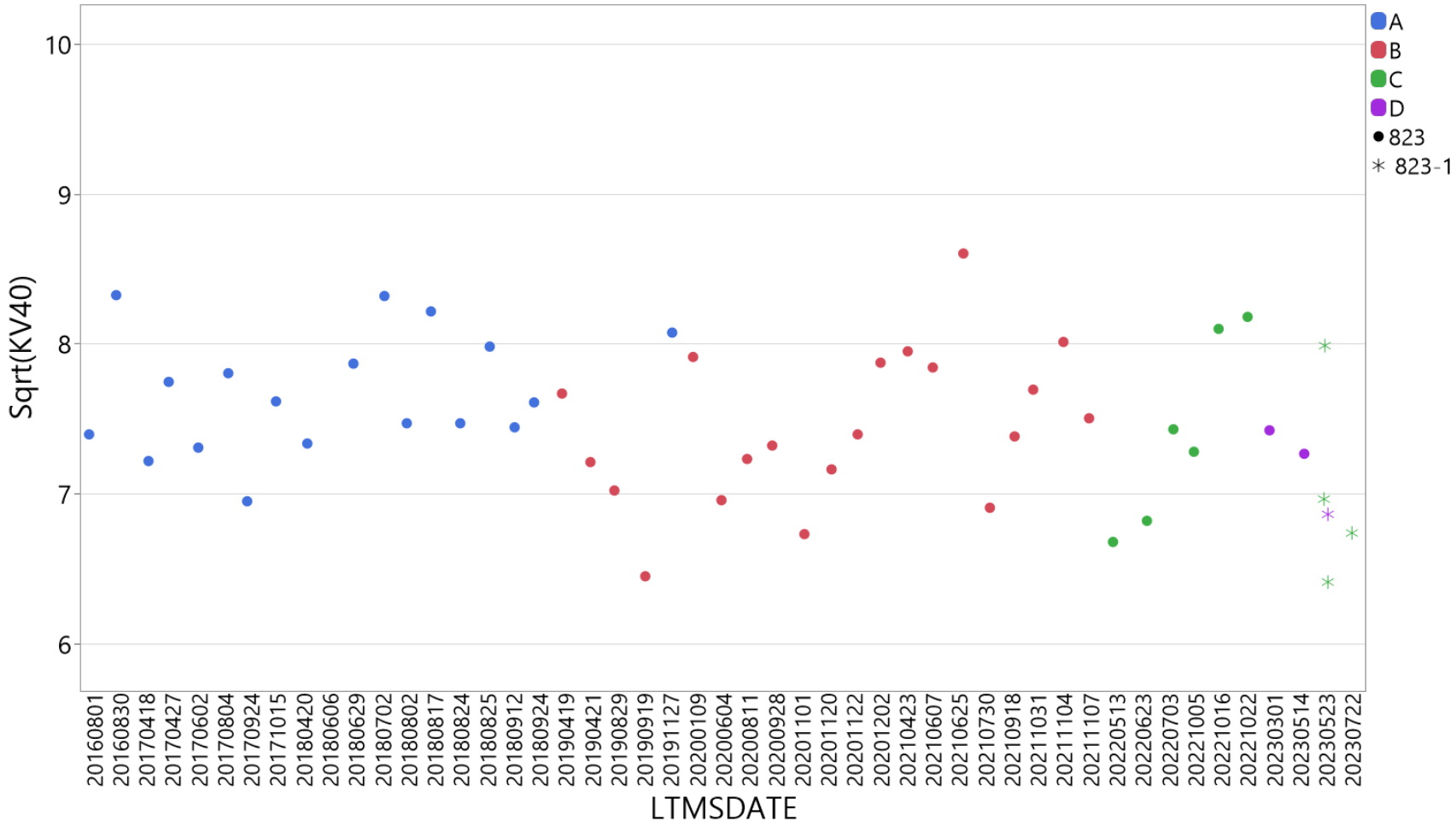
The Current Severity Level

- The remaining data was also labeled as post. Only “post” data used.
- Lab E removed again.
- High Lab B result removed again.
- Lab D single data point during severity transition also removed.



The Current Severity Level

Liner batches have been fairly consistent since the severity change during Batch A, other than a few low results during Batch B.

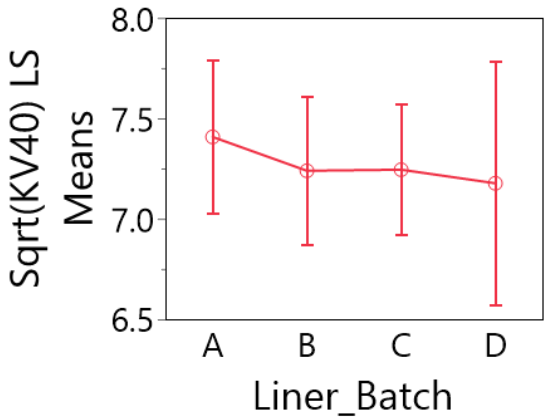


The Current Severity Level

- Liner batch and lab are not significant in the model.
  - Slight drop from A going into B and C liners. Recommend using 7.47 as expected current performance level of 823 (average prediction on C Liners for all 4 labs).
  - This would mean a correction factor of 1.14.
  - Recommend lower target for 823-1 by 0.45, for a new target of 8.16.
  - Update standard deviation to 0.485.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	3	3	0.39351393	0.5409	0.6569
Liner_Batch	3	3	0.30504709	0.4193	0.7401
Oil	1	1	0.59807544	2.4661	0.1238



Least Squares Means Table

Level	Least Sq Mean	Lower 95%	Upper 95%
A	7.408	7.025	7.791
B	7.240	6.872	7.607
C	7.245	6.919	7.571
D	7.177	6.572	7.782

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
823	823-1	0.4493150	0.2861171	-0.128093	1.026723	0.1238

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Liner_Batch	3	3	0.49230665	0.6980	0.5582
Oil	1	1	0.51369781	2.1851	0.1463

Summary of Fit

RSquare	0.137299
RSquare Adj	0.060614
Root Mean Square Error	0.484865
Mean of Response	7.455786
Observations (or Sum Wgts)	50

KV40 Summary

- Initial target setting data appears to have been off by 0.40 in transformed units. This would have initially put candidates with about a 7% disadvantage at the pass/fail limit. However, to account for this error now (subtract 0.40 from proposed ICF and subtract 0.40 from proposed target for 823-1) would mean treating candidates differently moving forward than they have been treated for the past 8 years.

- Recommend an industry correction factor of 1.14.

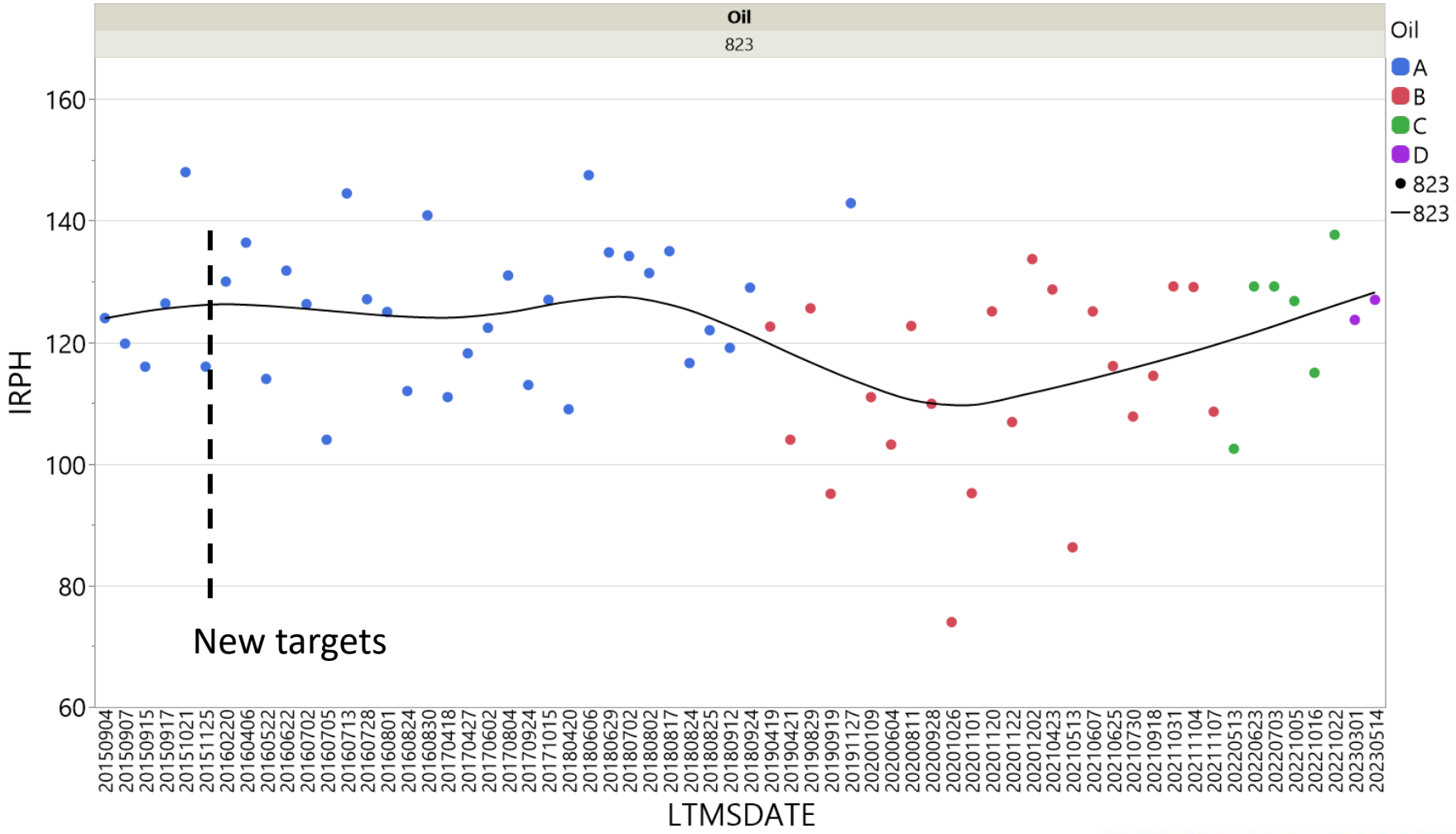
- Recommend the target for oil 823-1 be 8.16.

- Update standard deviation to 0.485.

IRPH

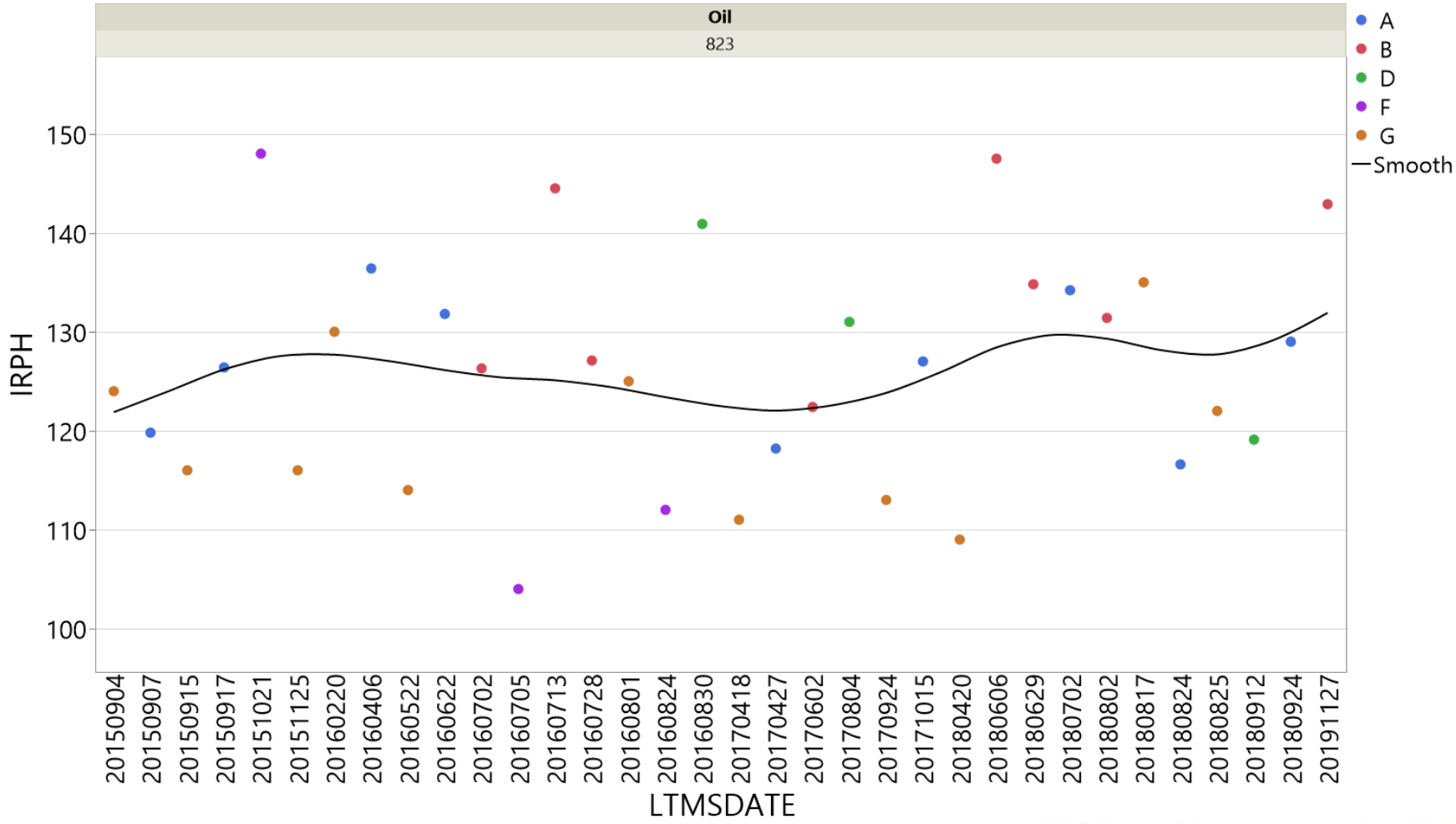
Analysis Begins with Fuel Flow Control Adoption

IRPH data appears stable other than lower performance with Batch B liners.



Batch A Only

IRPH data appears stable over Batch A. Lab F removed again.



Batch A Model

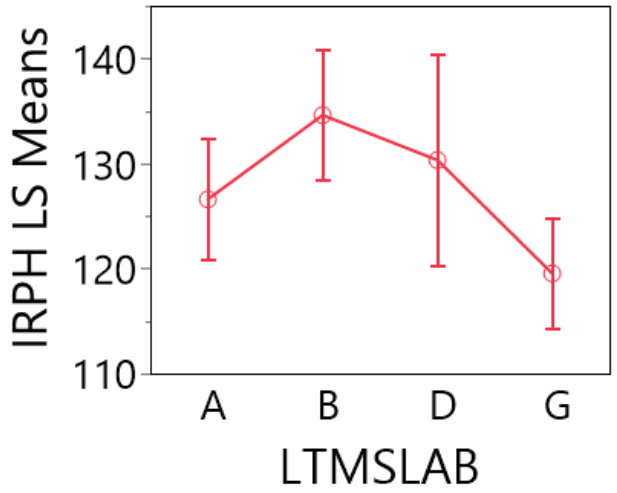
Average of 4 labs LS means is 127.8, nearly identical to the current target of 127.4.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	3	3	1102.6767	5.0993	0.0063*

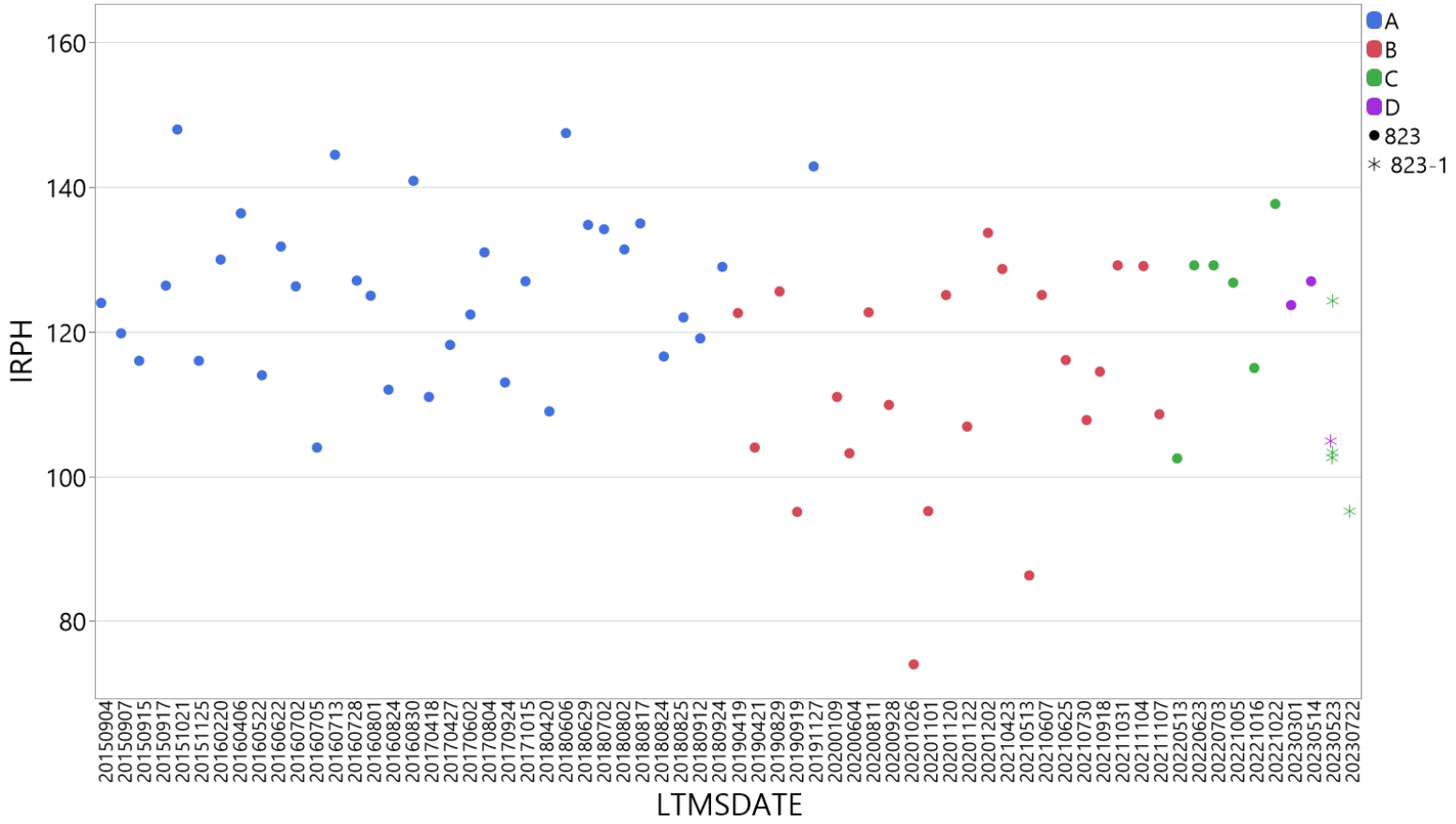
Least Squares Means Table

Level	Least Sq Mean	Lower 95%	Upper 95%
A	126.600	120.793	132.407
B	134.613	128.454	140.771
D	130.333	120.276	140.391
G	119.545	114.293	124.798



The Current Severity Level

All of the data shown here was used to determine the current severity level of 823 and to estimate the difference in the re-blend.

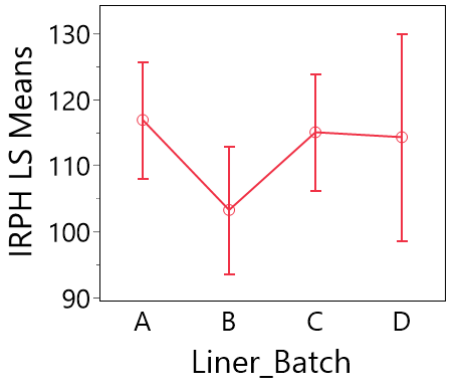


The Current Severity Level

- Liner batch and lab are not significant in the model.
  - Slight drop in B liners and similar performance for A, C, and D. Average prediction for C or D liners with 823 is 124-125. No ICF recommended.
  - Recommend lower target for 823-1 by 17.9, for a new target of 109.5.
  - RMSE of model with factors Oil and Liner (Liner B removed) is 11.3 (vs. 11.1 in LTMS), so no major need to update.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	4	4	848.2738	1.3212	0.2724
Liner_Batch	3	3	2435.5762	5.0580	0.0034*
Oil	1	1	959.3135	5.9766	0.0175*



Least Squares Means Table

Level	Least Sq Mean	Lower 95%	Upper 95%
A	116.89	108.05	125.72
B	103.27	93.65	112.88
C	115.02	106.23	123.81
D	114.28	98.62	129.93

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
823	823-1	17.90513	7.324024	3.254897	32.55535	0.0175*

IRPH Summary

- Initial target appears appropriate.
- No ICF recommended.
- Recommend the target for oil 823-1 be 109.5.
- Standard deviation of 11.1 can be retained or updated to 11.3.

Summary of All Recommendations.

Below are the summary of recommendations for both parameters, along with the current 823 LTMS targets.

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

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

Reference Oil	Mean	Standard Deviation
823	127.4	11.1

Parameter	823 Target	823-1 Target	ICF	Standard Deviation
KV40	Keep Current	8.16	1.14	0.485
IRPH	Keep Current	109.5	None	11.3 or Keep Current

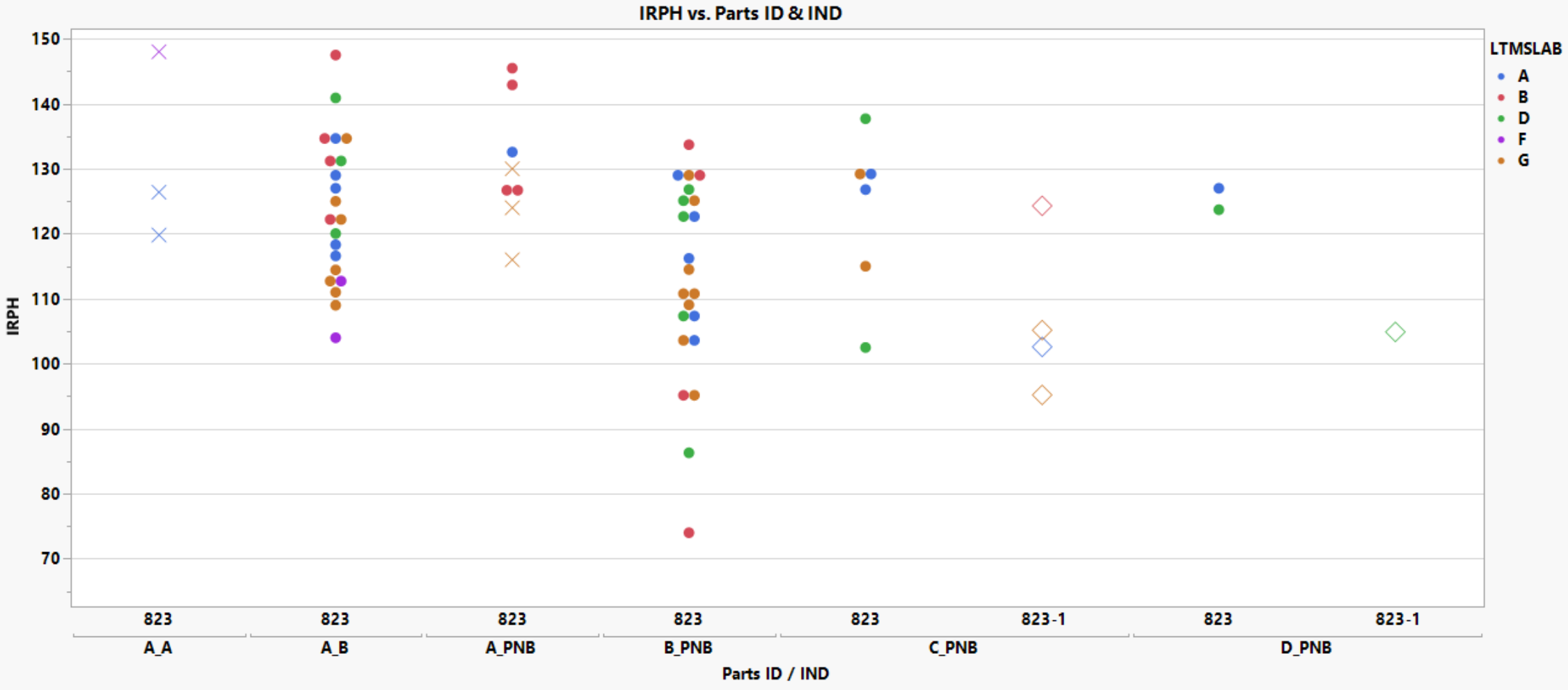
T13 Analysis

Jo Martinez
Chevron Oronite
Aug. 3, 2023

Recommendation

- New 823-1 Target for IRPH: 109.3
- 823-1 ICF for KV40: 1.328
- Compromise for KV40
  - 823-1 Target: 8.139
  - 832-1 ICF: 0.857

IRPH Data n=67



x – target setting (n=6)

Recommend new 823-1 Target for IRPH

Summary of Fit

RSquare	0.445779
RSquare Adj	0.149335
Root Mean Square Error	13.32919
Mean of Response	119.8463
Observations (or Sum Wgts)	67

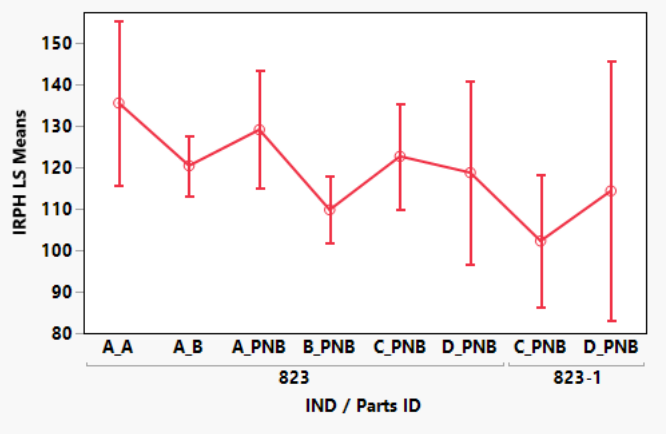
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	23	6144.857	267.168	1.5038
Error	43	7639.689	177.667	Prob > F
C. Total	66	13784.547		0.1221

Parameter Estimates

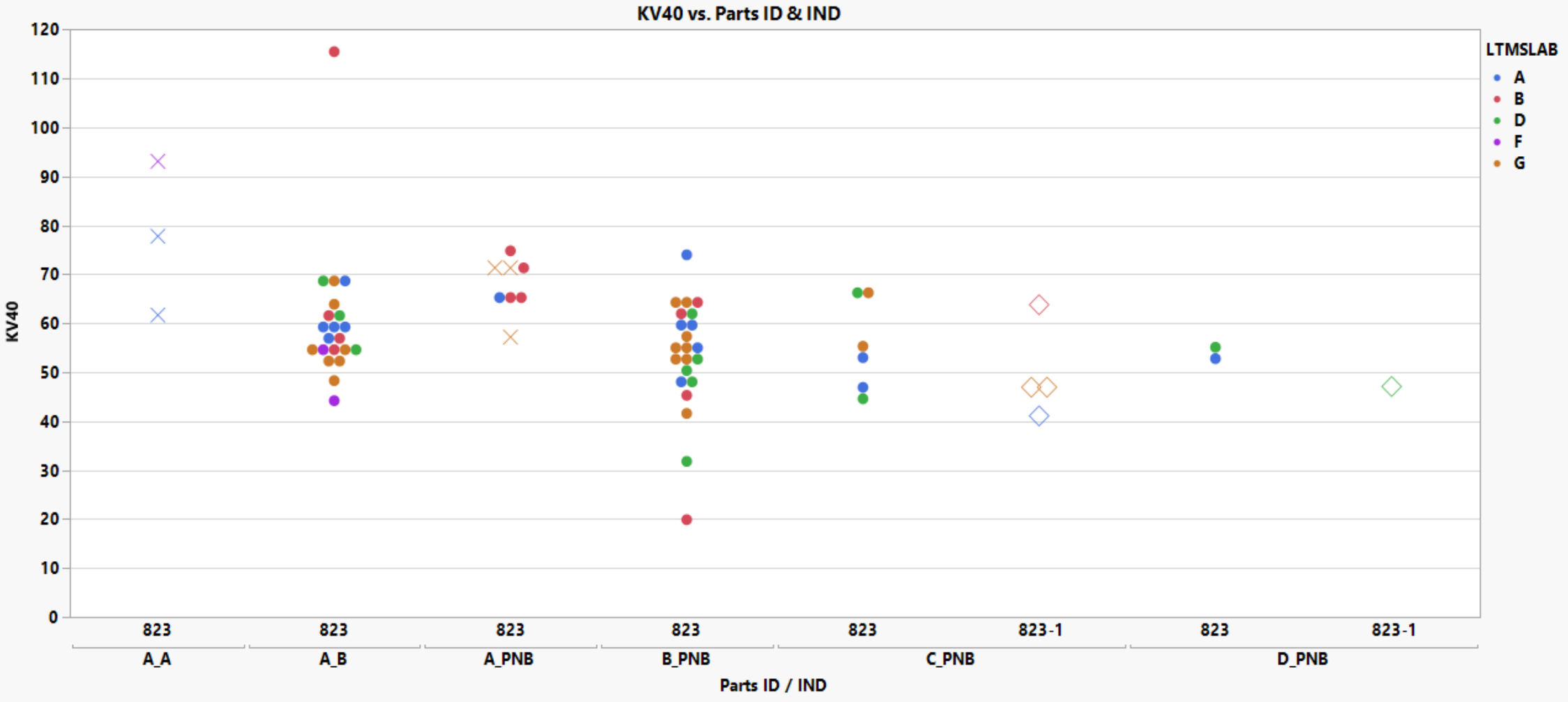
Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	4	4	390.0076	0.5488	0.7009
LTMSAPP[LTMSLAB]	12	12	1582.8465	0.7424	0.7029
IND	1	1	437.3755	2.4618	0.1240
Parts ID[IND]	6	6	2177.7727	2.0429	0.0804



- comparing 823 (n=6) and 823-1 (n=4) with batch C
  - difference = 20.4
  - p-value=0.0384
- New Target for 823-1: 109.3
  - Based on the model with equal weights for labs A, B, D, G

KV40 Data n=67



x – target setting (n=6)

Recommend 823-1 ICF for KV40

Summary of Fit

RSquare	0.362711
RSquare Adj	0.021836
Root Mean Square Error	0.841938
Mean of Response	7.56945
Observations (or Sum Wgts)	67

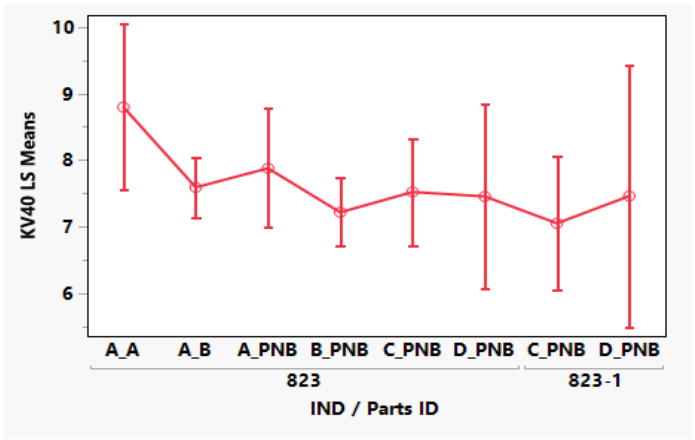
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	23	17.348188	0.754269	1.0641
Error	43	30.480998	0.708860	Prob > F
C. Total	66	47.829186		0.4183

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	4	4	0.8404438	0.2964	0.8787
LTMSAPP[LTMSLAB]	12	12	4.0286652	0.4736	0.9192
IND	1	1	0.5005888	0.7062	0.4054
Parts ID[IND]	6	6	4.3248855	1.0169	0.4272



- comparing 823 (n=6) and 823-1 (n=4) with batch C
  - difference =0.4709
  - p-value=0.44
- ICF for 823-1: 1.328
  - Prediction for 823-1: 7.282
    - Based on the model with equal weights for labs A, B, D, G
  - ICF = 8.610 – 7.282 = 1.328

Compromise
823-1 new target and ICF for KV40

Summary of Fit

RSquare	0.362711
RSquare Adj	0.021836
Root Mean Square Error	0.841938
Mean of Response	7.56945
Observations (or Sum Wgts)	67

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	23	17.348188	0.754269	1.0641
Error	43	30.480998	0.708860	Prob > F
C. Total	66	47.829186		0.4183

Parameter Estimates

Effect Tests

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LTMSLAB	4	4	0.8404438	0.2964	0.8787
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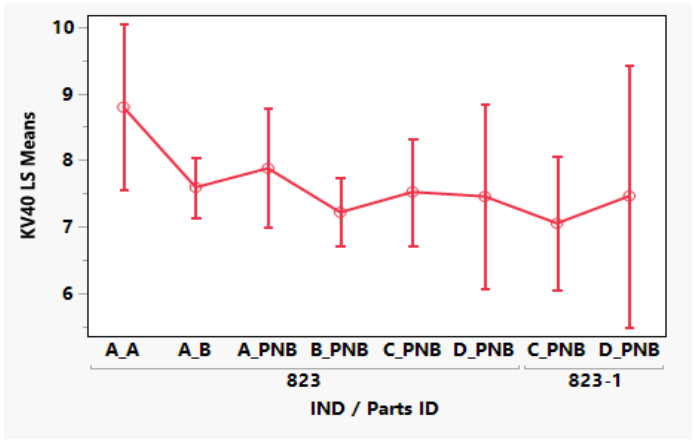

- comparing 823 (n=6) and 823-1 (n=4) with batch C
  - difference =0.4709
  - p-value=0.44
- New target: 8.139
  - Current 8.610 – 0.471 = 8.139
- ICF for 823-1: 0.857
  - Prediction for 823-1: 7.282
    - Based on the model with equal weights for labs A, B, D, G
  - ICF = 8.139 – 7.282 = 0.857

other methods

823-1 means and standard deviations (n=5)

IND 2	N Rows	Mean(sqrt(KV40))	Std Dev(sqrt(KV40))
823-1	5	6.9926	0.5936171325

IND 2	N Rows	Mean(IRPH)	Std Dev(IRPH)
823-1	5	106.06	10.8578542999...

Means using severity adjusted results

IRPH

	IRPH SA	823-1 IRPH	IRPH+SA
Lab G	9.5	103.3	112.80
Lab G	9.5	95.2	104.70

Lab	IRPH SA	823-1 IRPH	IRPH+SA
Lab A	2.7	102.6	105.30
Lab B	6.3	124.3	130.60
Lab D	6.4	104.9	111.30
Lab G Avg.	9.5	99.25	108.75

Average SA	6.23	<--ICF (not needed)	**Average Adj. Final Result**	113	Potential 823-1 Target (Equal Data Point Weighting)
			Average Adj. Final Result	114	Potential 823-1 Target (Equal Lab Weighting)

KV40

	KV40 SA	823-1 KV40	Sqrt (KV40)	Sqrt(KV40)+SA
Lab G	0.953	48.5	6.96	7.92
Lab G	0.953	45.4	6.74	7.69

Lab	KV40 SA	823-1 KV40	Sqrt (KV40)	Sqrt(KV40)+SA
Lab A	1.232	41.1	6.41	7.64
Lab B	0.972	63.8	7.99	8.96
Lab D	1.253	47.1	6.86	8.12
Lab G Avg.	0.953		6.85	7.80

Average SA	1.10	<--ICF	**Average Adj. Final Result**	8.07	<--Alternative 823-1 Target (Equal Data Point Weighting)
			Average Adj. Final Result	8.13	<--New 823-1 Target (Equal Lab Weighting)