Mack T-12 – Impact of New Parts and ICF Review
SP Discussion (3 Test ICF Determination)

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09/09/2021

Performance you can rely on.

Summary of proposal

Before and After ICF applied by parameter						additive ICF		multiplicative ICF		
ALW	**ln ALW**		**Lab**	**original ALW**	**ln ALW**	**afterCF**	**Original scale after CF**		**afterCF**	**Original scale after CF**	**Current ICF 02/23/2017 multiplicative**
Predicted	3.6615		G	40.1	3.6914	2.8144	16.7	**0.761**	2.8092	16.6	
TARGET	2.7850	Target on Original scale= 16.2	D	37.7	3.6297	2.7527	15.7		2.7622	15.8	0.7430
additive ICF	**-0.8770**		A	35.6	3.5723	2.6953	14.8		2.7185	15.2	
OILCON	**ln OILCON**		**Lab**	**original OILCON**	**ln OILCON**	**afterCF**	**Original scale after CF**		**afterCF**	**Original scale after CF**	
Predicted	4.5102		G	94.7	4.5507	4.1337	62.4	**0.907**	4.1275	62	0.926
TARGET	4.0930		D	87.2	4.4682	4.0512	57.5		4.0527	57.6	
additive ICF	**-0.4170**		A	96.7	4.5716	4.1546	63.7		4.1464	63.2	
ATRWL	**Keep current ICF as is**										0.846
PB	**Keep current ICF as is**										
PB2	**Keep current ICF as is**										

If $OC_{100\text{-}300} > 65.0$

$\Delta Lead_{Final} = \exp[\ln(\Delta Lead) + (65.0 - OC_{100\text{-}300}) \times 0.03234]$

If $OC_{100\text{-}300} \leq 65.0$

$\Delta Lead_{Final} = \Delta Lead$

If $OC_{100\text{-}300} > 65.0$

$\Delta Lead\ (250\text{-}300)_{Final} = \exp[\ln(\Delta Lead(250\text{-}300)) + (65.0 - OC_{100\text{-}300}) \times 0.04089$

If $OC_{100\text{-}300} \leq 65.0$

$\Delta Lead\ (250\text{-}300)_{Final} = \Delta Lead(250\text{-}300)$

In general, test results after additive and multiplicative ICFs are applied are close to each other

Includes: Lab A (159933), Lab D (159843) and Lab G (159551)

Impact of using Additive ICF versus Multiplicative ICF

What happens close to the pass/fail region?

					Multiplicative	0.761
					Additive	-0.877
	passing value	**ln ALW**	**after ICF**	**original scale**		
Liner Wear	24					
Test result before Additive ICF	57.8	4.057	3.18	24		
Test result before Multiplicative ICF	65.2	4.1775	3.1791	24		
					Multiplicative	0.907
					Additive	-0.417
	passing value	**ln OILCON**	**after ICF**	**original scale**		
OILCON	85					
Test result before Additive ICF	129	4.8598	4.4428	85		
Test result before Multiplicative ICF	134	4.8978	4.4423	85		

Motion 1: Additive ICF

Before and After ICF applied by parameter						additive ICF	
ALW	**ln ALW**		**Lab**	**original ALW**	**ln ALW**	**afterCF**	**Original scale after CF**
Predicted	3.6615		G	40.1	3.6914	2.8144	16.7
TARGET	2.7850	Target on Original scale= 16.2	D	37.7	3.6297	2.7527	15.7
additive ICF	**-0.8770**		A	35.6	3.5723	2.6953	14.8
OILCON	**ln OILCON**		**Lab**	**original OILCON**	**ln OILCON**	**afterCF**	**Original scale after CF**
Predicted	4.5102		G	94.7	4.5507	4.1337	62.4
TARGET	4.0930		D	87.2	4.4682	4.0512	57.5
additive ICF	**-0.4170**		A	96.7	4.5716	4.1546	63.7
ATRWL	**Keep current ICF as is**	**Multiplicative ICF = 0.846**					
PB	**Keep current ICF as is**	If $OC_{100\text{-}300}$>65.0 $\Delta Lead_{Final}$ = exp[ln(ΔLead) +(65.0 – $OC_{100\text{-}300}$) x 0.03234] If $OC_{100\text{-}300}$≤65.0 $\Delta Lead_{Final}$ = ΔLead					
PB2	**Keep current ICF as is**	If $OC_{100\text{-}300}$>65.0 $\Delta Lead\ (250\text{-}300)_{Final}$ = exp[ln(ΔLead(250-300))+(65.0 – $OC_{100\text{-}300}$) x 0.04089 If $OC_{100\text{-}300}$≤65.0 $\Delta Lead\ (250\text{-}300)_{Final}$ = ΔLead(250-300)					

Motion 2: Multiplicative ICF

Before and After ICF applied by parameter						multiplicative ICF		
ALW	**ln ALW**		**Lab**	**original ALW**	**ln ALW**		**afterCF**	**Original scale after CF**
Predicted	3.6615		G	40.1	3.6914	**0.761**	2.8092	16.6
TARGET	2.7850	Target on Original scale= 16.2	D	37.7	3.6297		2.7622	15.8
			A	35.6	3.5723		2.7185	15.2
OILCON	**ln OILCON**		**Lab**	**original OILCON**	**ln OILCON**		**afterCF**	**Original scale after CF**
Predicted	4.5102		G	94.7	4.5507	**0.907**	4.1275	62
TARGET	4.0930		D	87.2	4.4682		4.0527	57.6
			A	96.7	4.5716		4.1464	63.2
ATRWL	**Keep current ICF as is**	**Multiplicative ICF = 0.846**						
PB	**Keep current ICF as is**	If $OC_{100\text{-}300}$>65.0 $\Delta Lead_{Final} = \exp[\ln(\Delta Lead) + (65.0 - OC_{100\text{-}300}) \times 0.03234]$ If $OC_{100\text{-}300}$≤65.0 $\Delta Lead_{Final} = \Delta Lead$						
PB2	**Keep current ICF as is**	If $OC_{100\text{-}300}$>65.0 $\Delta Lead\ (250\text{-}300)_{Final} = \exp[\ln(\Delta Lead(250\text{-}300)) + (65.0 - OC_{100\text{-}300}) \times 0.04089$ If $OC_{100\text{-}300}$≤65.0 $\Delta Lead\ (250\text{-}300)_{Final} = \Delta Lead(250\text{-}300)$						

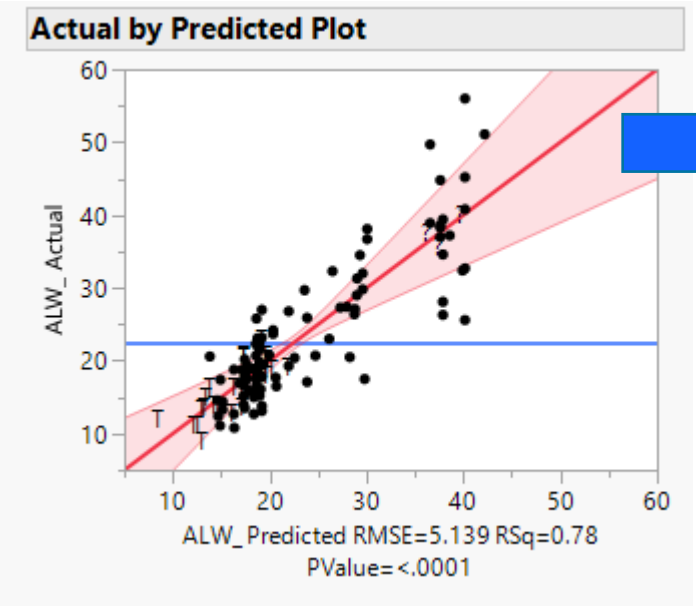
Outline

- Summary of proposal
  - Impact of using Additive ICF versus Multiplicative ICF
- Dataset – LTMS 2021/08/26
  - Tests on Reference oil 821 and re-blends
  - Exclusions:
    - Exclude tests with Chart = N (except W/ X/ Y/ P/ F4945E)
    - Testkeys: 98459, 98867 (goofy tests)
    - 109182 (thrown out last time)
    - 110864 (VUXPB)
    - 158884 & 164848 (Lab B tests on W/ X/ Y/ P/ F4945E)
  - Total number of tests: 127
- General comments
- Proposed correction factors by parameter with plots before and after ICF
  - Calculations
- Appendix 1: Targets and Standard Deviation by parameter
- Appendix 2: Current ICF
- Appendix 3: Equations for PB and PB2

General comments

- Latest batch of parts:
  - Cyl.Liner/TopRing/Rodbearing/MainBearing/PistonCrown[W/ X/ Y/ P/ F4945E]
- Original precision matrix
  - LTMS adopted use natural logarithm transformations for Pb, Pb2, and OC.
  - Liner Wear and Top Ring Weight Loss were not transformed.
- This review indicates that CLW and TRWL need LN transformation.

Liner Wear



High results raise the question about transforming or not liner wear. This discussion is not new… last time SP decided to transform liner wear

Keeping original scale => Multiplicative ICF
Transformed scale => Additive ICF

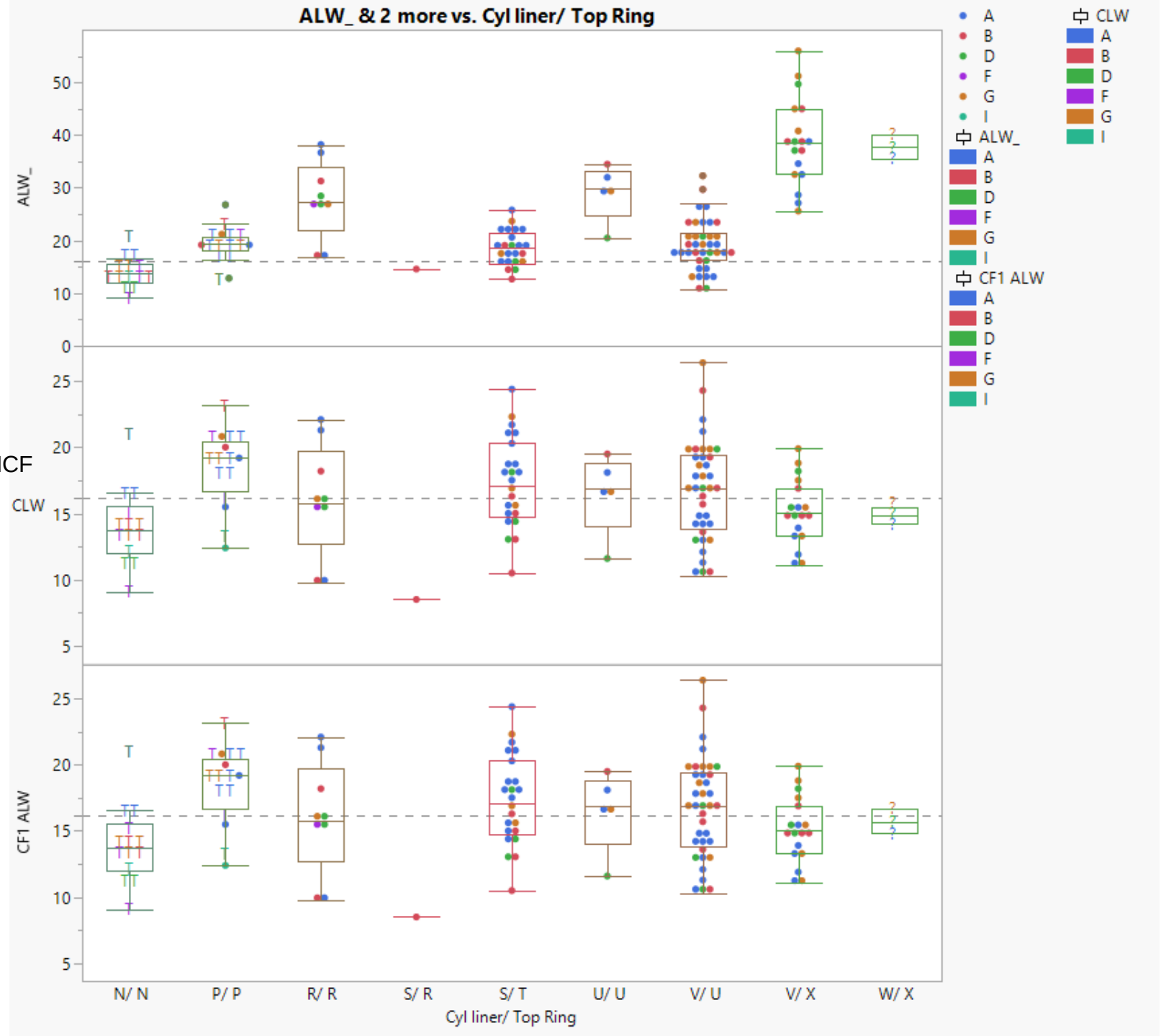
Impact on proposed ICF is small: see three test results using the new set of parts corrected by both methods below

Before and After ICF applied by parameter						additive ICF		multiplicative ICF		
ALW	**ln ALW**		**Lab**	**original ALW**	**ln ALW**	**afterCF**	**Original scale after CF**		**afterCF**	**Original scale after CF**	**Current ICF 02/23/2017 multiplicative**
Predicted	3.6615		G	40.1	3.6914	2.8144	16.7	0.761	2.8092	16.6	
TARGET	2.7850	Target on Original scale= 16.2	D	37.7	3.6297	2.7527	15.7		2.7622	15.8	0.7430
additive ICF	-0.8770		A	35.6	3.5723	2.6953	14.8		2.7185	15.2	

Before ICF

After current ICF

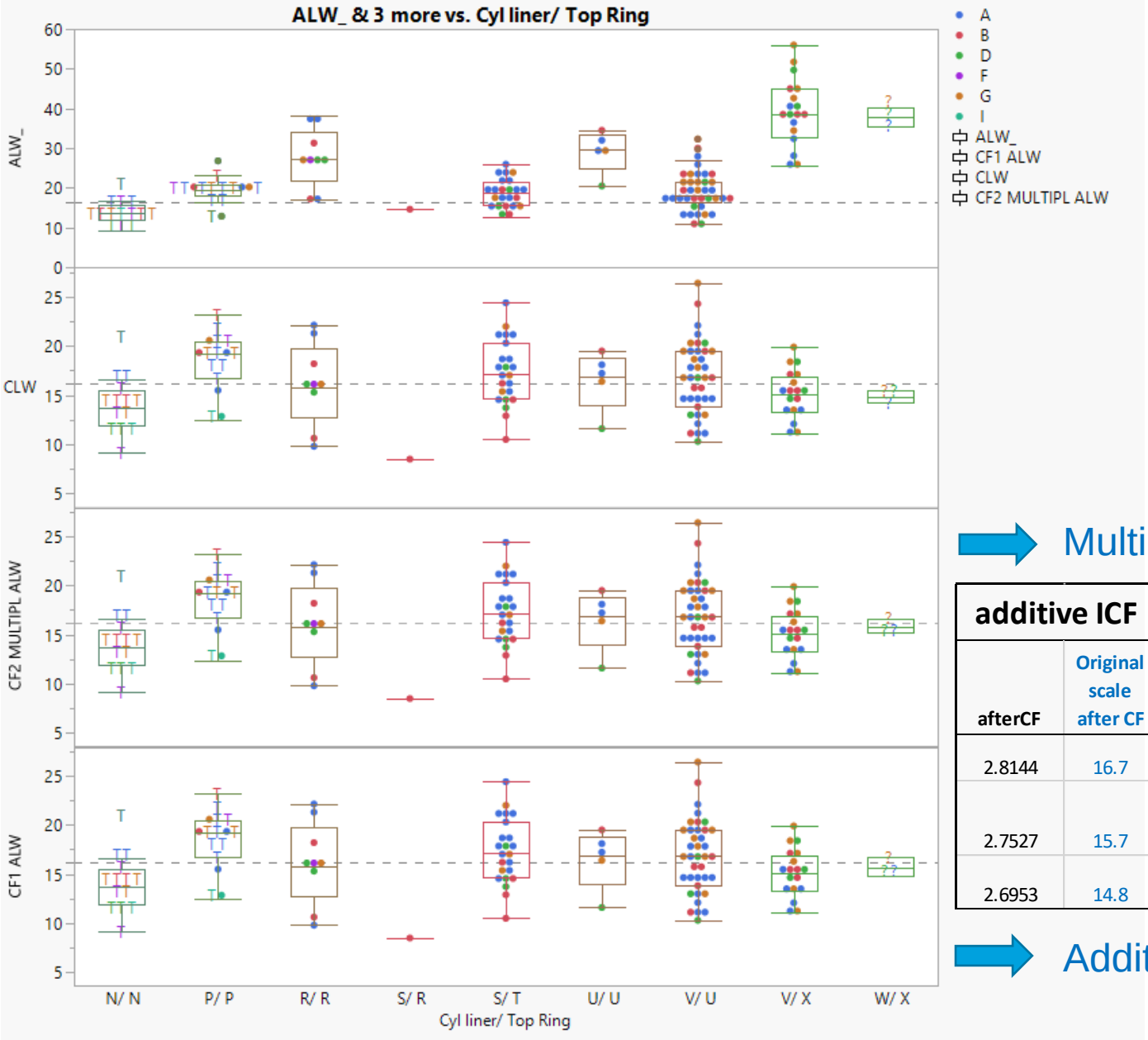
Proposed additive ICF based on LN



Calculations

LN ALW	option 2	n=127								
Expanded Estimates										
Nominal factors expanded to all levels										
						Predicted	TARGET	additive ICF		
Term	Estimate	Std Err	t Ratio	Prob>|t|		3.661537525	2.7850112	-0.8765		
Intercept	3.0611582	0.043	70.62	<.0001	1					
IND 2[PC10E/ 821]	-0.054345	0.134	-0.41	0.6847	1					
IND 2[821-1]	0.0639349	0.076	0.84	0.4023	0	Lab	original ALW	ln	afterCF	Original scale after CF
IND 2[821-2]	0.0949662	0.073	1.3	0.1959	0	G	40.1	3.69138	2.815	16.6907
IND 2[821-3]	-0.022785	0.095	-0.24	0.8112	0	D	37.7	3.62966	2.753	15.6917
IND 2[821-4]	-0.08177	0.096	-0.85	0.3946	0	A	35.6	3.57235	2.696	14.8177
LTMSLAB[A]	0.0828572	0.042	1.99	0.0492	0.25					
LTMSLAB[B]	0.0699692	0.05	1.41	0.1609	0.25			pred		
LTMSLAB[D]	-0.029196	0.056	-0.52	0.6031	0.25		A	39.7806		
LTMSLAB[F]	-0.000995	0.089	-0.01	0.9911	0		G	41.3037		
LTMSLAB[G]	0.1204297	0.048	2.53	0.013	0.25		B	39.2712		
LTMSLAB[I]	-0.243065	0.112	-2.18	0.0315	0		D	35.5637	ln	
Cyl liner/ Top Ring[N/ N]	-0.419427	0.146	-2.88	0.0048	0			38.9798	3.663	
Cyl liner/ Top Ring[P/ P]	-0.132461	0.126	-1.05	0.2955	0					
Cyl liner/ Top Ring[R/ R]	0.1101179	0.104	1.06	0.292	0					
Cyl liner/ Top Ring[S/ R]	-0.514041	0.209	-2.46	0.0157	0					
Cyl liner/ Top Ring[S/ T]	-0.302596	0.08	-3.79	0.0002	0					
Cyl liner/ Top Ring[U/ U]	0.2540285	0.132	1.92	0.0575	0					
Cyl liner/ Top Ring[V/ U]	-0.169721	0.093	-1.83	0.0696	0					
Cyl liner/ Top Ring[V/ X]	0.5803891	0.108	5.36	<.0001	0					
Cyl liner/ Top Ring[W/ X]	0.5937093	0.148	4.01	0.0001	1					

Average Liner Wear: including additive and multiplicative ICFs

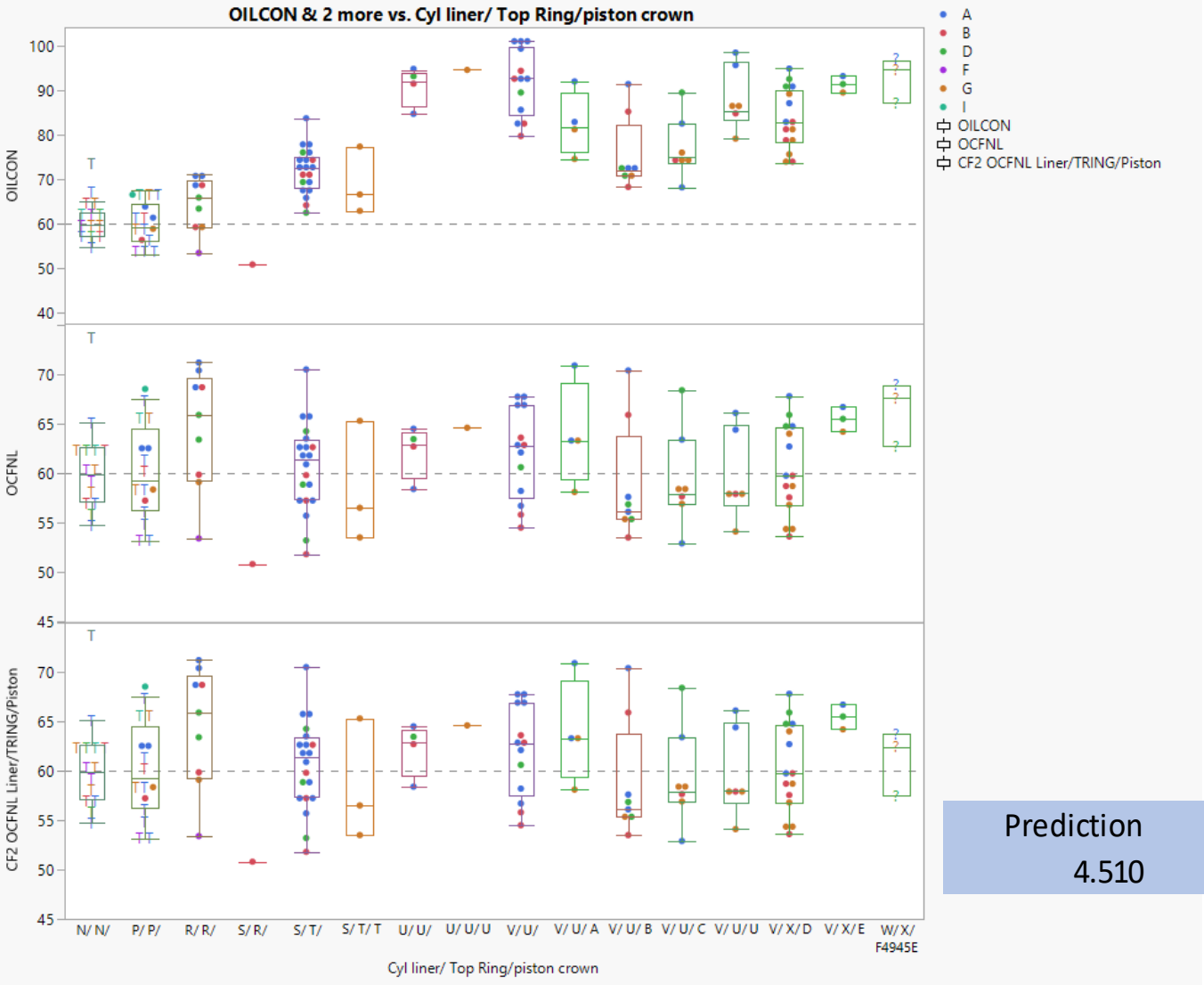


Multiplicative ICF

additive ICF		multiplicative ICF			
afterCF	Original scale after CF		afterCF	Original scale after CF	Current ICF 02/23/2017 multiplicative
2.8144	16.7	0.761	2.8092	16.6	0.7430
2.7527	15.7		2.7622	15.8	
2.6953	14.8		2.7185	15.2	

Additive ICF

Oil Consumption: Proposed ICF keeps current LN transformation

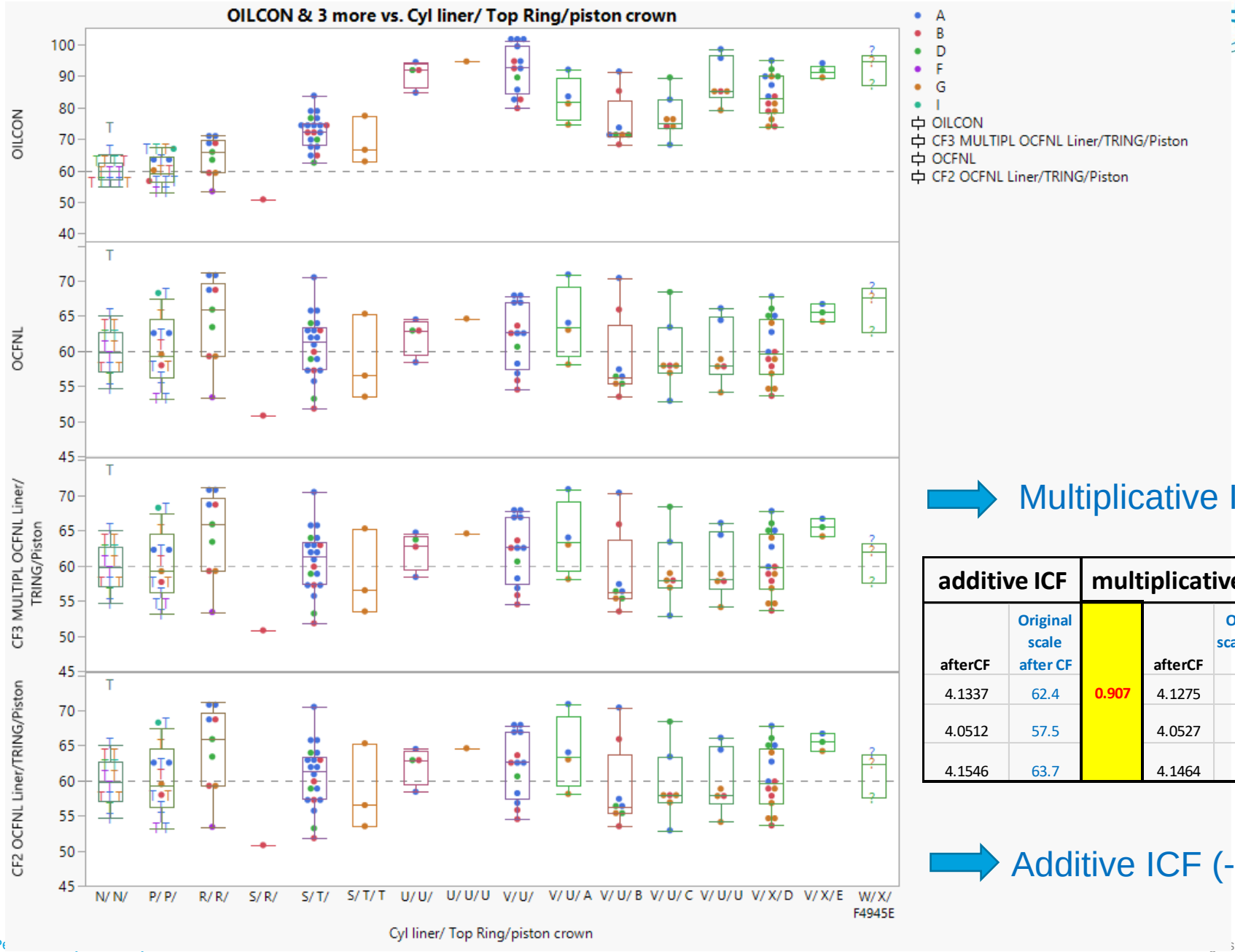


Additive ICF

Prediction	TARGET	ICF
4.510	4.093	-0.417

LN OILCON with liner/TopRing/piston											
Expanded Estimates											
Nominal factors expanded to all levels											
Term	Estimate	Std Error	t Ratio	Prob>|t|			TARGET	ICF			
Intercept	4.3496831	0.018798	231.39	<.0001	1	4.510206025	4.093	-0.41721			
IND 2[PC10E/ 821]	-0.014291	0.048649	-0.29	0.7695	1						
IND 2[821-1]	0.0164004	0.028113	0.58	0.5609	0						
IND 2[821-2]	0.0218347	0.027061	0.81	0.4216	0	Lab	original OILCON	ln	afterCF	Original scale after CF	
IND 2[821-3]	-0.023263	0.035943	-0.65	0.5189	0	G	94.7	4.550714	4.133508	62.39642	
IND 2[821-4]	-0.00068	0.039802	-0.02	0.9864	0	D	87.2	4.468204	4.0509983	57.45479	
LTMSLAB[A]	0.0236673	0.015347	1.54	0.1261	0.25	A	96.7	4.571613	4.1544074	63.71419	
LTMSLAB[B]	-0.032704	0.018545	-1.76	0.0808	0.25						
LTMSLAB[D]	-0.001999	0.020707	-0.1	0.9233	0.25						
LTMSLAB[F]	-0.032336	0.032276	-1	0.3188	0		94.3956235	4.547495			
LTMSLAB[G]	-0.043451	0.018907	-2.3	0.0236	0.25		88.26791061	4.480377			
LTMSLAB[I]	0.086823	0.040458	2.15	0.0342	0		89.22164559	4.491124			
Cyl liner/ Top Ring/piston crown[N/ N/]	-0.22322	0.062009	-3.6	0.0005	0		92.00363288	4.521828			
Cyl liner/ Top Ring/piston crown[P/ P/]	-0.258112	0.055502	-4.65	<.0001	0			4.510206			
Cyl liner/ Top Ring/piston crown[R/ R/]	-0.195827	0.045845	-4.27	<.0001	0						
Cyl liner/ Top Ring/piston crown[S/ R/]	-0.405483	0.083891	-4.83	<.0001	0						
Cyl liner/ Top Ring/piston crown[S/ T/]	-0.101921	0.036739	-2.77	0.0066	0						
Cyl liner/ Top Ring/piston crown[S/ T/ T]	-0.09651	0.054491	-1.77	0.0795	0						
Cyl liner/ Top Ring/piston crown[U/ U/]	0.1782652	0.049069	3.63	0.0004	0						
Cyl liner/ Top Ring/piston crown[U/ U/ U]	0.2677451	0.080838	3.31	0.0013	0						
Cyl liner/ Top Ring/piston crown[V/ U/]	0.1783875	0.032193	5.54	<.0001	0						
Cyl liner/ Top Ring/piston crown[V/ U/ A]	0.071164	0.047166	1.51	0.1344	0						
Cyl liner/ Top Ring/piston crown[V/ U/ B]	-0.022036	0.037281	-0.59	0.5558	0						
Cyl liner/ Top Ring/piston crown[V/ U/ C]	0.0074665	0.04051	0.18	0.8541	0						
Cyl liner/ Top Ring/piston crown[V/ U/ U]	0.1470127	0.035832	4.1	<.0001	0						
Cyl liner/ Top Ring/piston crown[V/ X/ D]	0.0905369	0.03489	2.59	0.0109	0						
Cyl liner/ Top Ring/piston crown[V/ X/ E]	0.1740965	0.05196	3.35	0.0011	0						
Cyl liner/ Top Ring/piston crown[W/ X/ F4945E]	0.1884356	0.05196	3.63	0.0005	1						

Oil Consumption: Original scale including additive and multiplicative ICFs

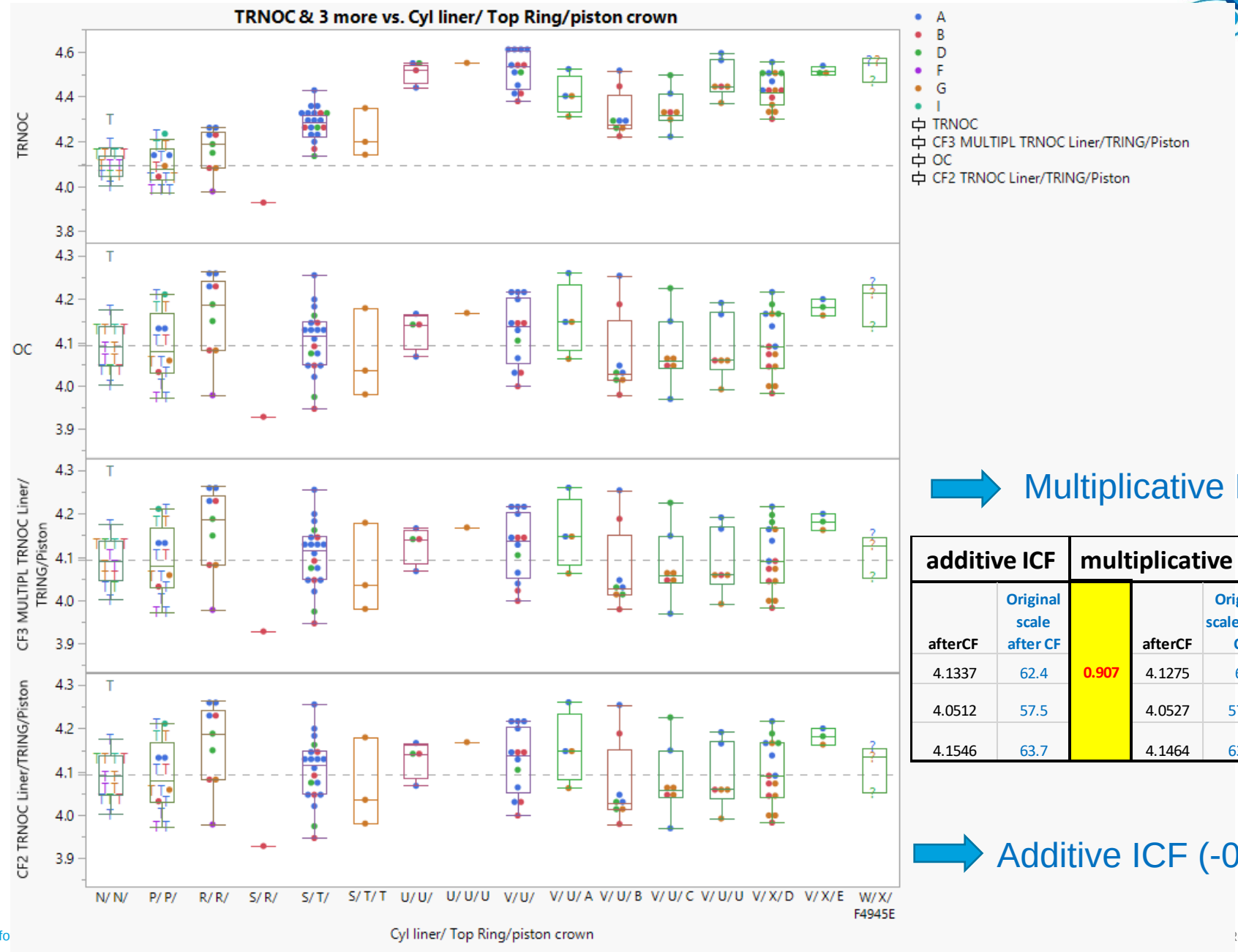


Multiplicative ICF

additive ICF			multiplicative ICF	
afterCF	Original scale after CF		afterCF	Original scale after CF
4.1337	62.4	0.907	4.1275	62
4.0512	57.5		4.0527	57.6
4.1546	63.7		4.1464	63.2

Additive ICF (-0.417)

Oil Consumption: transformed scale including additive and multiplicative ICFs



Multiplicative ICF

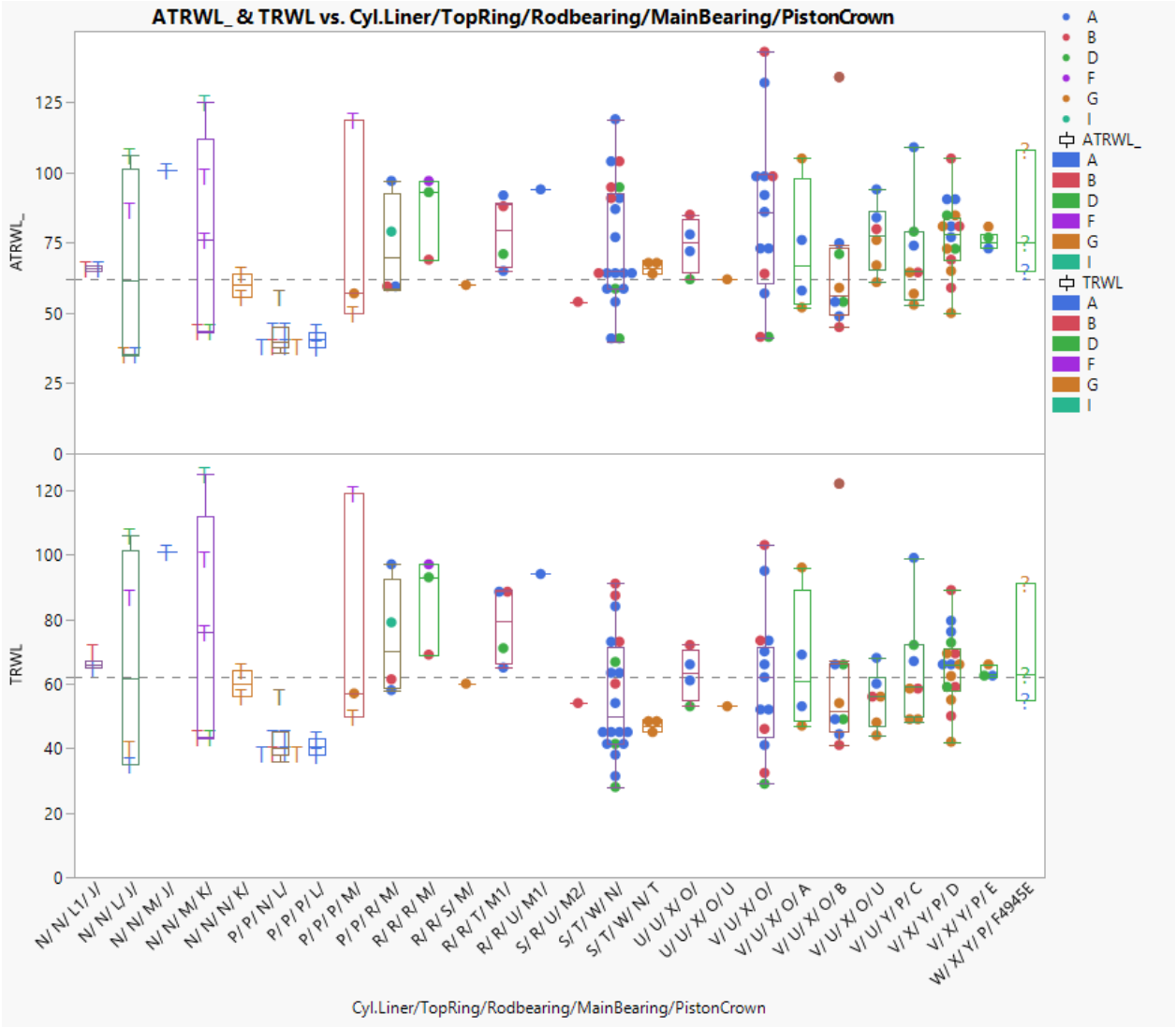
additive ICF		multiplicative ICF		
afterCF	Original scale after CF		afterCF	Original scale after CF
4.1337	62.4	0.907	4.1275	62
4.0512	57.5		4.0527	57.6
4.1546	63.7		4.1464	63.2

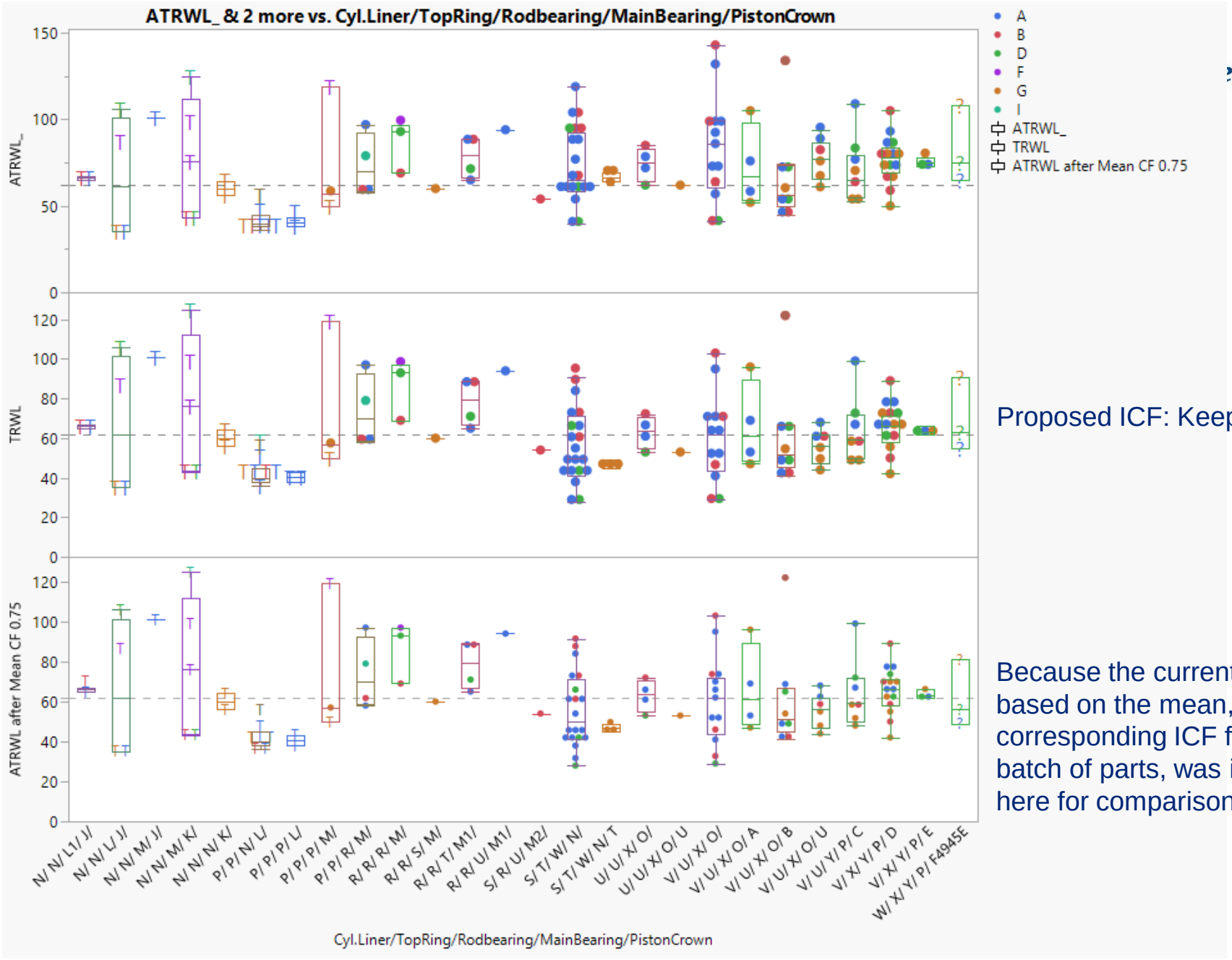
Additive ICF (-0.417)

Top Ring Weight Loss: the plot below shows that the current ICF seems ok for now

Before ICF

After current ICF





Proposed ICF: Keep ICF as is

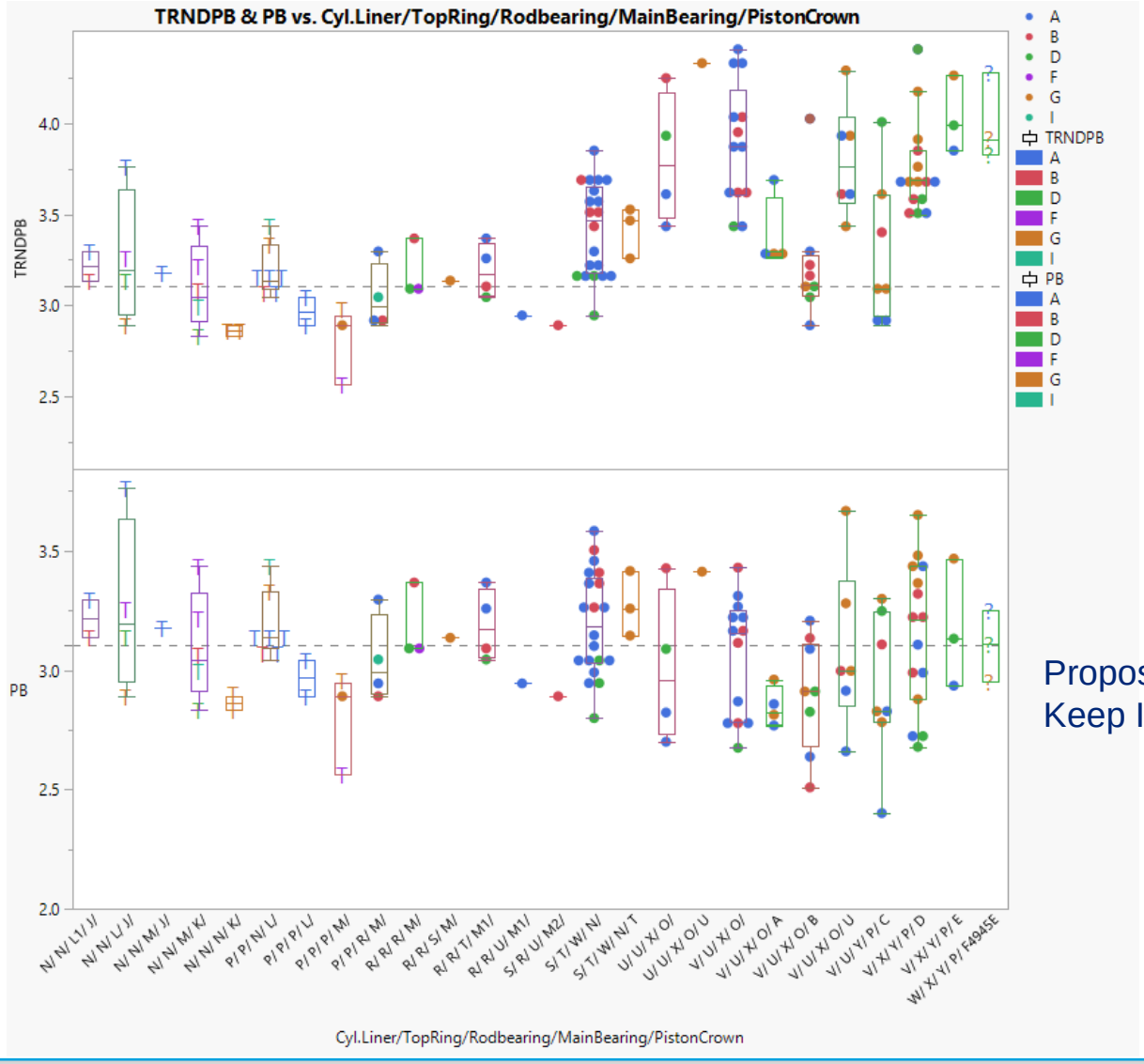
Because the current ICF is based on the mean, the corresponding ICF for the new batch of parts, was included here for comparison

Pb Oil Consumption Correction: Keep correction as is - updated correction is very close to current correction

PB

Before ICF

After Current ICF



Proposed ICF: Keep ICF as is

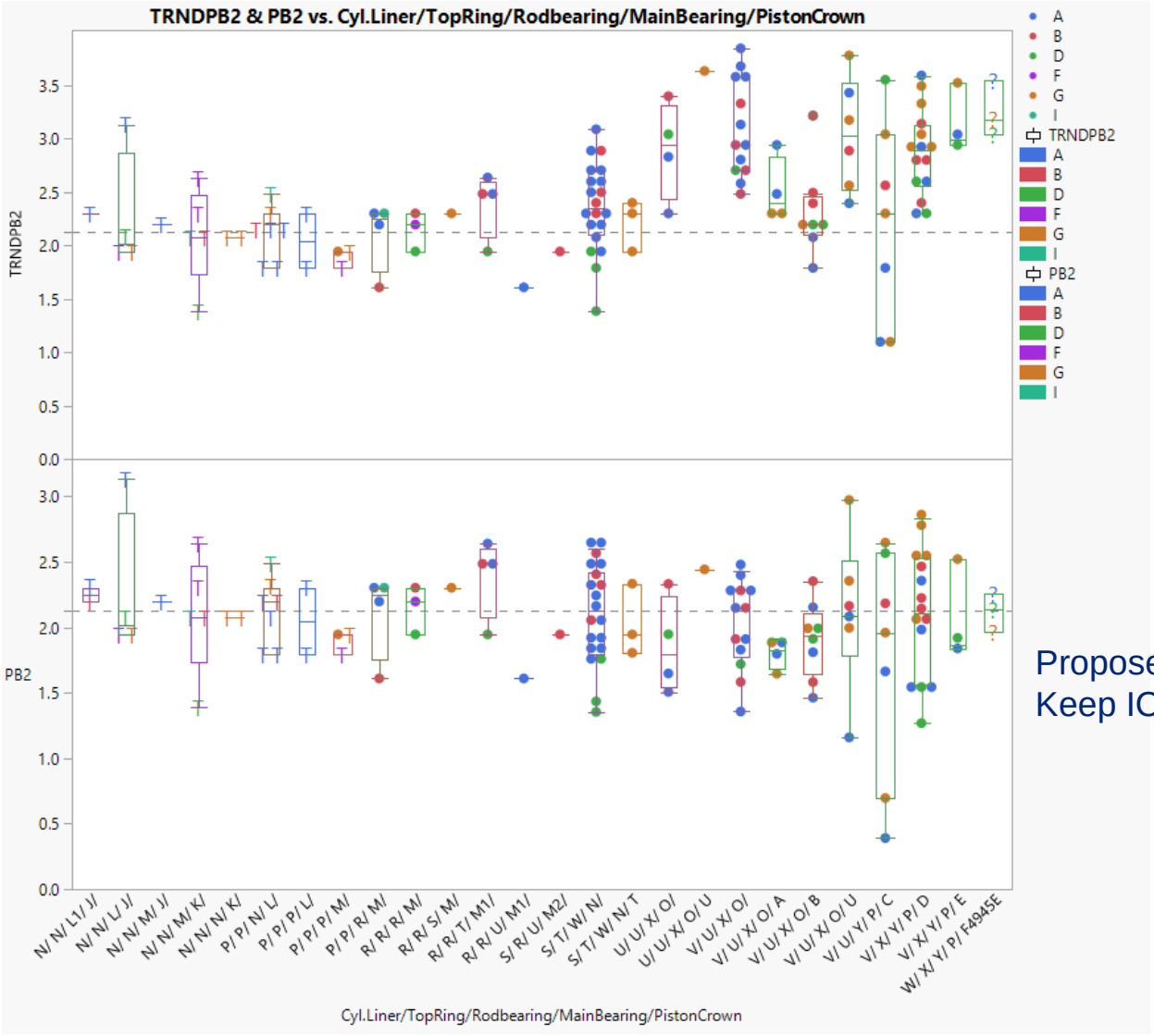
Pb2 Oil Consumption Correction: Keep correction as is - updated correction is very close to current correction

Infineum

PB2

Before ICF

After Current ICF



Proposed ICF: Keep ICF as is

Appendix 1: Targets and Standard Deviation by parameter

CYLINDER LINER WEAR
Unit of Measure: Micrometres
CRITICAL PARAMETER
NORMAL K VALUE

Reference Oil	Level	Mean	Standard Deviation
821-2	Stand	16.2	3.7
821-2	Lab	15.1	2.8
821-3	Stand	16.2	3.7
821-3	Lab	15.1	2.8
821-4	Stand	16.2	3.7
821-4	Lab	15.1	2.8

TOP RING WEIGHT LOSS
Unit of Measure: Milligrams
CRITICAL PARAMETER
EXPANDED K VALUE

Reference Oil	Mean	Standard Deviation
821-2	62.0	28.2
821-3	62.0	28.2
821-4	62.0	28.2

OIL CONSUMPTION
Unit of Measure: LN(OC grams/hour)
CRITICAL PARAMETER
EXPANDED K VALUE

Reference Oil	Mean	Standard Deviation
821-2	4.0930	0.0790
821-3	4.0930	0.0790
821-4	4.0930	0.0790

ΔPB AT END OF TEST
Unit of Measure: LN(ΔPb ppm)
CRITICAL PARAMETER
NORMAL K VALUE

Reference Oil	Mean	Standard Deviation
821-2	3.1060	0.2420
821-3	3.1060	0.2420
821-4	3.1060	0.2420

ΔPB 250 – 300 HOURS
Unit of Measure: LN(ΔPb 250-300 ppm)
NONCRITICAL PARAMETER
NORMAL K VALUE

Reference Oil	Mean	Standard Deviation
821-2	2.1250	0.3330
821-3	2.1250	0.3330
821-4	2.1250	0.3330

Appendix 2: Current ICF

VXYPD proposed 2/23/2017					
	TRNOC	ALW_	lnALW	ATRWL_	lnTRWL
Predicted	4.422		3.749		
Target	4.093		2.785	62	
ICF	0.926		0.743	0.846	

mean

Appendix 3: Equations for PB and PB2

Additional text for PB

For all tests starting on or after September ?th, 2021, using W/ X/ Y/ P/ F4945E hardware, determine the final ΔLead at EOT result by applying the correction factor calculated according to the following equations:

If $OC_{100\text{-}300} > 65.0$

$$\Delta Lead_{Final} = \exp[\ln(\Delta Lead) + (65.0 - OC_{100\text{-}300}) \times \mathbf{0.03234}]$$

If $OC_{100\text{-}300} \leq 65.0$

$$\Delta Lead_{Final} = \Delta Lead$$

Where:

ΔLead = final ΔLead at EOT

$OC_{100\text{-}300}$ = average oil consumption

Additional text for PB2

For all tests starting on or after September ?th, 2021, using W/ X/ Y/ P/ F4945E hardware, determine the final ΔLead (250 to 300) h by applying the correction factor calculated according to the following equations:

If $OC_{100\text{-}300} > 65.0$

$\Delta Lead\ (250\text{-}300)_{Final} = \exp[\ln(\Delta Lead(250\text{-}300)) + (65.0 - OC_{100\text{-}300}) \times$ **0.04089**

If $OC_{100\text{-}300} \leq 65.0$

$\Delta Lead\ (250\text{-}300)_{Final} = \Delta Lead(250\text{-}300)$

Where:

ΔLead (250-300) = final ΔLead (250 to 300) h

ΔLead (250-300) = value calculated per XXXX

$OC_{100\text{-}300}$ = average oil consumption