ISB Correction Factor and RO Blend Target Review

Statistics Group

August 21, 2020

Statistics Group

- Elisa Santos, Infineum

- Jo Martinez, Chevron Oronite

- Sean Moyer, TMC

- Abaigh Ritzenthaler, Afton

- Todd Dvorak, Afton

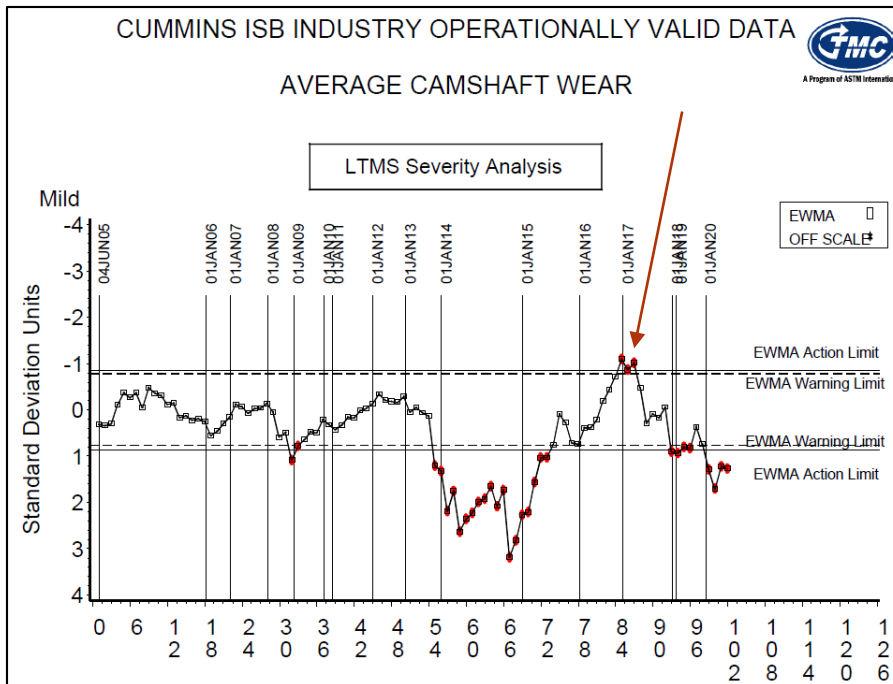- Travis Kostan, SwRI

Executive Summary

ISB Correction Factor and RO Blend Target Review

- Executive Summary:

  - Use reference oil test data that corresponds with all hardware Camshaft-Tappet batches to generate targets and CFs

  - Recommended Correction Factor is Multiplicative with a value of 0.77 for "LE" Camshaft-Tappet Hardware

  - Revised reference oil target for 831-3|4 is 52.4

  - Revised Standard Deviation Target for Reference Oil 831-3|4 is 9.2
    - Currently it is 8.7

  - Revised Severity Adjustment Standard deviation is 8.5
    - Currently it is 8.7

ISB Analysis

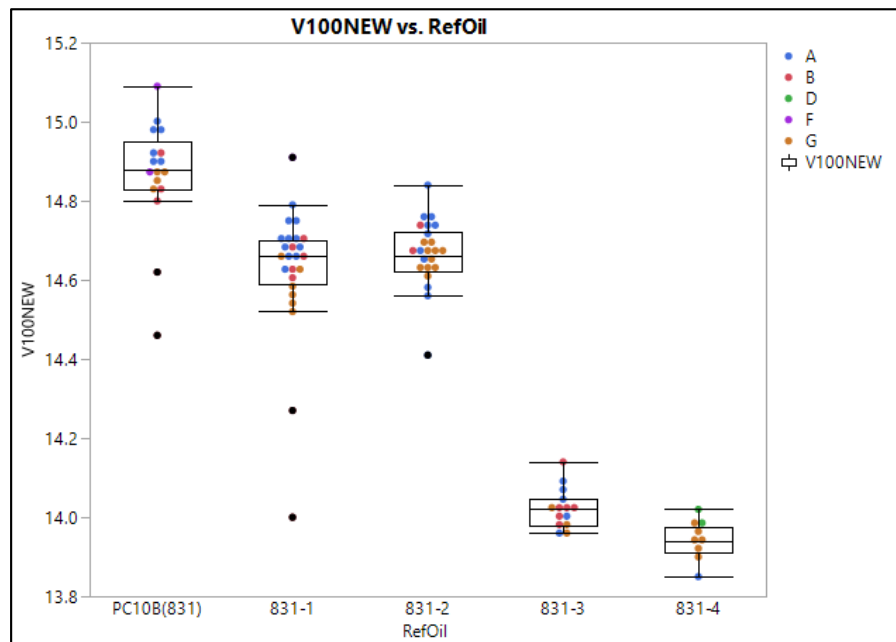# ISB Correction Factor and RO Blend Target Review

- Current test is showing has been trending severe of target since January of 2017

- Severity trend continues following the Correct Factor update in October of 2017

			All tests using batch B tappets with batch E, F, and G cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
	April 21, 2011	October 18, 2017		
	December 11, 2011	November 12, 2012	All tests using batch C tappets with batch H cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
ISB	November 13, 2012	October 18, 2017	All tests using batch C tappets with batch H and J cams	Multiply ATWL by 0.711; Add -5.6 to ACSW
	None	October 18, 2017	All test using batch D tappets and batch K cams	Multiply ATWL by 1; Add -11.3 to ACSW
	October 19, 2017	***	All tests using batch K cams with batch D tappets and batch E crossheads	Multiply ATWL by 0.7851; Add -18.5 to ACSW

ISB Correction Factor and RO Blend Target Review

- Issues related to reference oil 831X re-blends:
  - Data suggests a ~1.0 cSt difference between 831(PC10B) & 831-4
  - Feedback from Supplier/TMC indicates RO831-3|4 can be combined

V100 New			
RefOil	Mean	Stdev	N
PC10B(831)	14.865	0.145	17
831-1	14.625	0.173	25
831-2	14.660	0.082	23
831-3	14.021	0.050	15
831-4	13.941	0.049	9

V100NEW vs. RefOil

ISB Correction Factor and RO Blend Target Review

- What are the tested hardware & reference oil blend combinations?
  - Plot of Camshaft and Tappet Hardware by Reference Oil batch is shown below
  - Initial Cam/Tap batch (PM phase) AA hardware tested with Reference oils 830-2, PC10B, and PC10E
  - Recent hardware batches JC, KD, and LE tested with RO 831-1, 831-2, & 831-3|4
  - Correction Factor Proposal corresponds to hardware & Ref Oil data for Model 19M
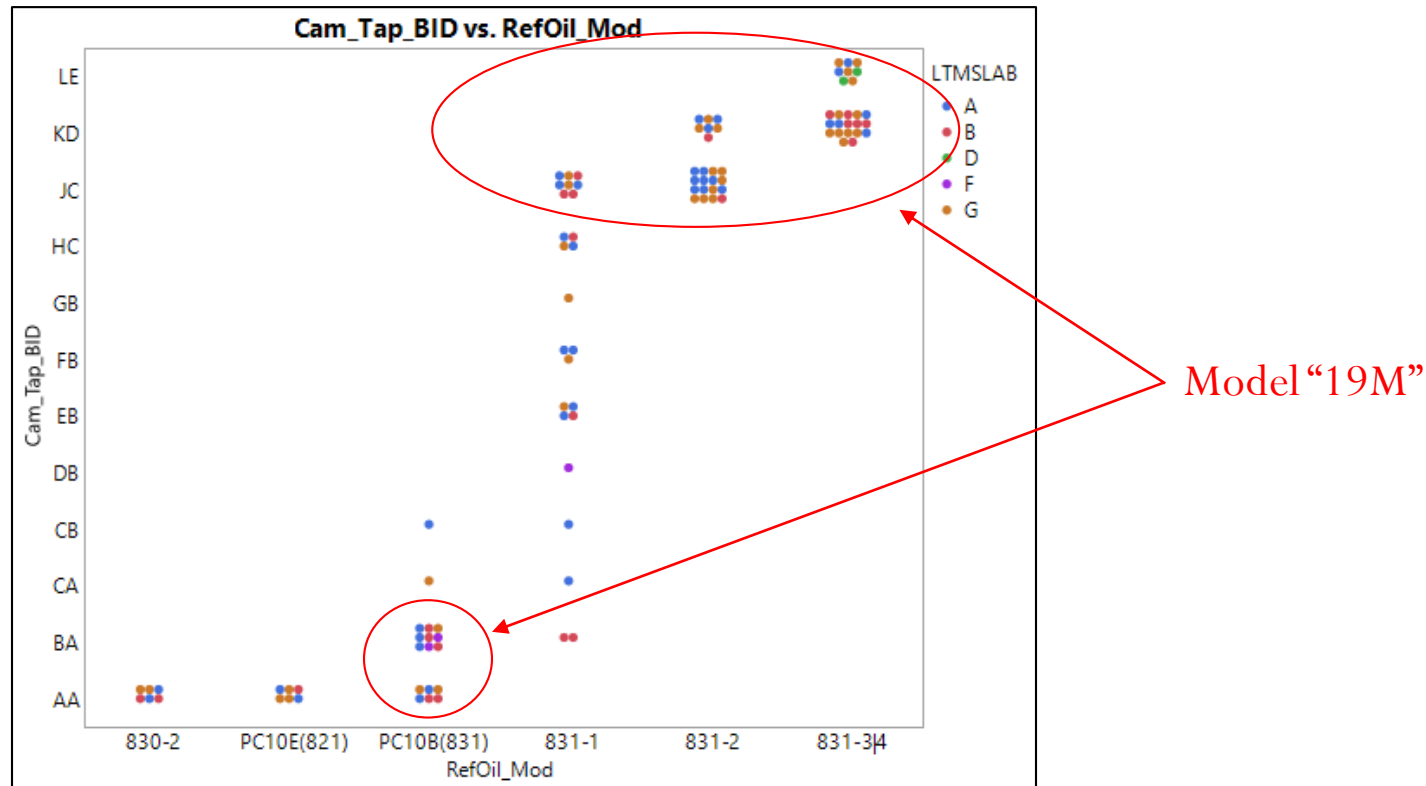
ISB Correction Factor and RO Blend Target Review

- Are current hardware Correction Factors (CFs) resulting in "*on target performance?*"
  - Corrected_ACSW – ACSW_Target (w/o Lab D) data is plotted below.
  - Plot suggests that means of corrected data by hardware batch may not equal zero *(not "on target performance")*
  - Advantageous to analyze with ACSWOrig data in lieu of using the corrected ACSW data
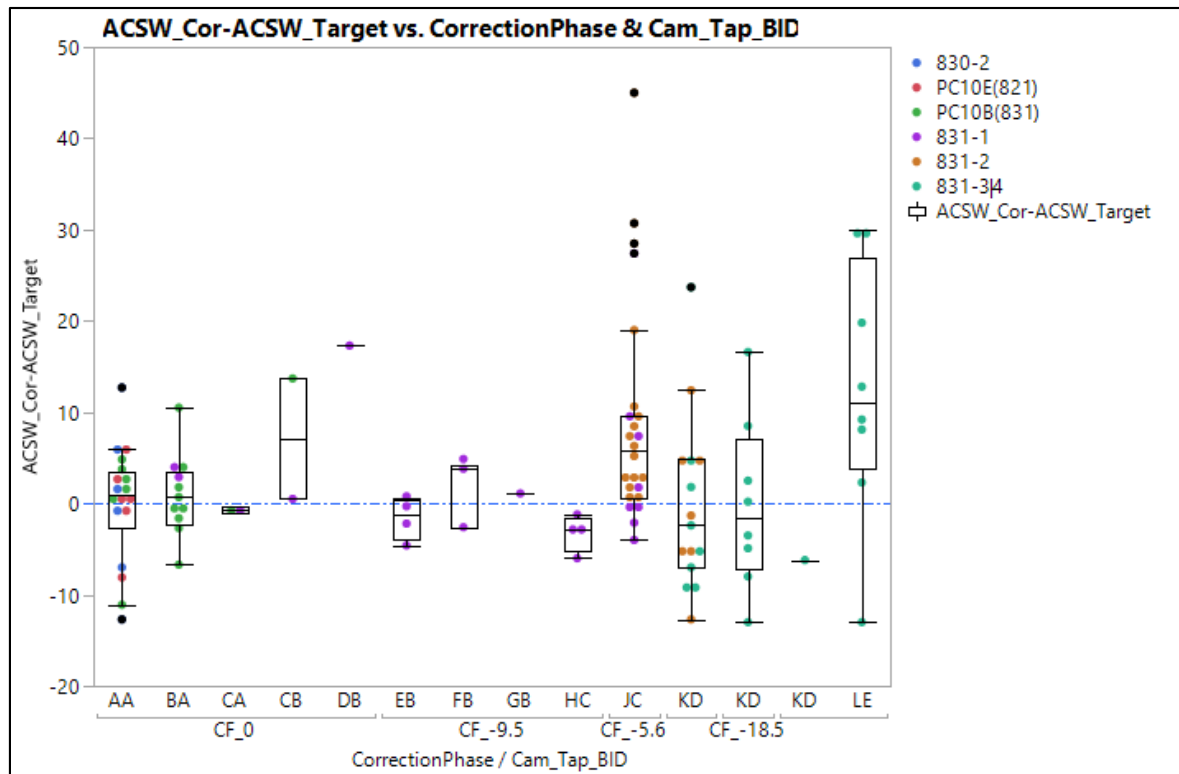
ISB Correction Factor and RO Blend Target Review

- Correction Factor history:
  - Both Linear vs. Multiplicative CFs have been applied to the ISB

ISB	April 21, 2011	October 18, 2017	All tests using batch B tappets with batch E, F, and G cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
	December 11, 2011	November 12, 2012	All tests using batch C tappets with batch H cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
	November 13, 2012	October 18, 2017	All tests using batch C tappets with batch H and J cams	Multiply ATWL by 0.711; Add -5.6 to ACSW
	None	October 18, 2017	All test using batch D tappets and batch K cams	Multiply ATWL by 1; Add -11.3 to ACSW
	October 19, 2017	***	All tests using batch K cams with batch D tappets and batch E crossheads	Multiply ATWL by 0.7851; Add -18.5 to ACSW

- Camshaft wear may be better represented as being proportional to the reference oil/candidate wear - in lieu of a linear constant
- Analysis will include evaluations of multiplicative and additive approaches to help drive a decision on the best Correction Factor approach

ISB Correction Factor and RO Blend Target Review

- Outline of the Analysis Process Methodology:

  - Analyze the data to predict the severity by hardware batch as compared to original "targets" hardware *(CamTap batch AA & BA)* with RO PC10B(831) to quantify severity shift by hardware batch

  - Use ACSWOrig *(vs. Corrected ACSW)* as the key dependent variable for the analyses

    - Best estimates of correction factor options will be obtained using the original uncorrected data

  - Use fitted ACSWOrig model to predict hardware and reference oil blend combinations - to estimate CFs

  - Apply CFs to the data & then re-analyze to generate new targets for RO 831-3|4

ISB Correction Factor and RO Blend Target Review

- How were original targets established?

  - Original Targets were generated with Cam-Tap Batch "AA" and reference oils PC10B, PC10E, and 830-2 (18 results) using raw means

    - ANOVA summary below shows *LSMeans* and *Raw Data Means* are similar in magnitude

  - Reference oil 831-X targets were updated and adjusted to 42.5
    - Target update based on additional Cam Tappet Hardware "AA" and "BA" test results (n=14)

Response ACSWorig

Whole Model

Summary of Fit

RSquare	0.345088
RSquare Adj	0.143577
Root Mean Square Error	6.509691
Mean of Response	38.75
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	290.27596	72.5690	1.7125
Error	13	550.88904	42.3761	Prob > F
C. Total	17	841.16500		0.2071

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil_Mod	2	2	116.58658	1.3756	0.2871
LTMSLAB	2	2	120.37262	1.4203	0.2768

RefOil_Mod

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
830-2	39.766667	2.6575703	39.7667
PC10E(821)	35.661056	2.7353693	34.5833
PC10B(831)	41.900000	2.6575703	41.9000

LTMSLAB

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	39.333333	2.6575703	39.3333
B	42.230363	2.9446584	42.9200
G	35.764026	2.4806496	35.2714

Targets

ISB Correction Factor and RO Blend Target Review

- The following slides explore correction factor options:

  - Numerous ANOVA models were evaluated with various data sets to generate correction factor options

  - Primary data sets evaluated to generate correction factor and target options included:

    - All Cam-Tappet batches and Reference Oil blends – with/without Lab "D" data *(n=100/102)*
    - All 831X blend data with Cam-Tap Hardware batches "AA_BA", "JC", "KD", and "LE" without Lab "D" data *(n = 71)*

  - Summary of all analyzed data sets & models are provided in the Appendix

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ISB Correction Factor and RO Blend Target Review

- What factors should be included in the models and what data should be analyzed?

  - Table of different models by reference oil, hardware, hardware coding, and laboratory datasets are shown below

  - Analysis highlights:

    - The Stand[Lab] nested factor is not significant in any of the evaluated data sets - recommend using Lab only factor in the models

    - The Camshaft and Tappet factors are confounded - recommend using combined Cam-Tappet factors in models

    - Models with yellow highlights will be analyzed - includes with & without Lab D data

Data Included in Model			Lab		Reference Oil						Hardware		Effect Test p values					Model Summary		Model Selection
ID	Data Notes	Lab D	Lab	Stand[Lab]	830-2	PC10E(821)	PC10B(831)	831-1	831-2	831-3|4	CamBID	CamTapBID	Lab	Stand[Lab]	RefOil	CamBID	CamTapBID	n	RMSE	
12	All Cam Batches	X^1	✓	✓	✓	✓	✓	✓	✓	✓	✓	X^1	0.2990	0.2452	0.3693	0.6327		100	8.8267	
13	All Cam-Tap Batches	X^1	✓	✓	✓	✓	✓	✓	✓	✓	X^1	✓	0.3072	0.3266	0.3808		0.7182	100	8.8888	
14	All Cam-Tap Batches	X^1	✓	X^1	✓	✓	✓	✓	✓	✓	X^1	✓	0.1100		0.3484		0.2432	100	8.9973	Evaluate
15	All Cam Batches	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X^1	0.0031	0.2342	0.3608	0.6221		102	8.7637	
16	All Cam-Tap Batches	✓	✓	✓	✓	✓	✓	✓	✓	✓	X^1	✓	0.0035	0.3142	0.3722		0.7084	102	8.8245	
17	All Cam-Tap Batches	✓	✓	X^1	✓	✓	✓	✓	✓	✓	X^1	✓	0.0047		0.3411		0.2340	102	8.9419	Evaluate
18	Cam-Tap Batches "AA_AB","JC","KD","LE"	X^1	✓	✓	X^1	X^1	✓	✓	✓	✓	X^1	✓	0.4453	0.3890	0.4006		0.3110	71	9.4932	
19	Cam-Tap Batches "AA_AB","JC","KD","LE"	X^1	✓	X^1	X^1	X^1	✓	✓	✓	✓	X^1	✓	0.0612		0.4110		0.0563	71	9.5771	Evaluate

Note 1 - "X" indicates that it is excluded from data set

ISB Correction Factor and RO Blend Target Review

- Analysis highlights (Continued):

  - Highlighted yellow - model ID's 14, 17, and 19 were all evaluated

  - Model ID 19 with Multiplicative CF, Lab only, and CamTapBID hardware coding, w/o Lab D data will be shown in the following slides

  - Recommend applying Multiplicative CFs to the data sets

    - A table summary of precision/standard deviations will be provided at the end of the modeling section that contrasts the Additive & Multiplicative CFs that supports their application

    - A complete summary of the analyses for model ID's 14, 17, and 19 are shown in the Appendix

ISB Correction Factor and RO Blend Target Review

- Data model to evaluate for CFs and revised Targets with Model ID 14M:
  - Includes Camshaft Tappet batches "AA_BA", "JC", "KD", "LE"
  - Includes RO's PC10B(831), 831-1, 831-2, & 831-3|4
  - Applies multiplicative CFs to the data

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

ISB Correction Factor and RO Blend Target Review

- Predicted LSMeans for (PM) PC10B(831) and Camshaft-Tappet hardware combinations are summarized below:

  - Predictions estimate the multiplicative effect of hardware severity on ACSWOrig with using the "Target" *("AA_BA")* hardware and reference oil PC10B(831)
  - LSMeans are used to establish multiplicative CFs (by hardware batch)
    - Correction Factor calculated from original updated target of 42.5
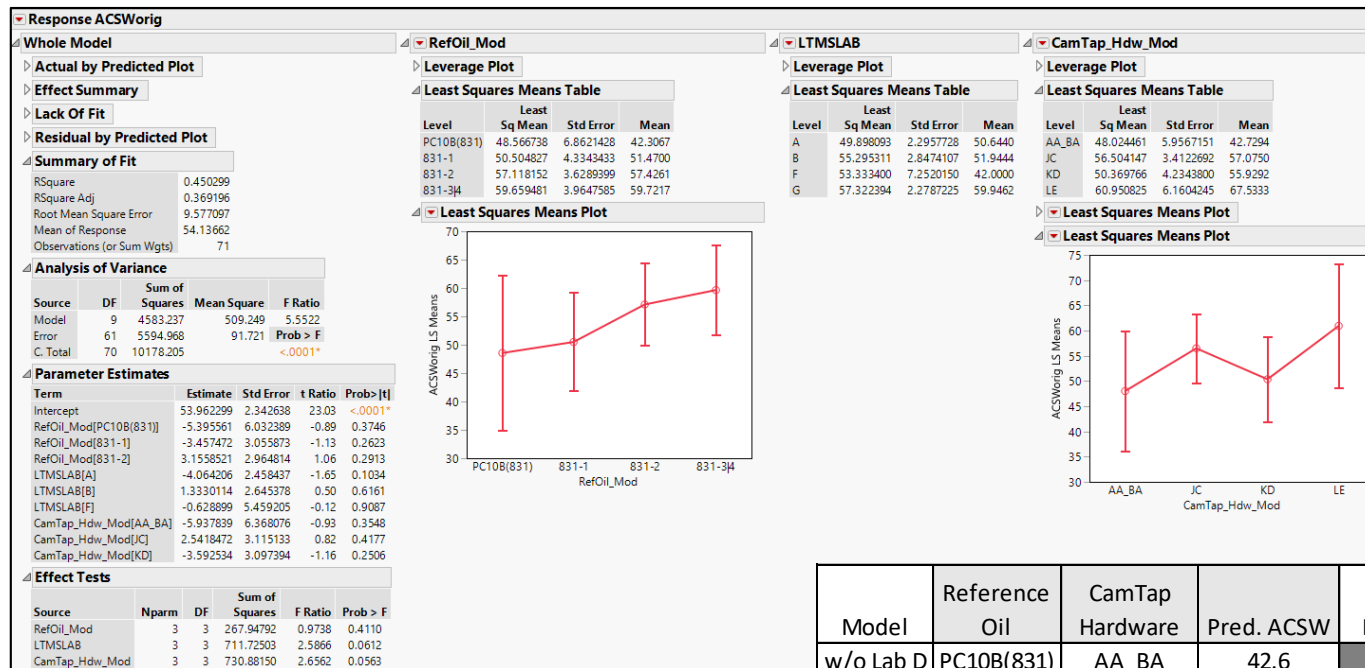
Correction Factor Example
0.83 = 42.5 / 51.1

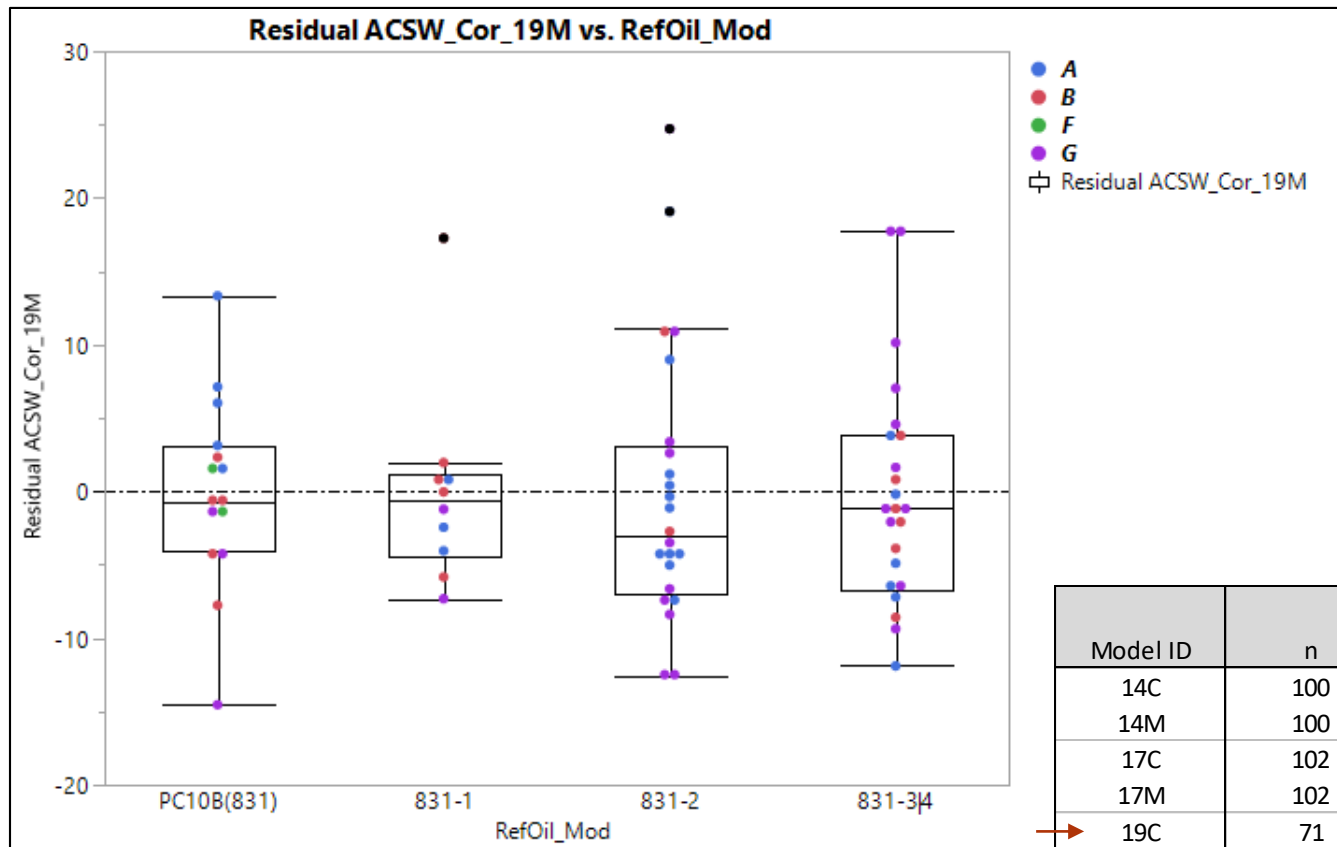| Model	Reference Oil	CamTap Hardware	Pred. ACSW	Correction Factor Delta	Multiplicative CF	Orig PM Target	Updated Target
						41.9	42.5
w/o Lab D	PC10B(831)	AA_BA	42.6				
w/o Lab D	PC10B(831)	JC	51.1	8.6	0.83		
w/o Lab D	PC10B(831)	KD	45.0	2.5	0.94		
w/o Lab D	PC10B(831)	LE	55.6	13.1	0.77		

ISB Correction Factor and RO Blend Target Review

- Analysis of ACSWOrig using (*multiplicative) corrected* data

- Overall model summary:
  - Reference oil is significant and lab is marginally significant
  - RMSE = 8.2, RO LSMeans Target for 831-3|4 = 52.4

Response ACSW_Cor_19M

Whole Model

Summary of Fit

RSquare	0.293437
RSquare Adj	0.227197
Root Mean Square Error	8.198974
Mean of Response	48.41127
Observations (or Sum Wgts)	71

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	1786.7474	297.791	4.4299
Error	64	4302.2835	67.223	Prob > F
C. Total	70	6089.0310		0.0008*

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil_Mod	3	3	965.54217	4.7877	0.0045*
LTMSLAB	3	3	518.66610	2.5719	0.0618

RefOil_Mod

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
PC10B(831)	42.563320	2.2440961	42.3067
831-1	44.140007	3.0472771	44.2900
831-2	49.812290	2.3933644	49.4565
831-3|4	52.390030	2.3403398	53.1391

LTMSLAB

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	43.729932	1.7174096	44.8040
B	48.516334	1.9564052	48.3722
F	46.663092	6.1125680	42.0000
G	49.996289	1.7508477	52.4000

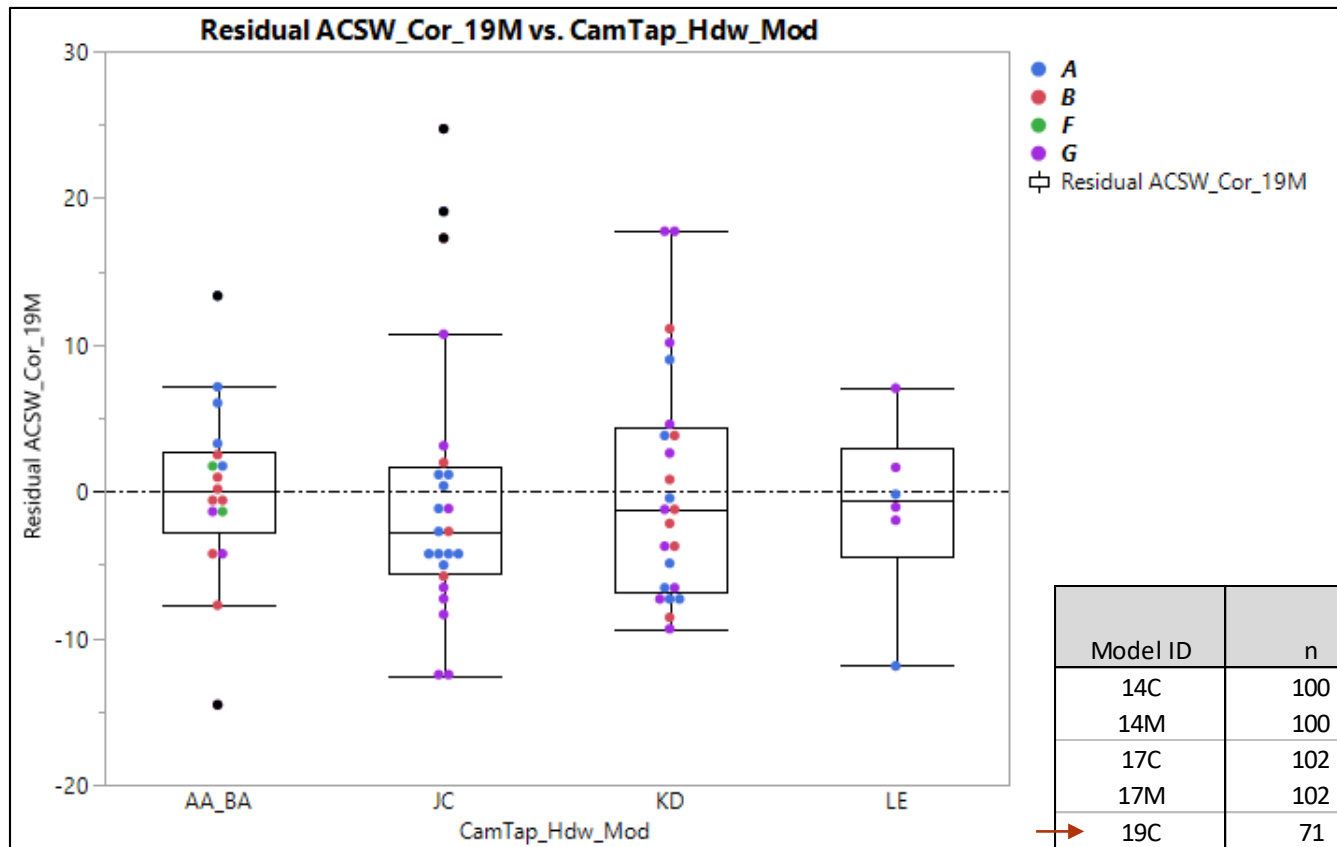# ISB Correction Factor and RO Blend Target Review

- Plot of model fit residuals with all hardware (no Lab D) - *for the multiplicative (19M) Correction Factor*
  - No apparent severity trend by Reference Oil – using corrected data

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

ISB Correction Factor and RO Blend Target Review

- Plot of model fit residuals with all hardware (no Lab D) - *for the multiplicative (19M) Correction Factor*
  - No apparent severity trend by Cam-Tappet Hardware with corrected data

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

ISB Correction Factor and RO Blend Target Review

- Why use multiplicative CFs in lieu of additive CFs?

  - Table below summarizes raw and (model fit) residual standard deviations by reference oil using the either additive or multiplicative corrected data
  - Results indicate that multiplicative correction factor models have smaller standard deviations (improved precision) - as compared to their additive counterparts

Analysis Columns	Statistics	830-2	PC10E(821)	PC10B(831)	831-1	831-2	831-3|4
ACSW_Cor_14C	Std Dev	9.0	4.6	4.6	6.1	11.6	10.2
ACSW_Cor_14M	Std Dev	9.0	4.6	4.5	4.8	9.1	8.5
Residual ACSW_Cor_14C	Std Dev	10.0	4.0	6.0	5.6	11.1	9.1
Residual ACSW_Cor_14M	Std Dev	9.7	4.0	5.6	4.3	8.7	7.7
ACSW_Cor_17C	Std Dev	9.0	4.6	4.6	6.1	11.6	11.6
ACSW_Cor_17M	Std Dev	9.0	4.6	4.6	4.8	9.3	9.4
Residual ACSW_Cor_17C	Std Dev	10.0	4.0	6.0	5.6	11.1	8.7
Residual ACSW_Cor_17M	Std Dev	9.7	4.0	5.6	4.4	8.9	7.4
ACSW_Cor_19C	Std Dev			4.9	9.0	11.6	10.2
ACSW_Cor_19M	Std Dev			4.9	7.5	9.8	9.2
Residual ACSW_Cor_19C	Std Dev			6.9	8.2	11.2	8.5
Residual ACSW_Cor_19M	Std Dev			6.5	6.8	9.4	7.8

Add CF Model

Mult CF Model

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

ISB Correction Factor and RO Blend Target Review

- Analysis of (14M) data for severity adjustment calculation
  - Based on reference oil model only (no laboratory factor)
  - RMSE for Severity Adjustment = 8.5

Response ACSW_Cor_19M

Whole Model

▷ **Actual by Predicted Plot**

▷ **Residual by Predicted Plot**

△ **Summary of Fit**

RSquare	0.208257
RSquare Adj	0.172805
Root Mean Square Error	8.482598
Mean of Response	48.41127
Observations (or Sum Wgts)	71

△ **Analysis of Variance**

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	1268.0813	422.694	5.8745
Error	67	4820.9496	71.954	Prob > F
C. Total	70	6089.0310		0.0013*

▷ **Parameter Estimates**

△ **Effect Tests**

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil_Mod	3	3	1268.0813	5.8745	0.0013*

RefOil_Mod

▷ **Leverage Plot**

△ **Least Squares Means Table**

Level	Least Sq Mean	Std Error	Mean
PC10B(831)	42.306667	2.1901974	42.3067
831-1	44.290000	2.6824331	44.2900
831-2	49.456522	1.7687440	49.4565
831-3|4	53.139130	1.7687440	53.1391

ISB Correction Factor and RO Blend Target Review

- Recommended Correction Factor & Target Updates:

  - Use model "19M" to generate Hardware CFs and Targets

    - Uses Camshaft-Tappet hardware batches "AA_BA", "JC", "KD", "LE"

    - Select Multiplicative CFs which have a lower RMSE and Reference Oil Standard Deviations

  - Multiplicative Correction Factor for "LE" Cam-Tap Hardware (w/RO 831-3|4) = 0.77

    - If using "KD" Cam-Tap Hardware, multiplicative correction factor = 0.94

  - Reference Oil Target (831-3|4) with hardware corrected data = 52.4

  - Standard Deviation Update for Reference Oil Yi calculations:

    - Raw Standard Deviation for (831-3|4) = 9.2 *(reference slide 19 in Table)*
    - Currently it is 8.7

  - Severity Adjustment Pooled S = 8.5 *(reference slide 20)*
    - Currently it is 8.7

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

Appendix – Summary of All Models

Evaluating Correction Factor Approaches

- Third Data Model to Evaluate:
  - Includes all Camshaft and Tappet batches
  - Includes all Reference Oil Data
  - Reference ID number 19 on slide 14 *(n = 71 without Lab "D")*

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
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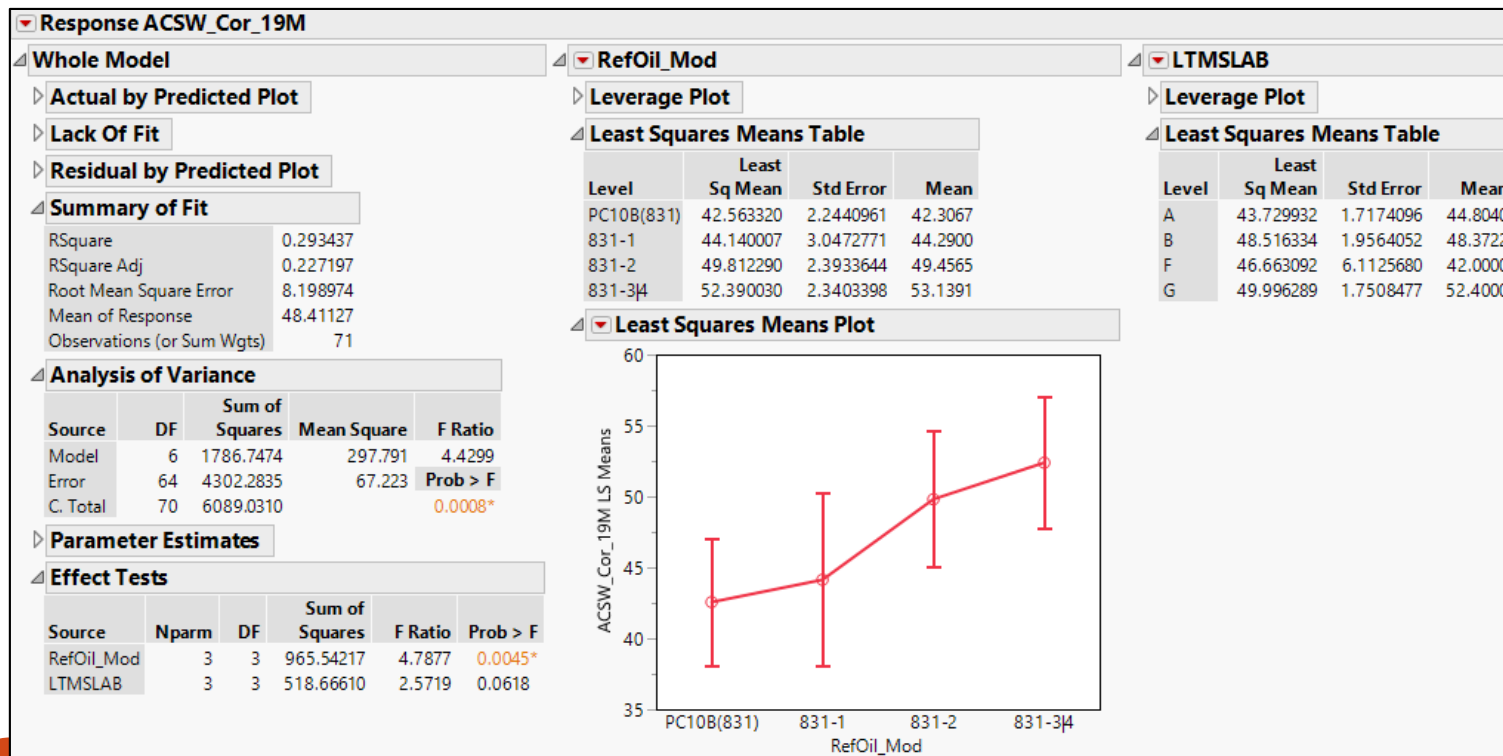# ISB Correction Factor and RO Blend Target Review

- Predicted LSMeans for (PM) PC10B(831) and Camshaft-Tappet hardware combinations are summarized below:
  - Predictions estimate the multiplicative effect of hardware severity on ACSW with using the Precision Matrix's reference oil PC10B(831)
  - Correction Factors calculated from original PM target of 42.5
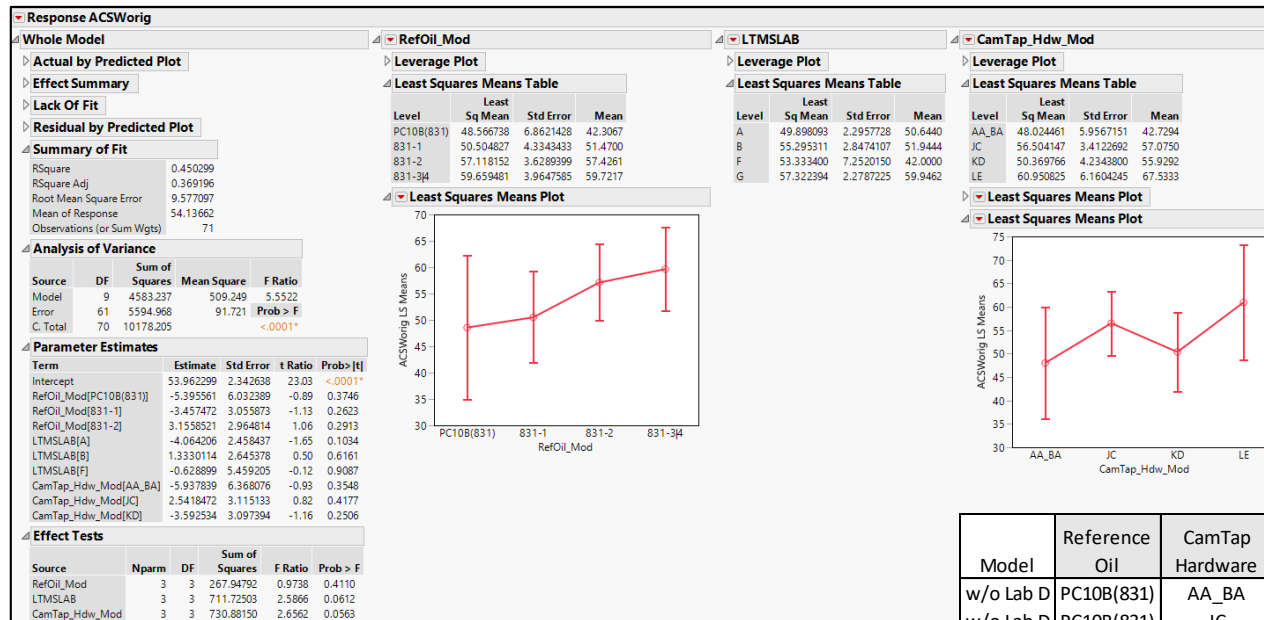
| Model	Reference Oil	CamTap Hardware	Pred. ACSW	Correction Factor Delta	Multiplicative CF	Orig PM Target	Updated Target
w/o Lab D	PC10B(831)	AA_BA	42.6			41.9	42.5
w/o Lab D	PC10B(831)	JC	51.1	8.6	0.83		
w/o Lab D	PC10B(831)	KD	45.0	2.5	0.94		
w/o Lab D	PC10B(831)	LE	55.6	13.1	0.77		

ISB Correction Factor and RO Blend Target Review

- Analysis of ACSWOrig using (*multiplicative*) *corrected* data

- Overall model summary:
  - Reference oil is significant and lab is marginally significant
  - RMSE = 8.2, RO LSMeans Target for 831-3|4 = 52.4

Response ACSW_Cor_19M

Whole Model				
▷ Actual by Predicted Plot				
▷ Lack Of Fit				
▷ Residual by Predicted Plot				

Summary of Fit

RSquare	0.293437
RSquare Adj	0.227197
Root Mean Square Error	8.198974
Mean of Response	48.41127
Observations (or Sum Wgts)	71

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	1786.7474	297.791	4.4299
Error	64	4302.2835	67.223	Prob > F
C. Total	70	6089.0310		0.0008*

▷ **Parameter Estimates**

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil_Mod	3	3	965.54217	4.7877	0.0045*
LTMSLAB	3	3	518.66610	2.5719	0.0618

RefOil_Mod

▷ Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
PC10B(831)	42.563320	2.2440961	42.3067
831-1	44.140007	3.0472771	44.2900
831-2	49.812290	2.3933644	49.4565
831-3|4	52.390030	2.3403398	53.1391

Least Squares Means Plot

LTMSLAB

▷ Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	43.729932	1.7174096	44.8040
B	48.516334	1.9564052	48.3722
F	46.663092	6.1125680	42.0000
G	49.996289	1.7508477	52.4000

ISB Correction Factor and RO Blend Target Review

- Analysis of ACSWOrig using (*additive*) *corrected* data

- Overall model summary:
  - Reference oil is significant and lab is marginally significant
  - RMSE = 9.3, RO LSMeans Target for 831-3|4 = 53.6
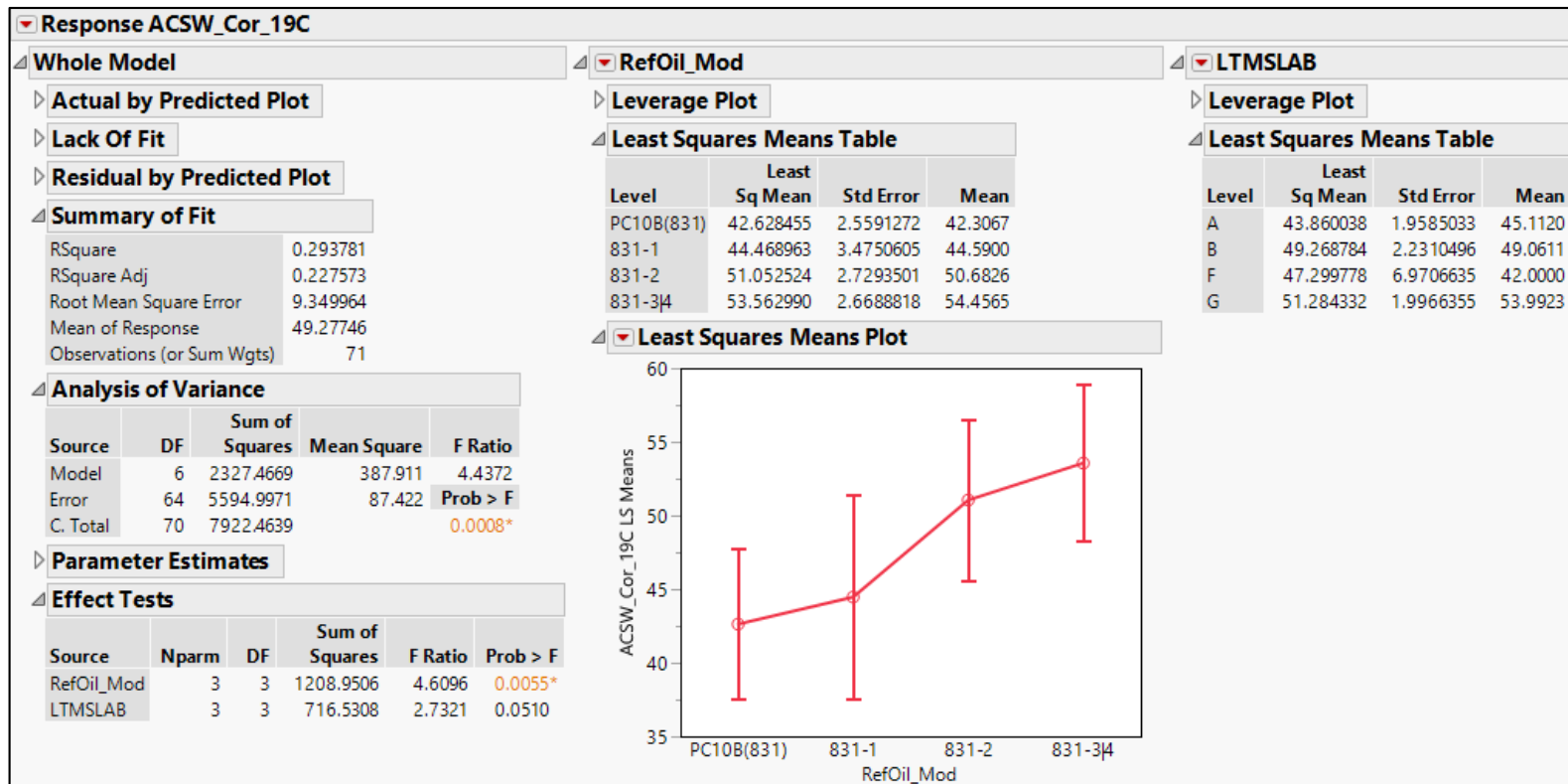
Evaluating Correction Factor Approaches

- Third Data Model to Evaluate:
  - Includes all Camshaft and Tappet batches
  - Includes all Reference Oil Data
  - Reference ID number 14 on slide 14 *(n = 100 without Lab"D")*

| Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

Evaluating Correction Factor Approaches

- Predicted LSMeans for (PM) PC10B(831) and Camshaft-Tappet hardware combinations are summarized below:

  - LSMeans are used to establish multiplicative CFs (by hardware batch)

  - Predictions estimate the multiplicative effect of hardware severity on ACSW with using the Precision Matrix's reference oil PC10B(831)
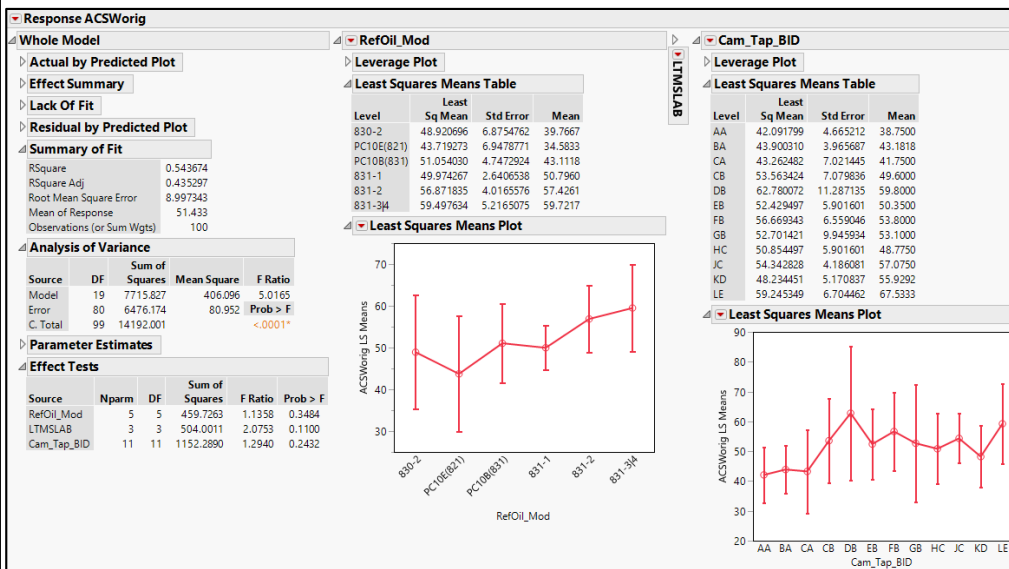
| Model	Reference Oil	Cam Hardware	Pred. ACSW	Correction Factor Delta	Multiplicative CF	Orig PM Target	Updated Target
w/o Lab D	PC10B(831)	AA	41.5			41.9	42.5
w/o Lab D	PC10B(831)	BA	43.3	1.81	0.96		
w/o Lab D	PC10B(831)	CA	42.6	1.17	0.97		
w/o Lab D	PC10B(831)	CB	52.9	11.47	0.78		
w/o Lab D	PC10B(831)	DB	62.2	20.69	0.67		
w/o Lab D	PC10B(831)	EB	51.8	10.34	0.80		
w/o Lab D	PC10B(831)	FB	56.1	14.58	0.74		
w/o Lab D	PC10B(831)	GB	52.1	10.61	0.80		
w/o Lab D	PC10B(831)	HC	50.2	8.76	0.83		
w/o Lab D	PC10B(831)	JC	53.7	12.25	0.77		
w/o Lab D	PC10B(831)	KD	47.6	6.14	0.87		
w/o Lab D	PC10B(831)	LE	58.6	17.15	0.71		

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Evaluating Correction Factor Approaches

- Analysis of ACSWOrig data with *additive correction factors* applied
  - Corrected data for all Camshaft-Tappet Hardware Batches
- Overall model summary:
  - Reference Oil is significant and Lab is marginally significant *(p=0.065)*
  - RMSE = 8.4, RO LSMeans Target for 831-3|4 = 49.9
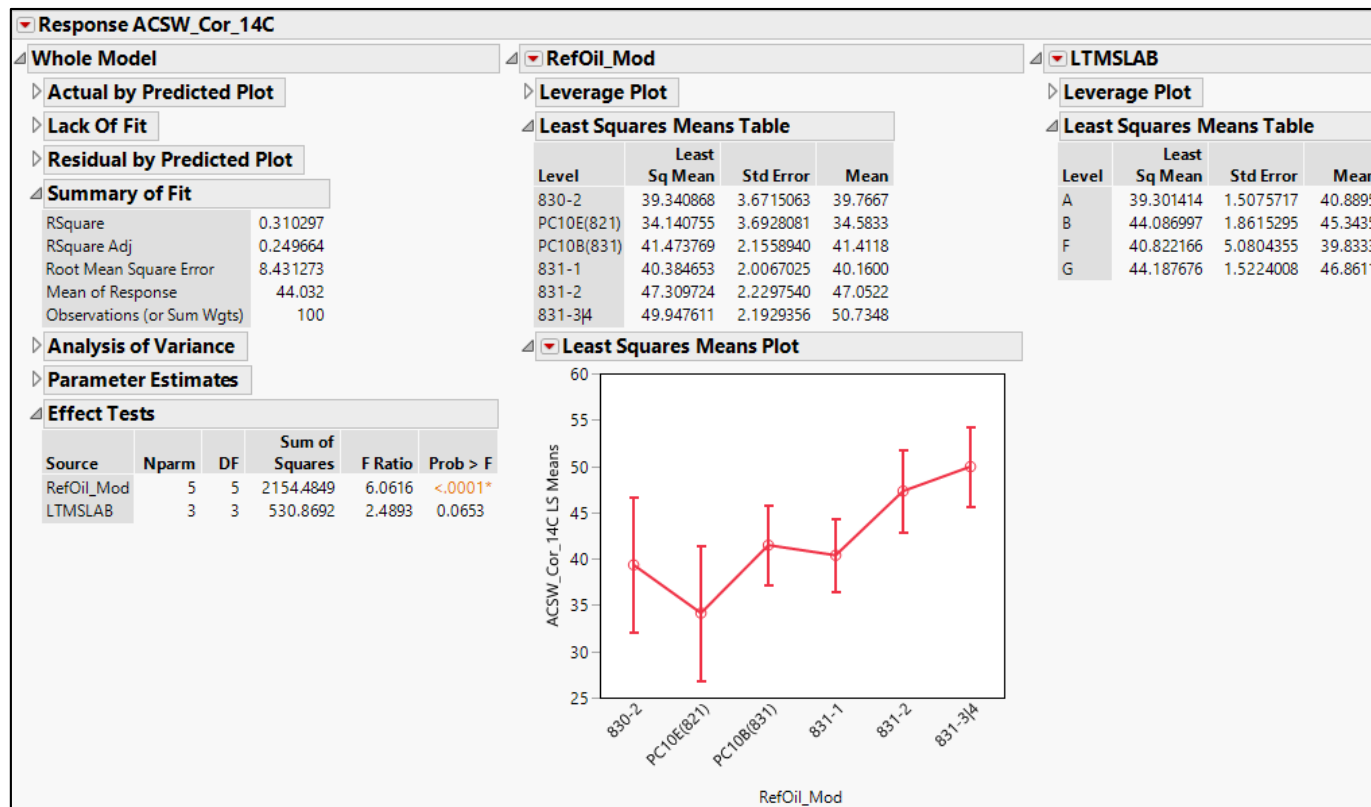
Evaluating Correction Factor Approaches

- Analysis of ACSWOrig data with *multiplicative correction factors* applied
  - Corrected data for all Camshaft-Tappet Hardware Batches
- Overall model summary:
  - Reference Oil is significant and Lab is marginally significant ($p = 0.08$)
 - RMSE = 7.0, RO LSMeans Target for 831-3|4 = 48.6
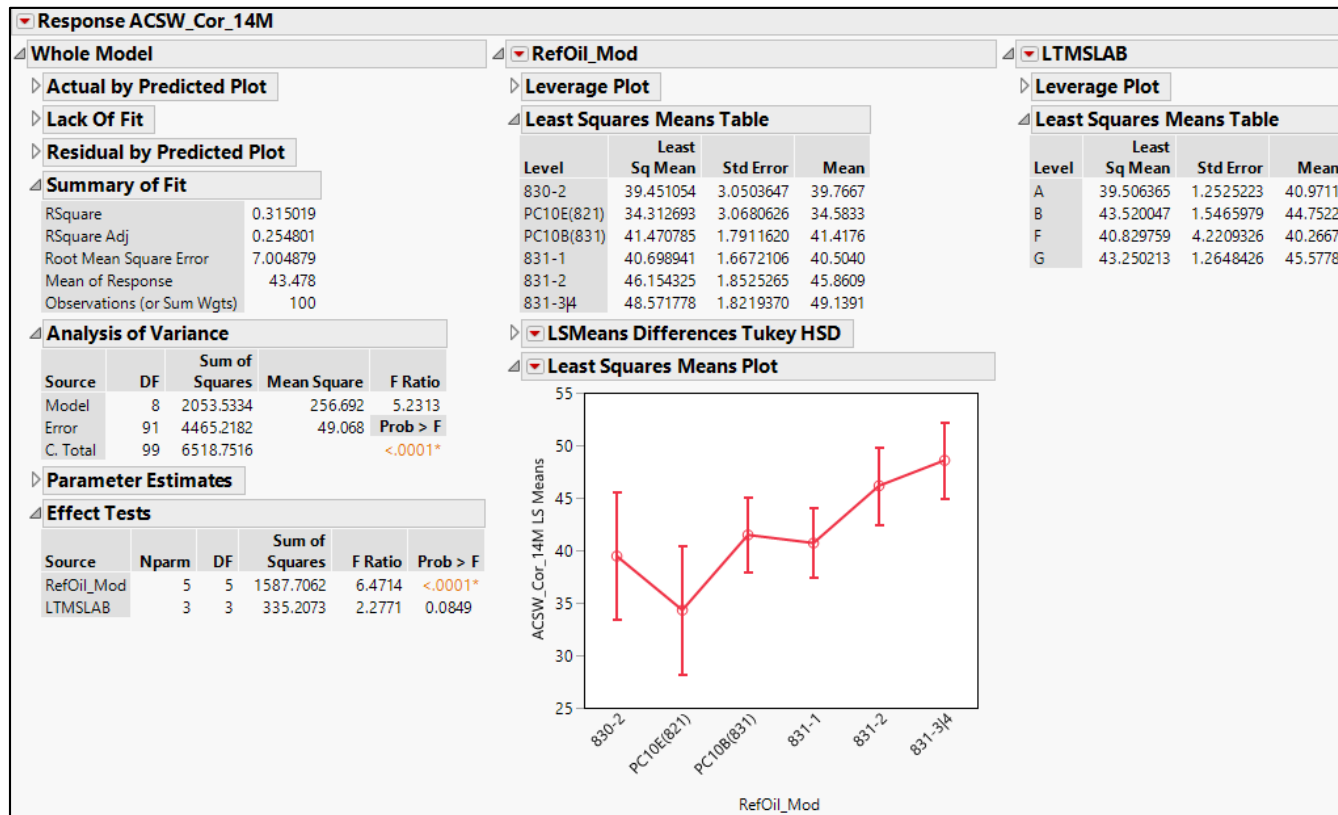
Evaluating Correction Factor Approaches

- Fourth Data Model to Evaluate:
  - Includes all Camshaft and Tappet batches
  - Includes all Reference Oils
  - Reference ID number 17 on slide 14 *(n = 102 with Lab "D")*

| Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

Evaluating Correction Factor Approaches

- Analysis of PM and current cams and reference oils (with Lab D):
  - Includes all Camshaft Tappet batches *(reference data ID #17 on slide 14)*
  - Includes RO's PC10B, PC10E, 830-2, PC10B, PC10E, 831-1, 831-2, & 831-3|4

- Predicted LSMeans for (PM) PC10B(831) and Camshaft-Tappet hardware combinations are shown below:
  - LSMeans used to establish additive and multiplicative CFs (by hardware batch)
  - Predictions estimate the effect of hardware severity on ACSW with (PM) PC10B(831)
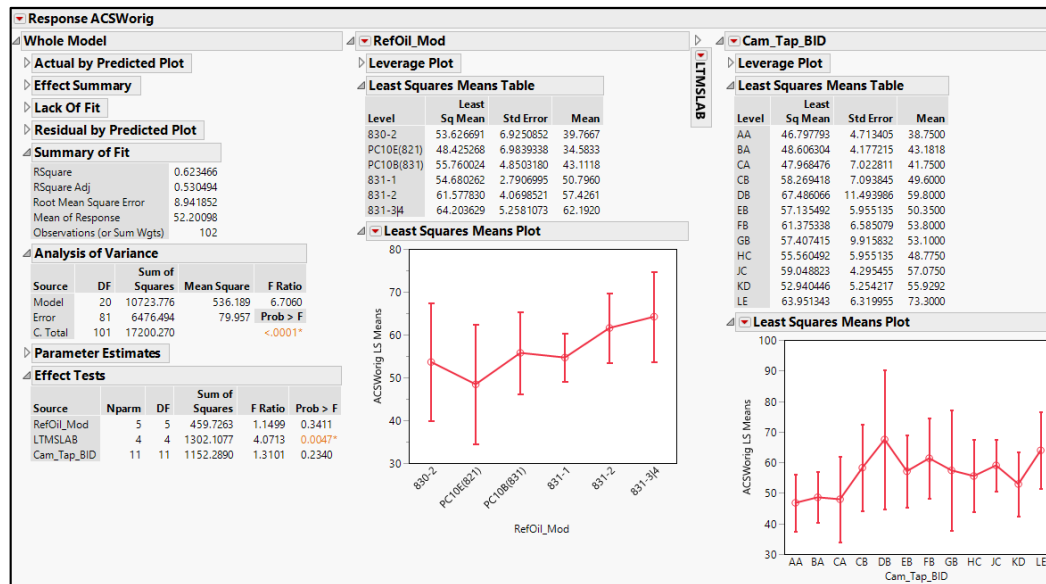
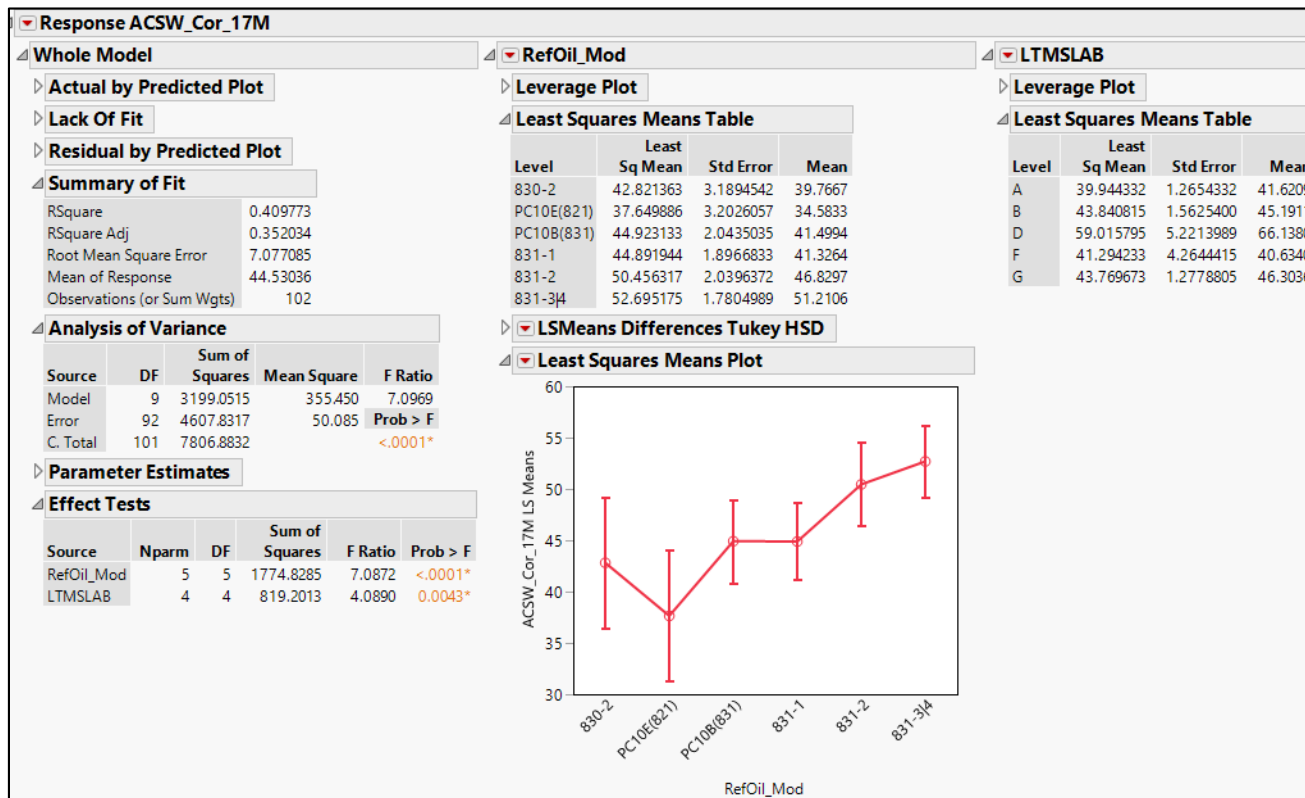| Model	Reference Oil	Cam Hardware	Pred. ACSW	Correction Factor Delta	Multiplicative CF	Orig PM Target	Updated Target
						41.9	42.5
w/ Lab D	PC10B(831)	AA	46.2				
w/ Lab D	PC10B(831)	BA	48.0	1.81	0.96		
w/ Lab D	PC10B(831)	CA	47.3	1.17	0.98		
w/ Lab D	PC10B(831)	CB	57.7	11.47	0.80		
w/ Lab D	PC10B(831)	DB	66.9	20.69	0.69		
w/ Lab D	PC10B(831)	EB	56.5	10.34	0.82		
w/ Lab D	PC10B(831)	FB	60.8	14.58	0.76		
w/ Lab D	PC10B(831)	GB	56.8	10.61	0.81		
w/ Lab D	PC10B(831)	HC	54.9	8.76	0.84		
w/ Lab D	PC10B(831)	JC	58.4	12.25	0.79		
w/ Lab D	PC10B(831)	KD	52.3	6.14	0.88		
w/ Lab D	PC10B(831)	LE	63.3	17.15	0.73		

Evaluating Correction Factor Approaches

- Analysis of ACSWOrig data with *additive correction factors* applied
  - Corrected data for all Camshaft-Tappet Hardware Batches
- Overall model summary:
  - Reference Oil and Lab are statistically significant
  - RMSE = 8.4, RO LSMeans Target for 831-3|4 = 54.6
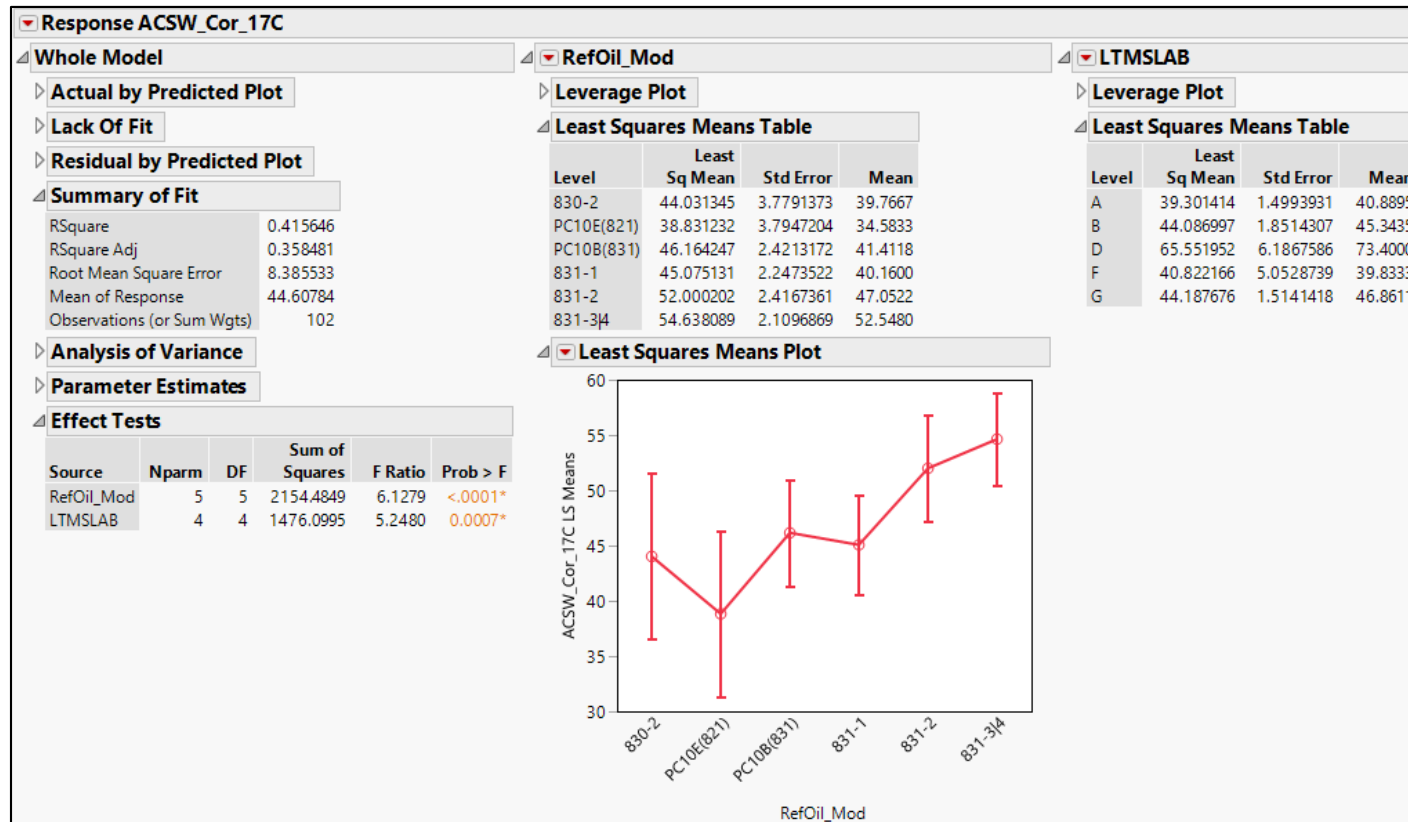
Evaluating Correction Factor Approaches

- Analysis of ACSWOrig data with *multiplicative correction factors* applied
  - Corrected data for all Camshaft-Tappet Hardware Batches
- Overall model summary:
  - Reference Oil and Lab are statistically significant
  - RMSE = 7.1, RO LSMeans Target for 831-3|4 = 52.7

Response ACSW_Cor_17M

Whole Model

Actual by Predicted Plot

Lack Of Fit

Residual by Predicted Plot

Summary of Fit

RSquare	0.409773
RSquare Adj	0.352034
Root Mean Square Error	7.077085
Mean of Response	44.53036
Observations (or Sum Wgts)	102

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	3199.0515	355.450	7.0969
Error	92	4607.8317	50.085	Prob > F
C. Total	101	7806.8832		<.0001*

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil_Mod	5	5	1774.8285	7.0872	<.0001*
LTMSLAB	4	4	819.2013	4.0890	0.0043*

RefOil_Mod

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
830-2	42.821363	3.1894542	39.7667
PC10E(821)	37.649886	3.2026057	34.5833
PC10B(831)	44.923133	2.0435035	41.4994
831-1	44.891944	1.8966833	41.3264
831-2	50.456317	2.0396372	46.8297
831-3|4	52.695175	1.7804989	51.2106

LSMeans Differences Tukey HSD

Least Squares Means Plot

LTMSLAB

Leverage Plot

Least Squares Means Table

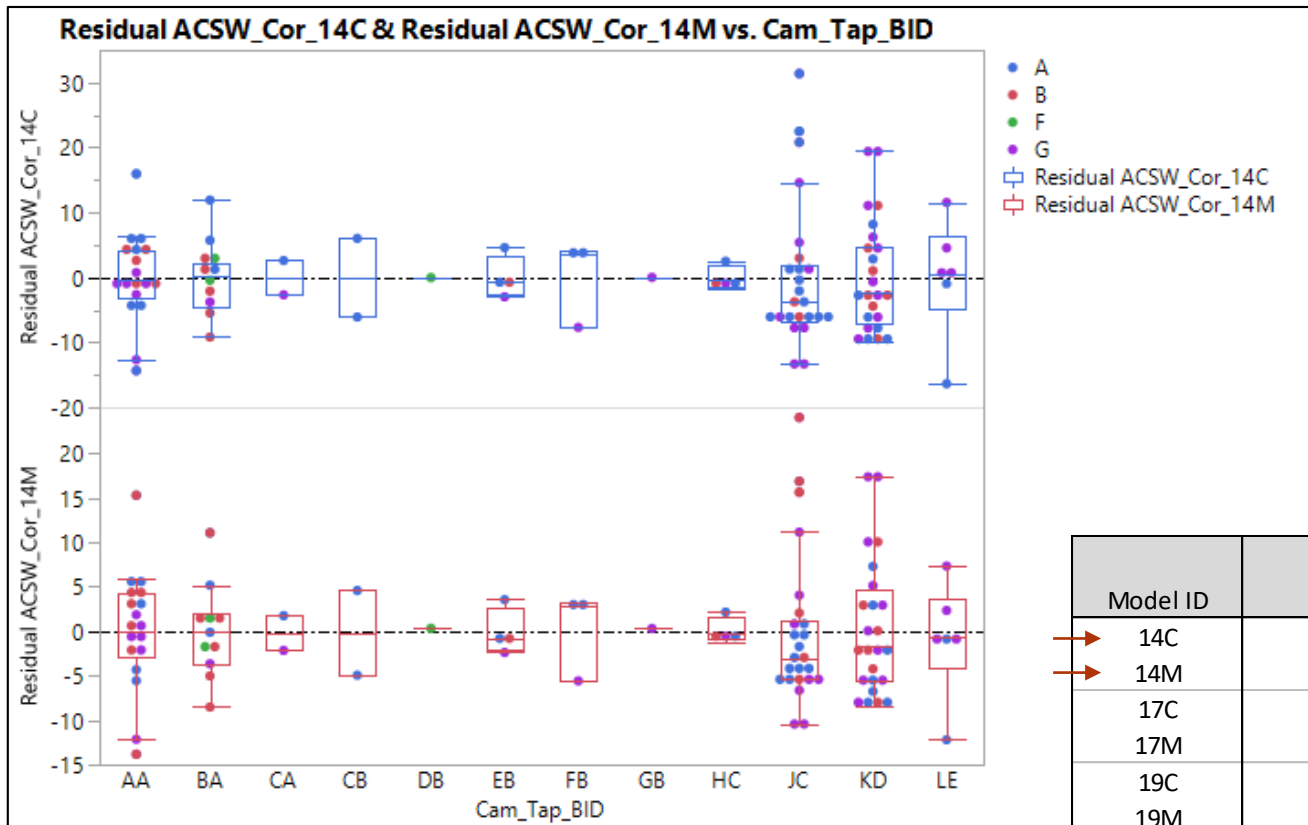| Level	Least Sq Mean	Std Error	Mean
A	39.944332	1.2654332	41.6209
B	43.840815	1.5625400	45.1911
D	59.015795	5.2213989	66.1380
F	41.294233	4.2644415	40.6340
G	43.769673	1.2778805	46.3036

Summary of all Models

ISB Correction Factor and RO Blend Target Review

- Summary of all evaluated models with CFs are provided in below table

- Highlights of Analyses:

  - Overall Precision (RMSE) of ISB data is improved with *Multiplicative CFs* as compared to *Additive CFs*

  - Similar Correction Factor ranges for both multiplicative and additive methods – regardless of the data set analyzed

  - Calculated LSMeans for PC10B(831) appear higher when Lab D is included in the data set

Model ID	n	LSMeans PC10B(831)	LSMeans 831-3|4	RMSE	Lab D Data	Correction Factor Type	CamTap "LE" Cor-Factor
14C	100	41.5	49.9	8.4	No	Additive	-17.2
14M	100	41.5	48.6	7.0	No	Multiplicative	0.71
17C	102	46.2	54.6	8.4	Yes	Additive	-17.2
17M	102	44.9	52.7	7.1	Yes	Multiplicative	0.73
19C	71	42.6	53.6	9.3	No	Additive	-13.1
19M	71	42.6	52.4	8.2	No	Multiplicative	0.77

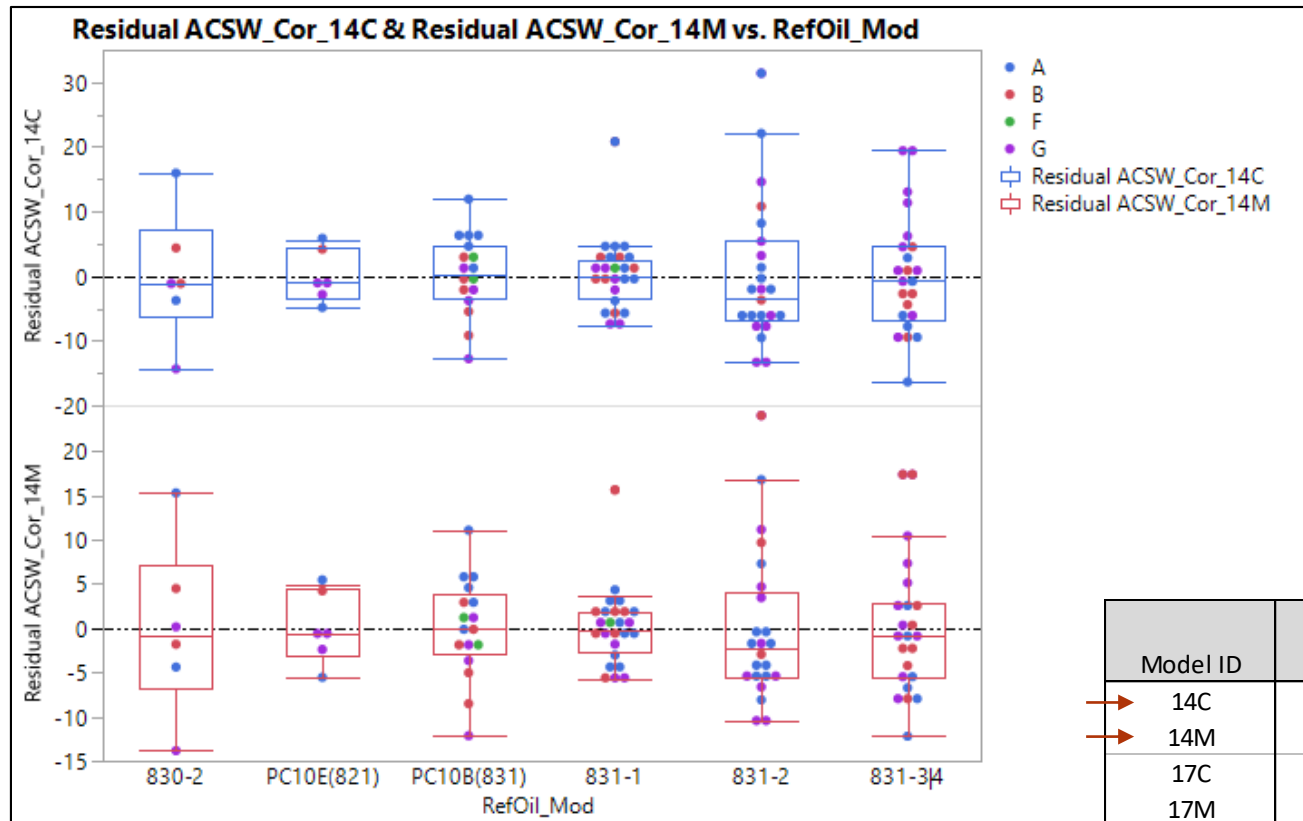# ISB Correction Factor and RO Blend Target Review

- Plot of model fit residuals with all hardware (no Lab D) - *for additive (14C) and multiplicative (14M) CFs*
  - No apparent severity trend by Camshaft-Tappet batch – using corrected data

Residual ACSW_Cor_14C & Residual ACSW_Cor_14M vs. Cam_Tap_BID

Model ID	n	Lab D Data	Correction Factor Type
→ 14C	100	No	Additive
→ 14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

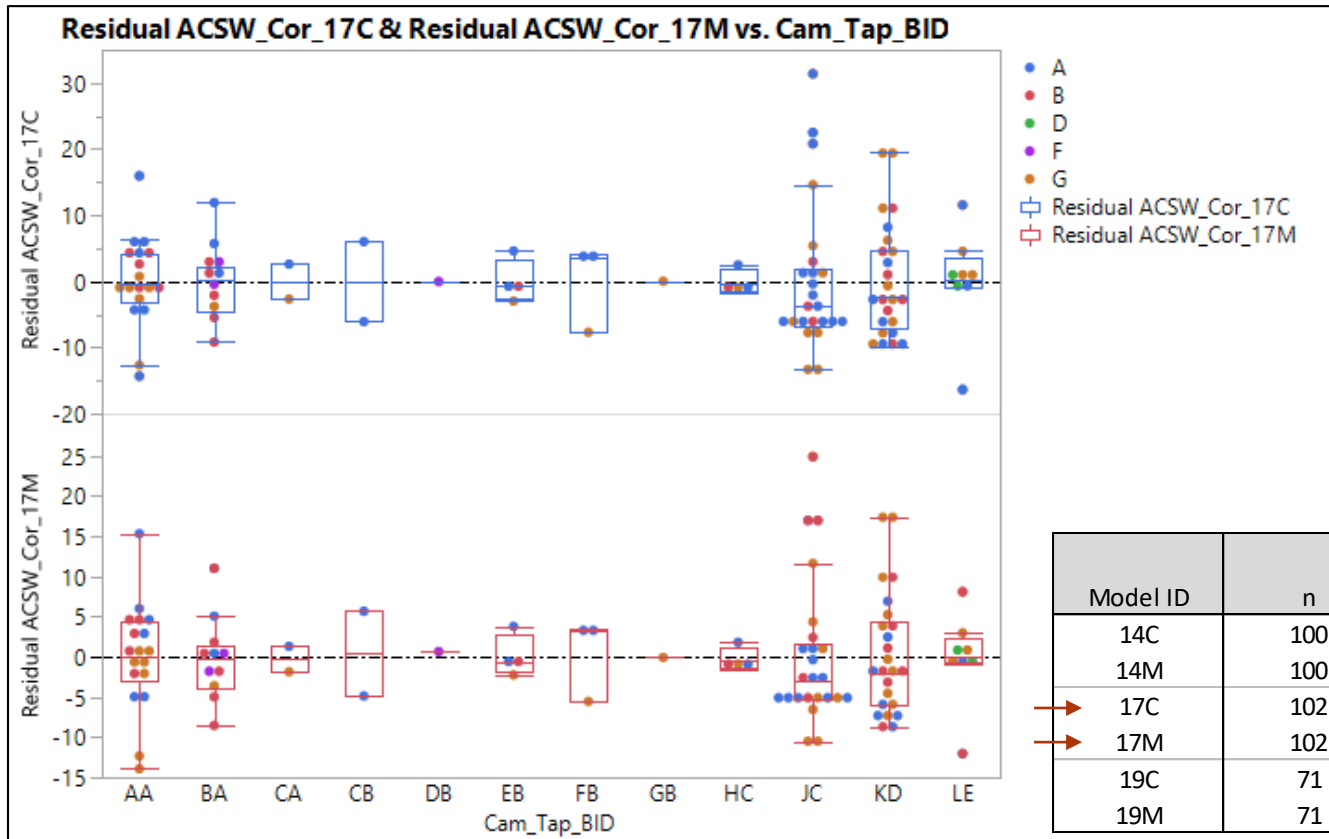# ISB Correction Factor and RO Blend Target Review

- Plot of model fit residuals with all hardware (no Lab D) - *for additive (14C) and multiplicative (14M) CFs*
  - No apparent severity trend by Reference Oil – using corrected data

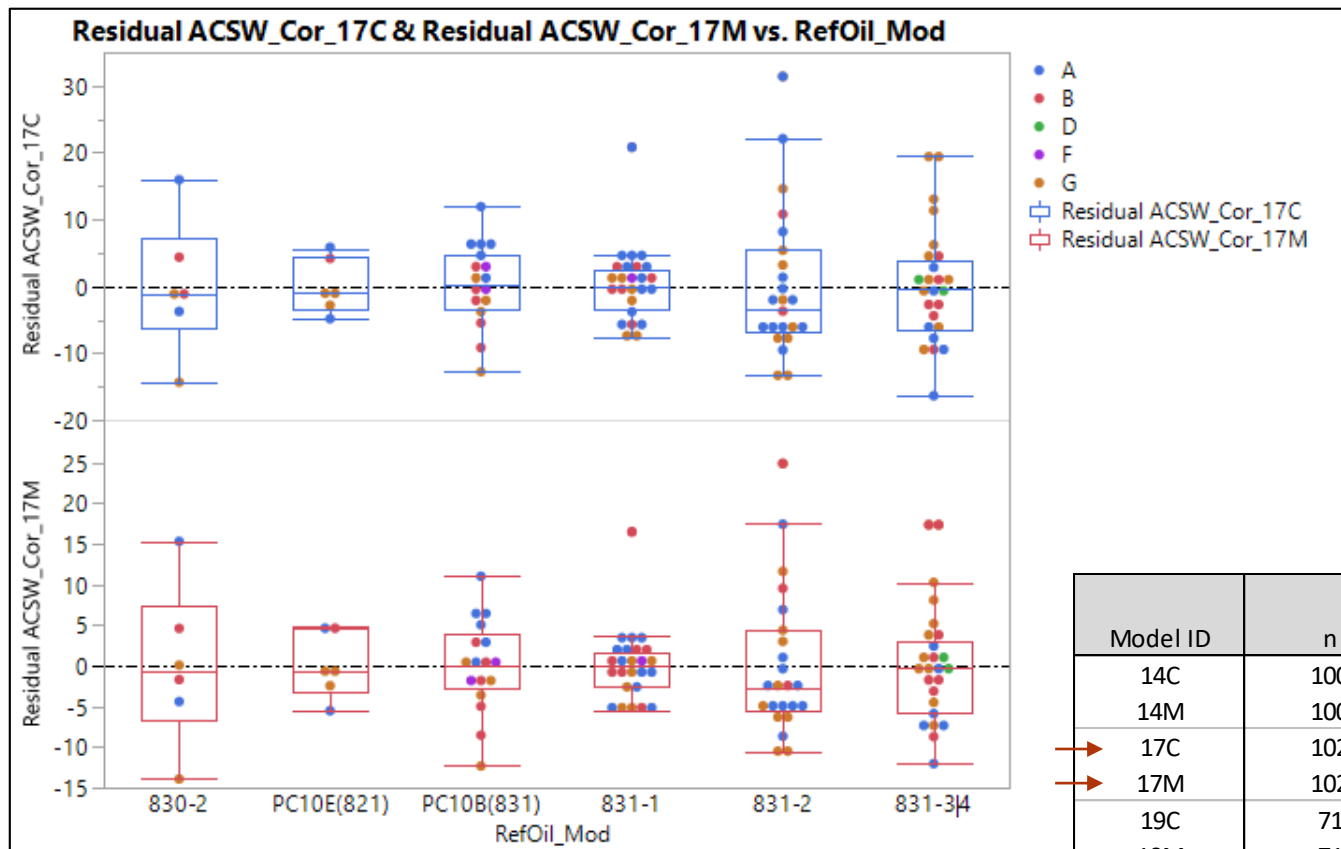| Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

ISB Correction Factor and RO Blend Target Review

- Plot of model fit residuals with all hardware (w/Lab D) - *for additive (17C) and multiplicative (17M) CFs*
  - No apparent severity trend by Cam-Tap Hardware – using corrected data

Residual ACSW_Cor_17C & Residual ACSW_Cor_17M vs. Cam_Tap_BID

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

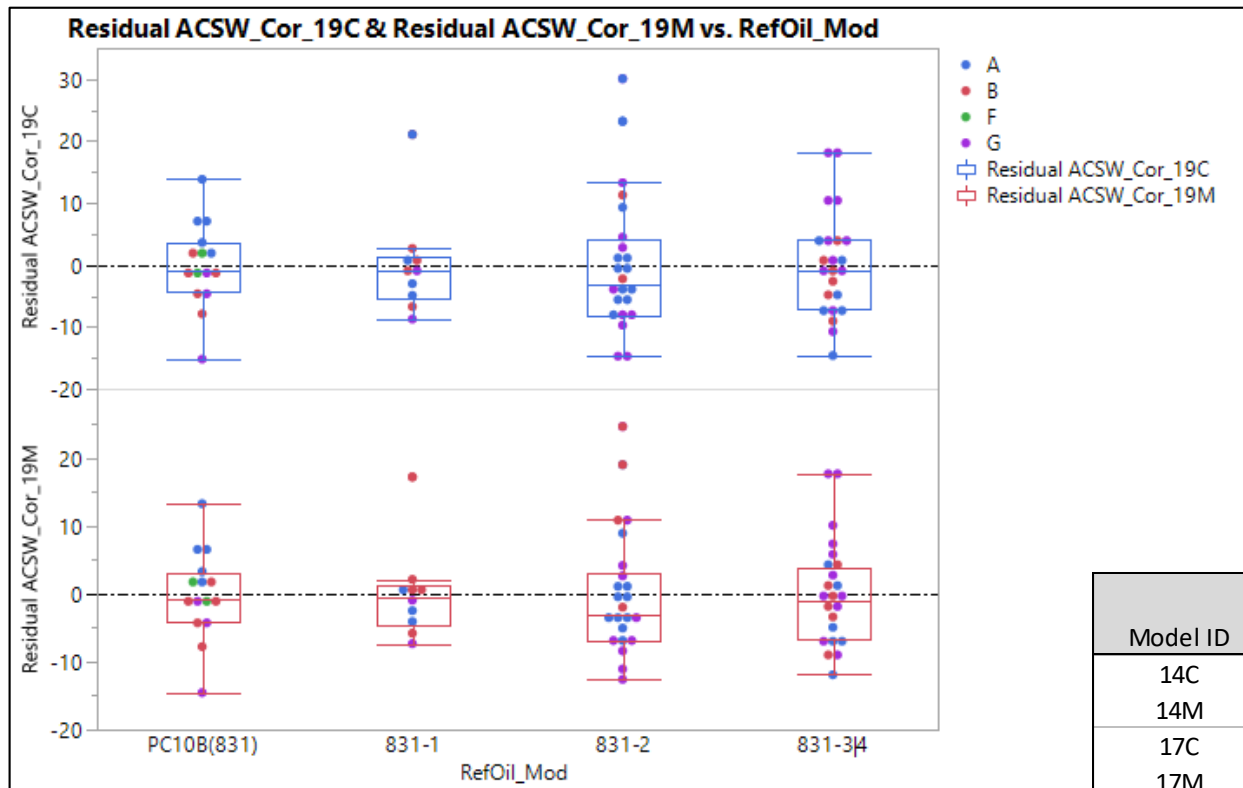# ISB Correction Factor and RO Blend Target Review

- Plot of model fit residuals with all hardware (w/ Lab D) - *for additive (17C) and multiplicative (17M) CFs*
  - No apparent severity trend Reference Oil – using corrected data

Residual ACSW_Cor_17C & Residual ACSW_Cor_17M vs. RefOil_Mod

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

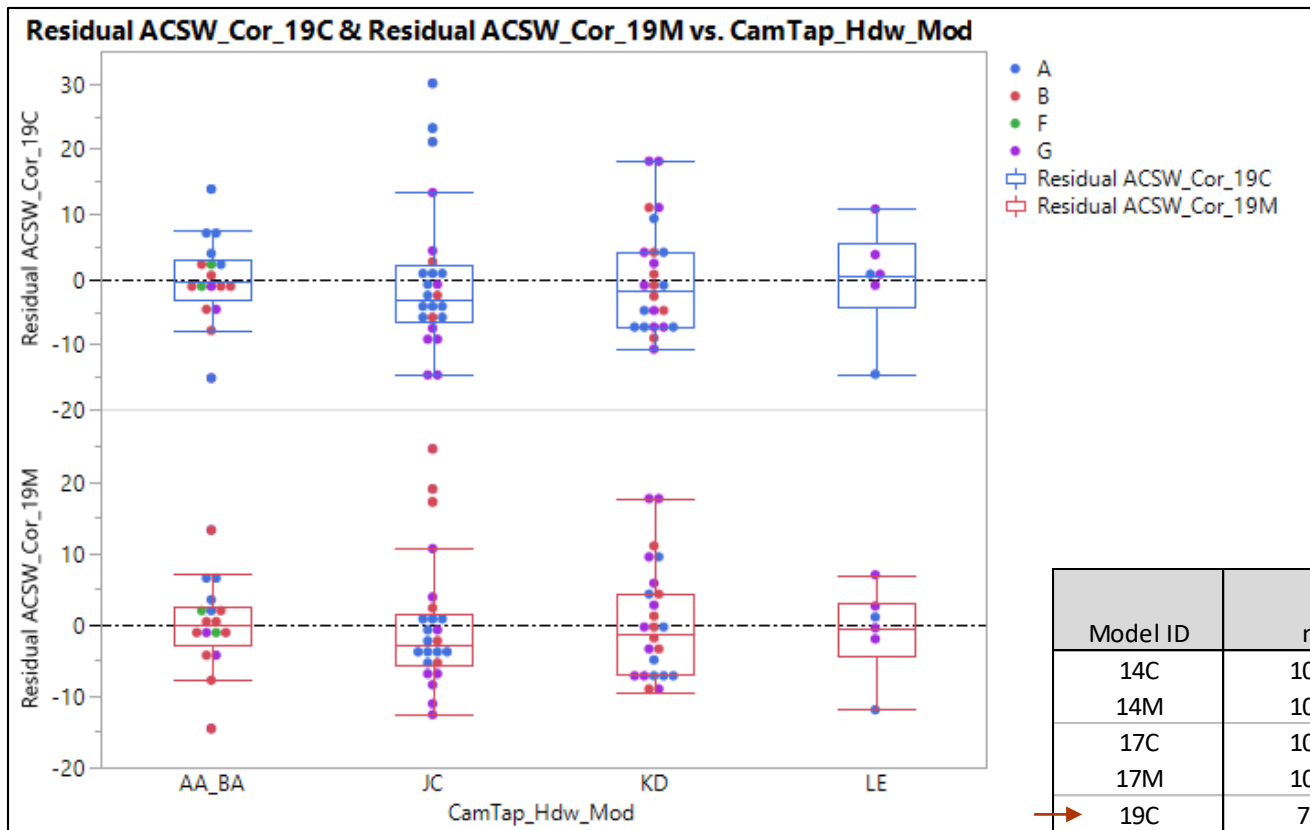# ISB Correction Factor and RO Blend Target Review

- Plot of model fit residuals with all hardware (no Lab D) - *for additive (19C) and multiplicative (19M) CFs*
  - No apparent severity trend by Reference Oil – using corrected data

Residual ACSW_Cor_19C & Residual ACSW_Cor_19M vs. RefOil_Mod

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

ISB Correction Factor and RO Blend Target Review

- Plot of model fit residuals with all hardware (no Lab D) - *for additive (19C) and multiplicative (19M) CFs*
  - No apparent severity trend by Cam-Tap Hardware – using corrected data

Residual ACSW_Cor_19C & Residual ACSW_Cor_19M vs. CamTap_Hdw_Mod

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

ISB Correction Factor and RO Blend Target Review

- Table summarizes raw and (model fit) residual standard deviations by reference oil – using corrected data

- Results indicate that multiplicative correction factor models have smaller standard deviations - as compared to their additive counterparts

Analysis Columns	Statistics	830-2	PC10E(821)	PC10B(831)	831-1	831-2	831-3|4
ACSW_Cor_14C	Std Dev	9.0	4.6	4.6	6.1	11.6	10.2
ACSW_Cor_14M	Std Dev	9.0	4.6	4.5	4.8	9.1	8.5
Residual ACSW_Cor_14C	Std Dev	10.0	4.0	6.0	5.6	11.1	9.1
Residual ACSW_Cor_14M	Std Dev	9.7	4.0	5.6	4.3	8.7	7.7
ACSW_Cor_17C	Std Dev	9.0	4.6	4.6	6.1	11.6	11.6
ACSW_Cor_17M	Std Dev	9.0	4.6	4.6	4.8	9.3	9.4
Residual ACSW_Cor_17C	Std Dev	10.0	4.0	6.0	5.6	11.1	8.7
Residual ACSW_Cor_17M	Std Dev	9.7	4.0	5.6	4.4	8.9	7.4
ACSW_Cor_19C	Std Dev			4.9	9.0	11.6	10.2
ACSW_Cor_19M	Std Dev			4.9	7.5	9.8	9.2
Residual ACSW_Cor_19C	Std Dev			6.9	8.2	11.2	8.5
Residual ACSW_Cor_19M	Std Dev			6.5	6.8	9.4	7.8

Add CF Model

Mult CF Model

Model ID	n	Lab D Data	Correction Factor Type
14C	100	No	Additive
14M	100	No	Multiplicative
17C	102	Yes	Additive
17M	102	Yes	Multiplicative
19C	71	No	Additive
19M	71	No	Multiplicative

ISB Correction Factor and RO Blend Target Review

- Table summarizes raw and (model fit) residual standard deviations by reference oil – using corrected data
- Results indicate that multiplicative correction factor models have smaller standard deviations - as compared to their additive counterparts

Analysis Columns	Statistics	830-2	PC10E(821)	PC10B(831)	831-1	831-2	831-3|4
ACSW_Cor_14C	Std Dev	9.0	4.6	4.6	6.1	11.6	10.2
ACSW_Cor_14M	Std Dev	9.0	4.6	4.5	4.8	9.1	8.5
Residual ACSW_Cor_14C	Std Dev	10.0	4.0	6.0	5.6	11.1	9.1
Residual ACSW_Cor_14M	Std Dev	9.7	4.0	5.6	4.3	8.7	7.7
ACSW_Cor_17C	Std Dev	9.0	4.6	4.6	6.1	11.6	11.6
ACSW_Cor_17M	Std Dev	9.0	4.6	4.6	4.8	9.3	9.4
Residual ACSW_Cor_17C	Std Dev	10.0	4.0	6.0	5.6	11.1	8.7
Residual ACSW_Cor_17M	Std Dev	9.7	4.0	5.6	4.4	8.9	7.4

Add CF Model

Mult CF Model

Model ID	n	Cam-Tap Hardware	Lab D Data Included?	Correction Factor Type
14C	100	All Hardware	No	Additive
14M	100	All Hardware	No	Multiplicative
17C	102	All Hardware	Yes	Additive
17M	102	All Hardware	Yes	Multiplicative