CAT Test Surveillance Panel
November 4, 2013 Conference Call
Meeting Minutes
11:00 am EST

Attendance
Martin Thompson, Jim McCord - SwRI
Andrew Stevens, Bill Larch, Chris Castanien - Lubrizol
Jeff Clark, Sean Moyer - TMC
Jim Gutzwiller, Elisa Santos, Bob Salgurieo (sp) - Infineum
Jason Bowden - OHT
Jim Moritz, Adam Roig - Intertek
Mark Cooper - ChevronOronite
Bob Campbell - Afton
Hind Abi-Akar, Beth Sebright - Caterpillar
Riccardo Conti - ExxonMobil
Zack Bishop - TEI

Review of Possible 1N Correction Factors - Elisa Santos (presentation attached)
Elisa reviewed her work for the surveillance panel. There were several questions/concerns about whether transformed correction factors increase variability of the data on the new liners. The discussion on this item was then paused to give Elisa time work up a plot that addressed the concerns about variability (see section below when discussion resumed).

C-13 Second Ring Top Carbon Severity (mild) Issue - Hind Abi-Akar
CAT has been investigating the lack of deposits on the top of the second ring. They are seeing that the 1Y rings and production rings are very much alike. The supplier states that there has been no change in the parts. The rings are nitrited and again the supplier states no changes have occurred. At this point, CAT is not certain what, if anything, has changed. Intertek is currently running a reference test that is scheduled to finish early the week of November 11th. SwRI has searched for older rings to compare with the current rings but they've not been able to locate any. It was noted that top ring deposits have reduced as well. It was noted that the other deposit levels (pistons) in the engine don't seem to have changed. CAT is checking to see if there have been any packaging changes to the rings. The question was asked if there have been any changes to the piston groove -- CAT is starting to investigate this issue. SwRI hasn't seen 'normal' severity levels since the May 2012 batch code of rings. Jim McCord noted that the rings in question have a powder coating that require more wiping for cleaning of the top surface then the previous rings. Jim Moritz confirmed that Intertek are seeing the same.

The discussion moved to devising a plan forward. Hind noted that it is hard to investigate because the only rings that are available are the current rings and there is nothing to compare to. Jim McCord noted that a comparison of used rings (old and new) didn't show any differences (other than the amount of carbon). Hind stated that the really don't have any solutions right now but they hope to receive some more analyses in the near future. Some discussion occurred as to whether or not labs should try to reference. It was noted that unless the panel declares the test out of control, then from a referencing standpoint, all normal protocol apply, and as always it is up to a test lab to decide when to reference. Jim Gutzwiller will ask Elisa Santos to examine the data for the shift. Hind noted that CAT feels the parameter is important and that it separates oils. CAT is trying to move quickly to find a cause and all

options are on the table. TMC will post individual ring ratings to the web (this items was completed by the end of the meeting).

C13 Oil Filter

Jim Gutzwiller noted Holt has been sending the high efficiency oil filter (1R-1808, 23 micron) for the C13 build kit. The oil filter required by the procedure is 1R-0716, 40 micron. It was agreed in consensus that tests should run the procedurally specified filter. Beth Sebright requested the part number for the kit to look into this issue, and Jim McCord agreed to provide it for her.

Resumption of 1N Correction Factor Discussion

After receiving an updated plot from Elisa Santos showing both uncorrected original units and corrected original units (attached), the discussion on 1N correction factors resumed. After much discussion, Elisa was asked to devise simple (untransformed) arithmetic correction factors (in engineering units) and calculate new reference oil standard deviations. The panel will have a follow up conference call once Elisa's additional work is available for review.

Timing Sensor for the 1Y3700 Engine

Beth Sebright is working on a solution as the electronics are available, but the casing isn't. SwRI will send photos to CAT of their setup. Andrew Stevens mentioned a way they have managed to get the new sensor to work by cutting the lock nut in half to allow the sensor to thread in far enough. Andrew will send out a description of their set up. The part number for the new sensor is 266-8576.

The conference ended at 1:15 pm.

1N: Correction Factor Analysis

August 2013

Elisa Santos

For CAT Surveillance Panel

Infineum

Outline

- Correction factors are proposed by parameter

1. TGF
2. WDN
3. TLHC
4. BSOC

- Standard Deviations are proposed by parameter
- Plots: Before and After CF
- Appendix
  1. Data preparation to reproduce Original Target calculations
  2. Oil selection
  3. Data Analysis: Need for transformations, test for change in variability, lab, oil, liner and fuel batch effects
  4. Correction factor calculations
  5. Applying the proposed correction to the new liner and comparing with original liner test results

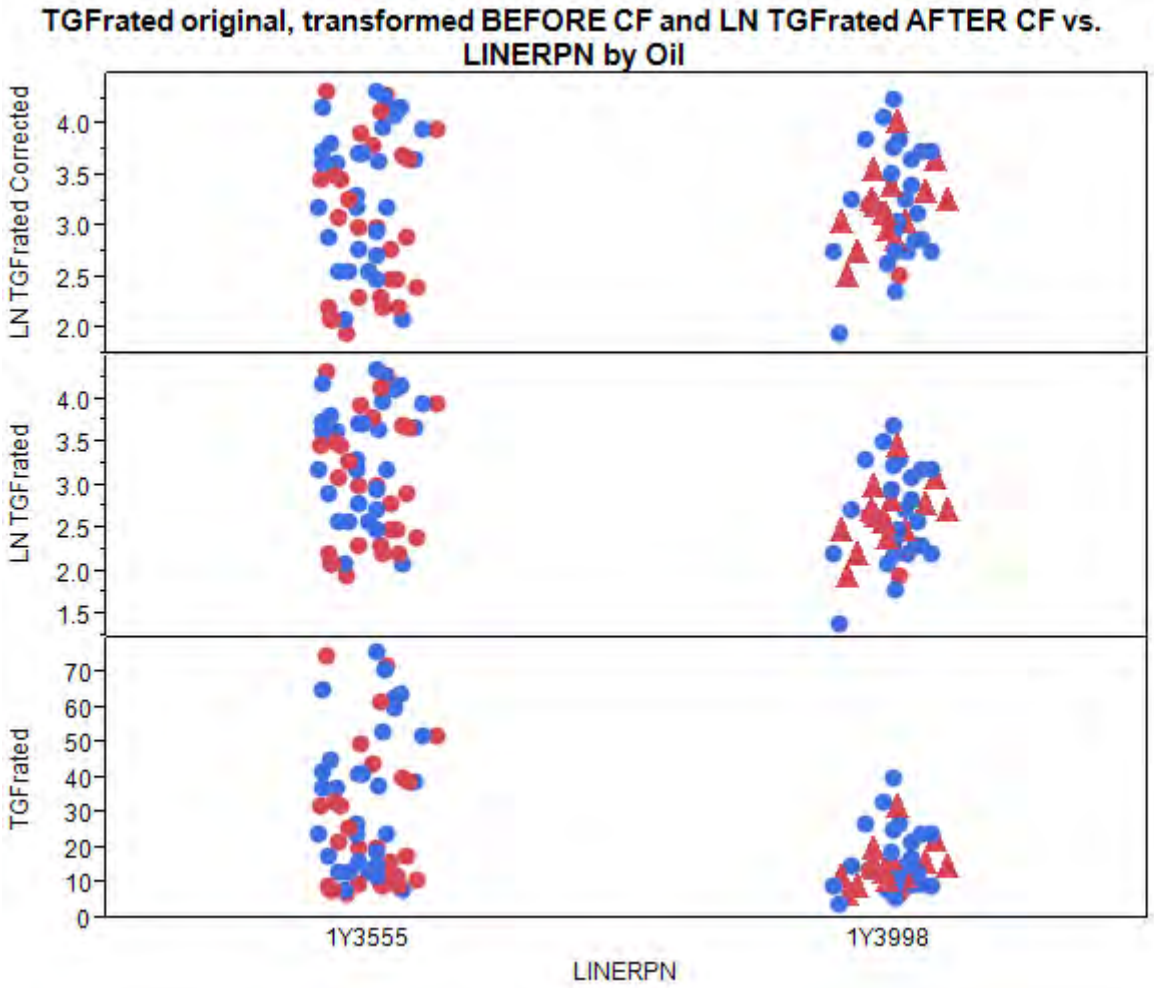
Summary of Correction Factors and Standard Deviations by Parameter

Parameter	sample size 809/1Y3555 809/1Y3998 811/1Y3555 811/1Y3998	Target Labs	Current Labs	Transformation	Lab effect	Oil effect	Liner effect	Correction Factor to be added to the transformed values	Standard deviation: RMSE	New Liner Standard Deviation: Pooled 809/811
TGF	30 - 25 - 29 - 19	A, B, B1, C, D, F, G, I, J, K, N	A, B1, D, G	LN(TGFrated)	no	no	yes	0.565696	0.632151	0.49
WDN*	30 - 25 - 29 - 19	A, B, B1, C, D, F, G, I, J, K, N	A, B1, D, G	LN(WDNrated)	no	yes	yes	0.074445	0.150728	0.1437
TLHC	30 - 25 - 29 - 19	A, B, B1, C, D, F, G, I, J, K, N	A, B1, D, G	LN(TLHCrated+1)	no	yes	yes	0.569846	0.859108	0.673469
BSOC	30 - 25 - 29 - 19	A, B, B1, C, D, F, G, I, J, K, N	A, B1, D, G	LN(BSOCrated)	no	yes	yes	0.2688	0.280647	0.208256

Kept several decimal places to allow for TMC to do the proper rounding for all values

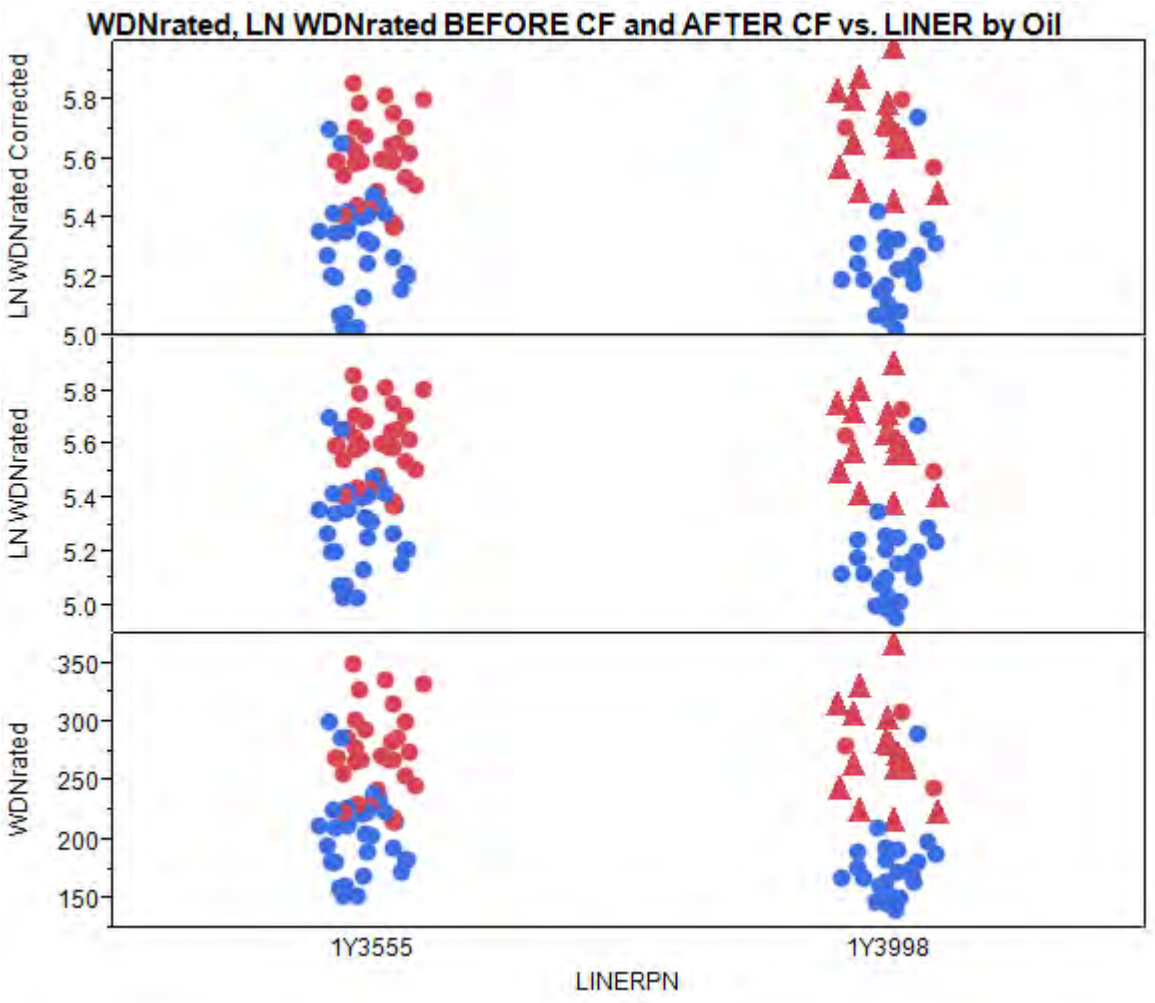
There is no evidence of Fuel Batch effect: Before and After introducing new batch in March 20th 2011

TGFrated original by Oil
LN(TGFrated) BEFORE CF by Oil
LN(TGFrated) AFTER CF by Oil



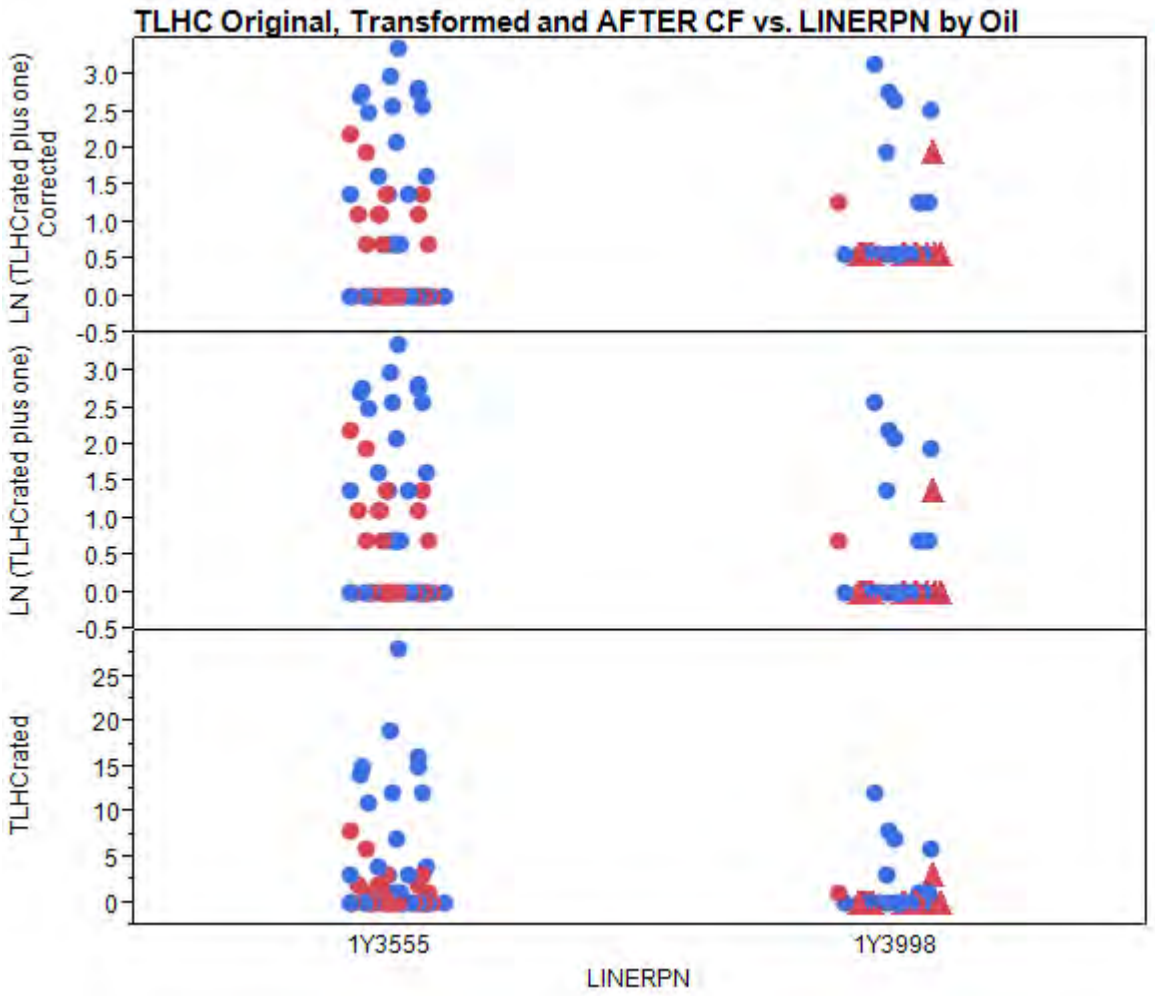
CF= 0.56569

WDNrated original by Oil
LN(WDNrated) BEFORE CF by Oil
LN(WDNrated) AFTER CF by Oil



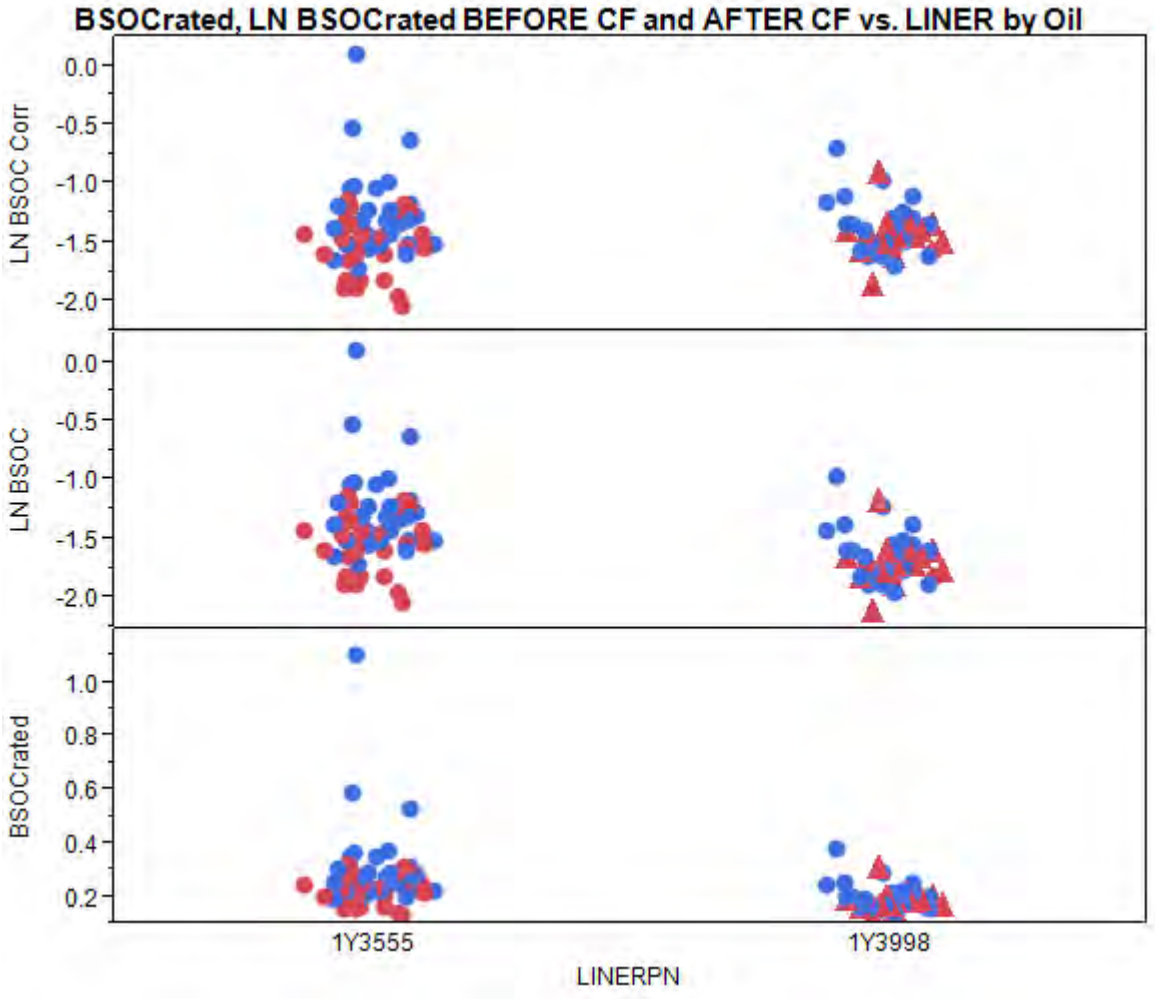
CF= 0.074444

TLHCrated by Oil
LN(TLHCrated +1) BEFORE CF by Oil
LN(TLHCrated +1) AFTER CF by Oil



CF= 0.569846

BSOCrated by Oil
LN(BSOCrated) BEFORE CF by Oil
LN(BSOCrated) AFTER CF by Oil



CF= 0.2688

Appendix:

1- Data preparation to reproduce Original Target calculations
2- Oil selection
3- Data Analysis: Need for transformations, test for change in variability, lab, oil, liner and fuel batch effects
4- Correction factor calculations
5- Applying the proposed correction to the new liner and comparing with original liner test results

1N Data selection and preparation: Chart =Y

- Oils used in this analysis
  - 809-1
  - 811-1
  - 811-2: initial targets based on 811-1
    811-1 and 811-2 were combined
- Additional oils
  - 810-2: last used in 2000 and only one test
  - 1004: oil depleted
  - 1004-1: oil depleted
  - 1004-2: oil depleted
  - 1004-3: oil depleted

- Labs that participated in the Target calculations but currently do NOT run the test are highlighted on the picture

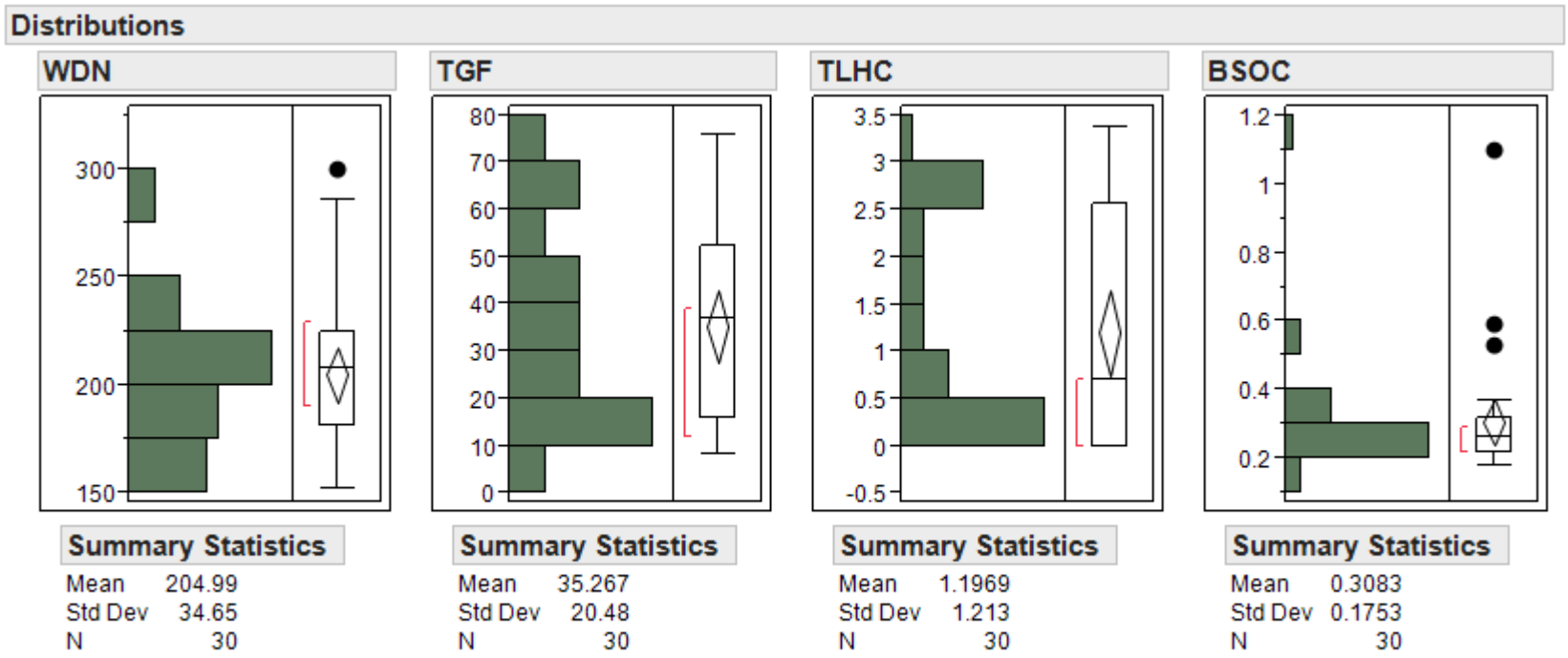
Final count

Oil	Liner	n sample size
809-1	1Y3555	30
809-1	1Y3998	25
811-1	1Y3555	29
811-1	1Y3998	19

	LTMSLAB	N Rows
1	A	26
2	B	4
3	B1	16
4	C	3
5	D	7
6	F	2
7	G	33
8	I	9
9	J	1
10	K	1
11	N	1

809-1 target data

Chart = Yes; N=30; from 03/14/1993 to 01/26/2002



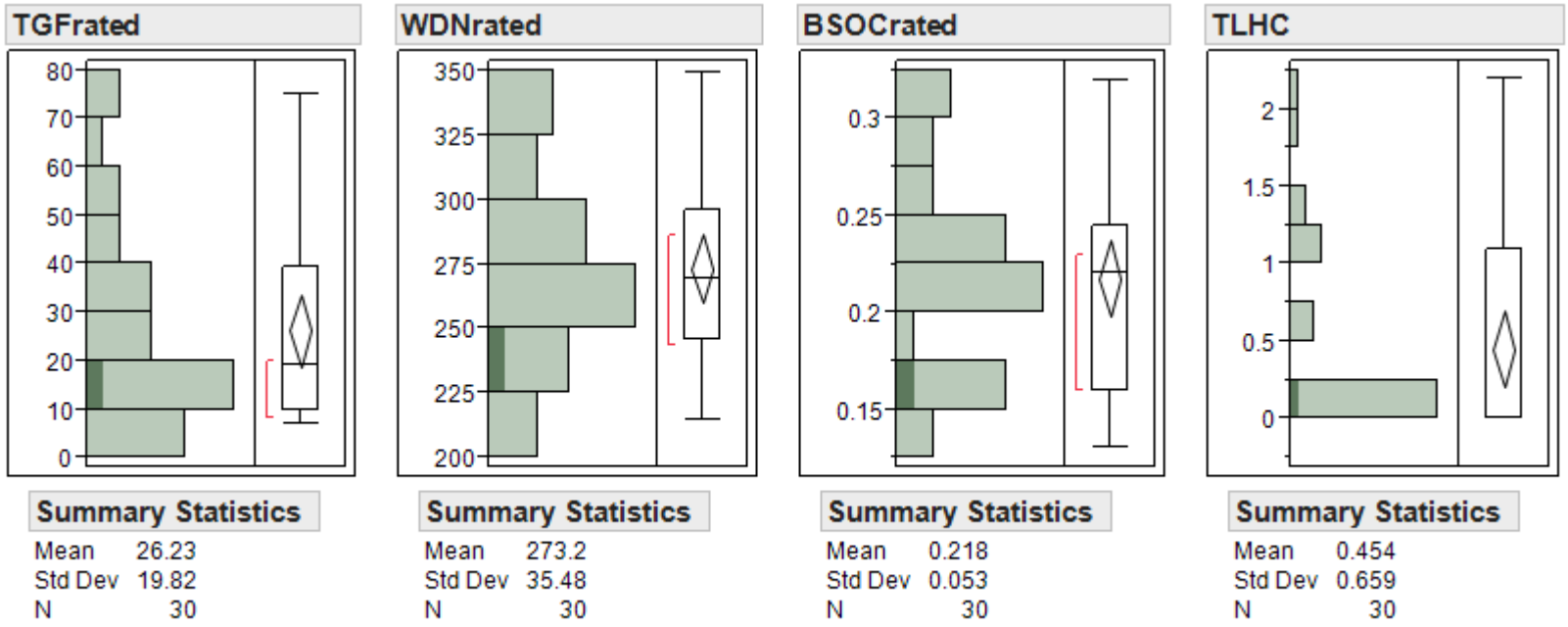
17349: liner is missing but assumed is 1Y3555

23960-1N 01/26/2002 is the last test included in the Target calculations, so data from the following tests with the old liner 23963-1N 01/19/2003, 28740-1N 03/30/2003, 31593-1N 01/21/2004 were excluded from the analysis

For 22998, TLHC = 3 LN (TLHC+1) = 1.386 instead of 0. This will impact calculations

811-1 target data

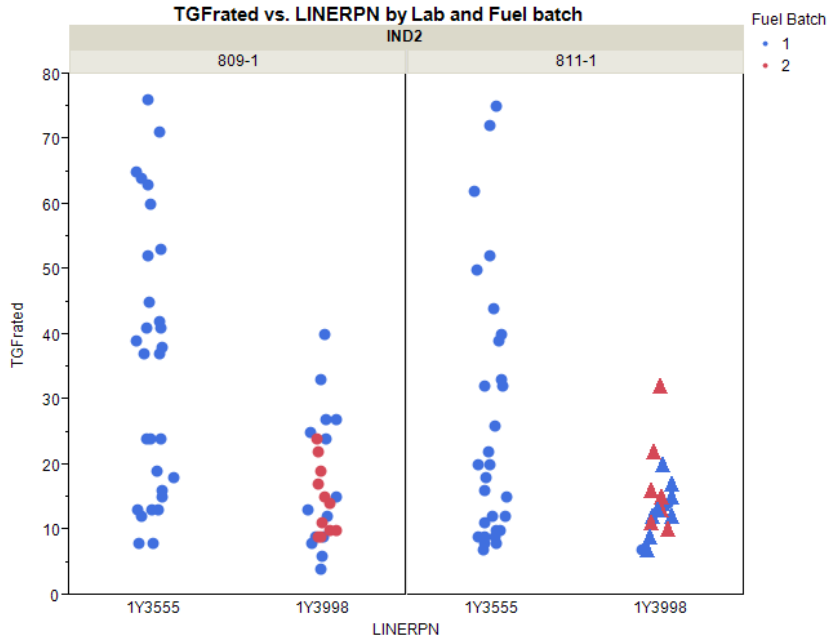
Chart = Yes; N=30*; from 03/22/1993 to 10/03/2006



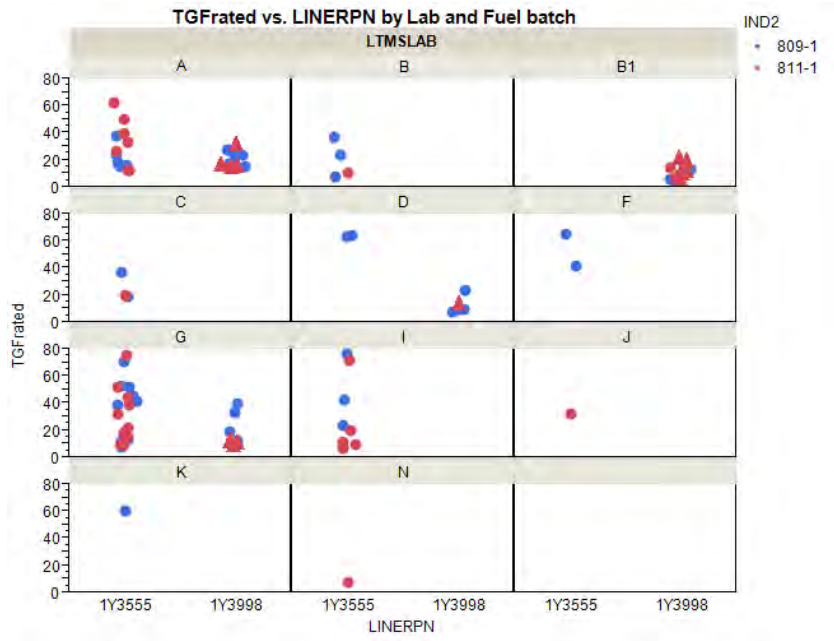
*Test 24229 10/03/2006 was included in the above target calculations to reproduce the LTMS table, but because it has the new liner will be in the analysis as having the new liner

TGFrated: Visualizing the data by Oil and Fuel Batch

All Labs by Oil, Liner and Fuel batch

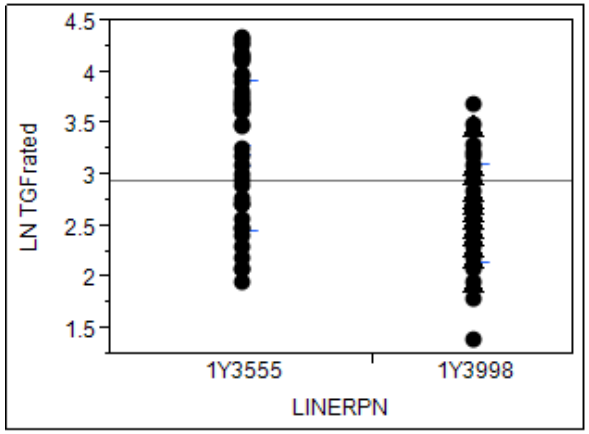


By Lab, Liner and Oil



Analysis of TGFrated: LN (TGFrated)

LN TGFrated vs. Liner



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
1Y3555	59	3.19651	0.722076	0.09401	3.0083	3.3847
1Y3998	44	2.63082	0.485133	0.07314	2.4833	2.7783

Summary of Fit

RSquare	0.166552
RSquare Adj	0.1583
Root Mean Square Error	0.632151
Mean of Response	2.954858
Observations (or Sum Wgts)	103

Analysis of Variance

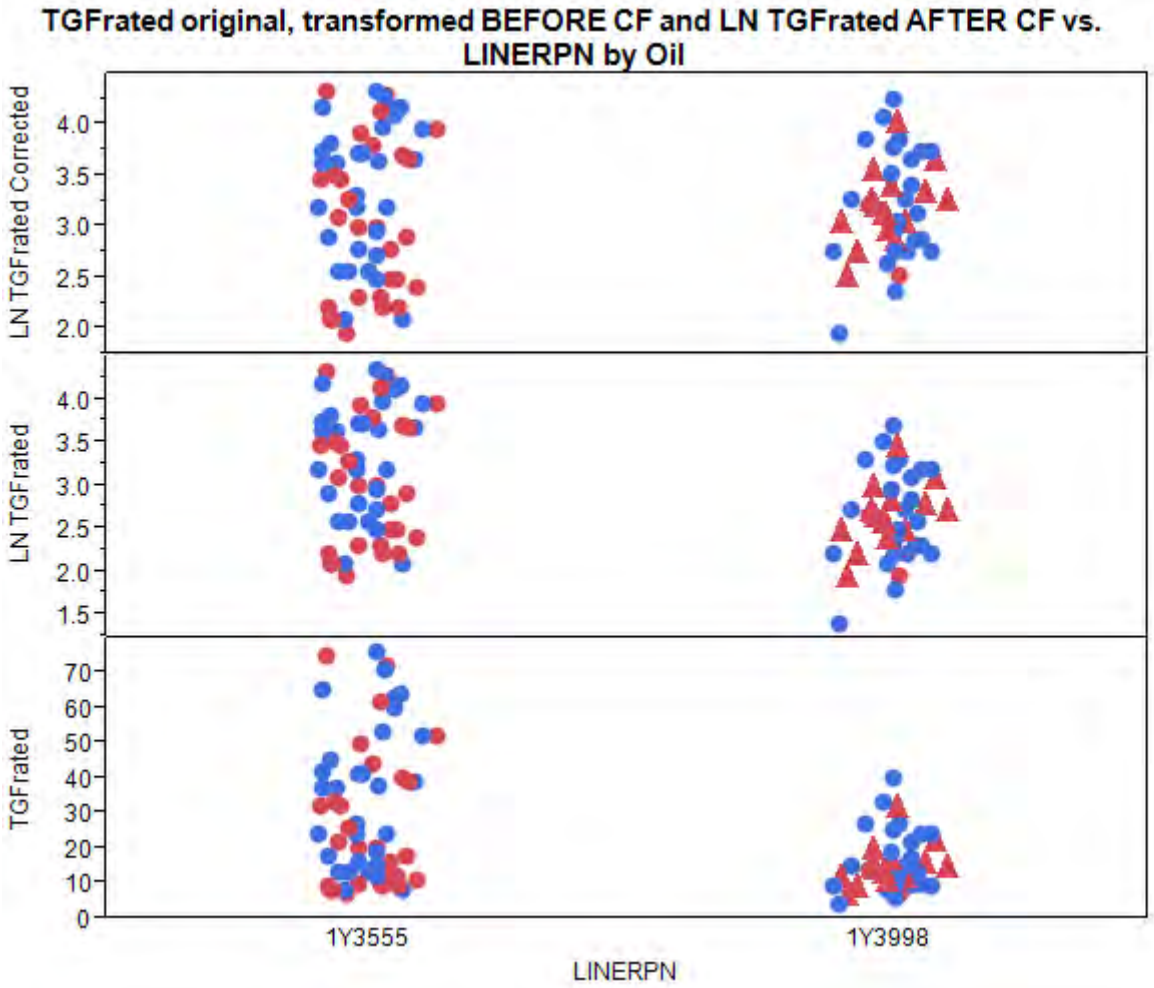
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	8.065538	8.06554	20.1833
Error	101	40.361079	0.39961	Prob > F
C. Total	102	48.426617		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	2.9136668	0.062959	46.28	<.0001*	.
LINERPN[1Y3555]	0.2828479	0.062959	4.49	<.0001*	1

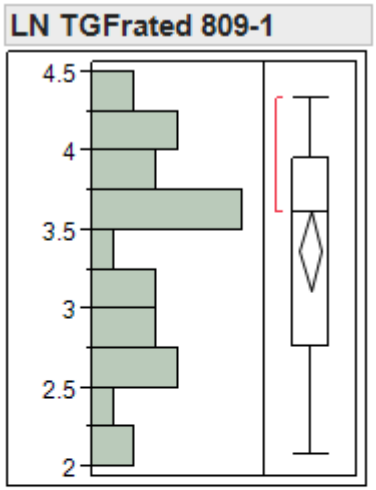
- Applied transformation: LN(TGFrated)
- Tested for statistically significant effects
- Means by liner group are statistically significantly different
- Standard deviations by liner group are also statistically significantly different. The sample size is large and able to detect small differences, not necessarily substantial. The plot on the next slide shows the TGFrated BEFORE and AFTER the transformation & CF are applied.
- Proposed Correction Factor (CF): add 0.5656958 to LN (TGFrated)
- CF= 3.19651-2.63082= 0.56569
- Standard deviation: RMSE of model on the left, i.e. 0.632151

TGFrated BEFORE CF and LN(TGFrated) AFTER CF by Oil

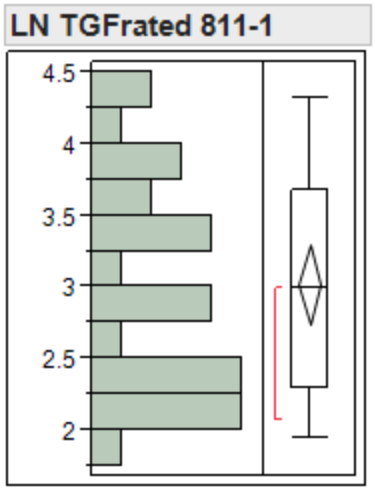


CF= 0.56569

Standard deviation for LN (TGFrated):



Summary Statistics	
Mean	3.3688081
Std Dev	0.6702206
Std Err Mean	0.122365
Upper 95% Mean	3.6190726
Lower 95% Mean	3.1185437
N	30



Summary Statistics	
Mean	3.0182802
Std Dev	0.7416768
Std Err Mean	0.1377259
Upper 95% Mean	3.300399
Lower 95% Mean	2.7361614
N	29

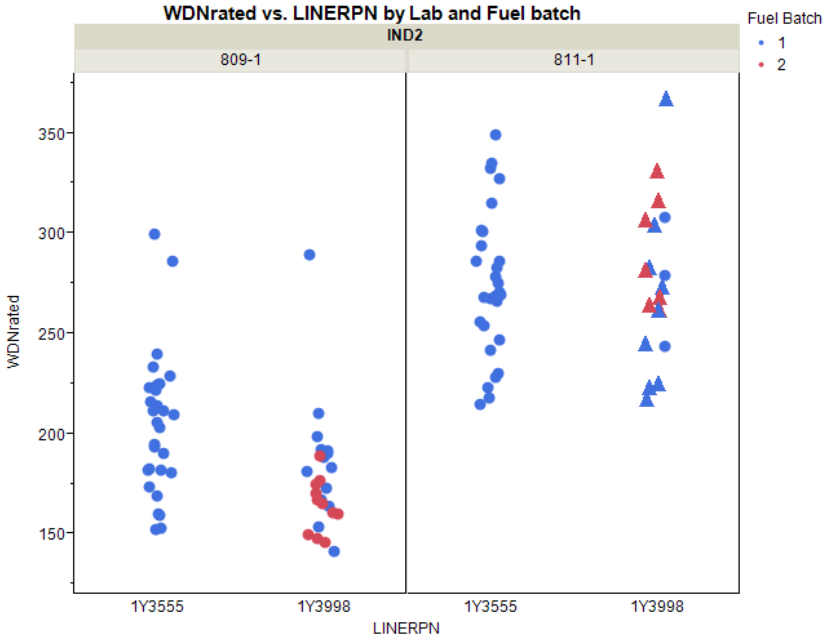
S_{pooled} for New Liner set 809/811= 0.49

- 809-1
  - STD for Target set= 0.67
- 811-1
  - STD for Target set= 0.74
- RMSE for model that includes both liners for oils 809 and 811-1/ 811-2= 0.632
- # of tests with new liner that do not calibrate before and after correction

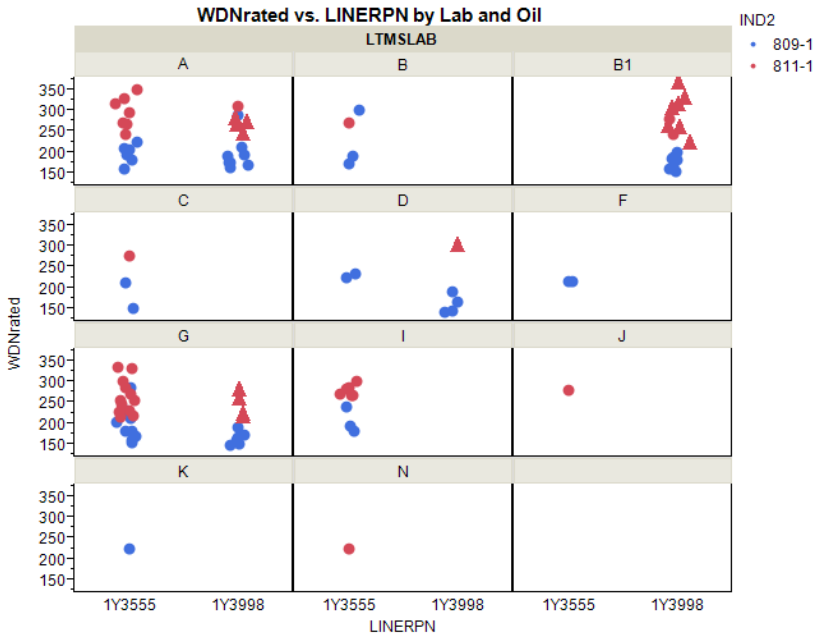
Using RMSE= 0.632	
809 (25 tests)	
Before	After
0	1
811 (19 tests)	
Before	After
0	0

WDNrated: Visualizing the data

All Labs by Oil, Liner and Fuel batch



By Lab, Liner and Oil



LN WDNrated: Model below includes Liner, Oil, Liner*Oil

Whole Model

Summary of Fit

RSquare	0.634918
RSquare Adj	0.623854
Root Mean Square Error	0.146578
Mean of Response	5.414266
Observations (or Sum Wgts)	103

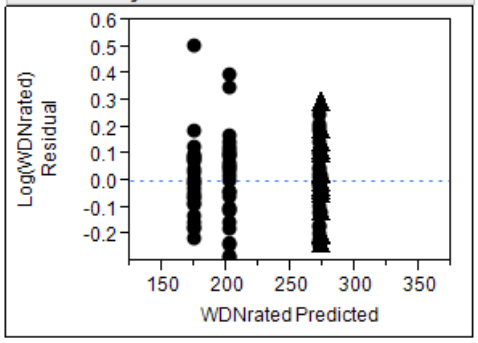
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	3.6991212	1.23304	57.3905
Error	99	2.1270230	0.02149	Prob > F
C. Total	102	5.8261442		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	5.4238275	0.014678	369.51	<.0001*	.
LINERPN[1Y3555]	0.0339484	0.014678	2.31	0.0228*	1.0109761
IND2[809-1]	-0.186219	0.014678	-12.69	<.0001*	1.0281113
LINERPN[1Y3555]*IND2[809-1]	0.0381144	0.014678	2.60	0.0108*	1.0304479

Residual by Predicted Plot



LSMeans Differences Tukey HSD

Differences are on transformed Y's
α= 0.050 Q= 2.61321

LSMean[j]

LSMean[i] / Mean[i]-Mean[j] Std Err Dif Lower CL Dif Upper CL Dif	1Y3555, 809-1	1Y3555, 811-1	1Y3998, 809-1	1Y3998, 811-1
1Y3555, 809-1	0	-0.2962	0.14413	-0.3045
	0	0.03817	0.03969	0.04298
	0	-0.396	0.0404	-0.4168
	0	-0.1965	0.24785	-0.1922
1Y3555, 811-1	0.29621	0	0.44034	-0.0083
	0.03817	0	0.04	0.04326
	0.19646	0	0.3358	-0.1214
	0.39596	0	0.54487	0.10472
1Y3998, 809-1	-0.1441	-0.4403	0	-0.4487
	0.03969	0.04	0	0.04461
	-0.2479	-0.5449	0	-0.5652
	-0.0404	-0.3358	0	-0.3321
1Y3998, 811-1	0.30454	0.00833	0.44867	0
	0.04298	0.04326	0.04461	0
	0.19224	-0.1047	0.33209	0
	0.41685	0.12139	0.56525	0

Level		Least Sq Mean
1Y3998, 811-1	A	274.29738
1Y3555, 811-1	A	272.02145
1Y3555, 809-1	B	202.28365
1Y3998, 809-1	C	175.13294

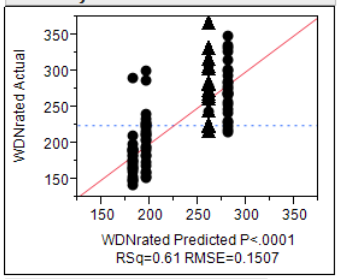
Levels not connected by same letter are significantly different.

Investigated the need to develop a correction dependent on the value observed.
I will share it if needed. Decided to use a correction that does not depend on the oil

LN WDNrated: Final Model includes Liner and Oil

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.610053
RSquare Adj	0.602254
Root Mean Square Error	0.150728
Mean of Response	5.414266
Observations (or Sum Wgts)	103

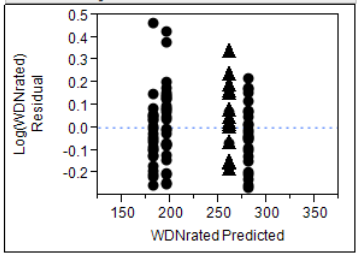
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	3.5542559	1.77713	78.2225
Error	100	2.2718883	0.02272	Prob > F
C. Total	102	5.8261442		<.0001*

Parameter Estimates

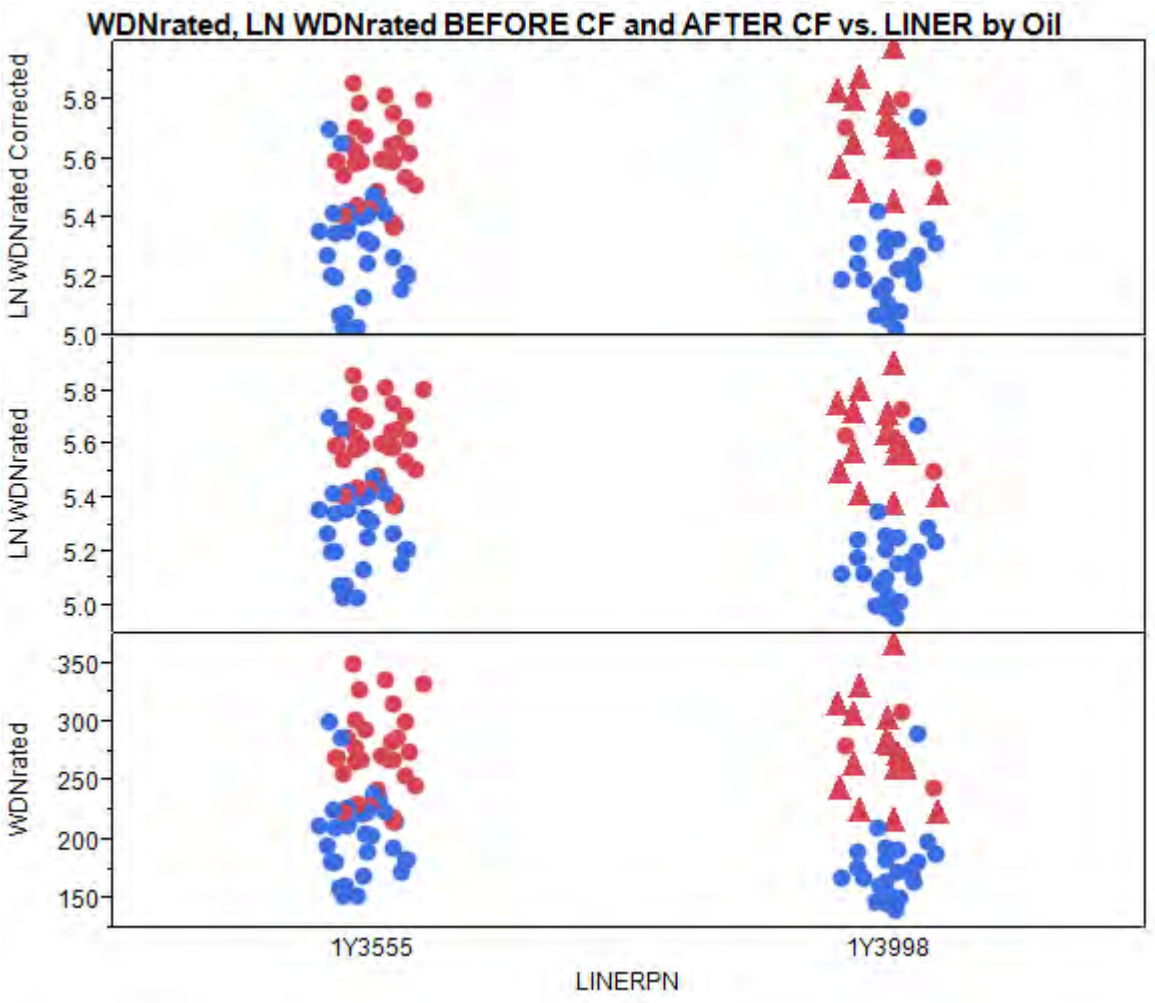
Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	5.4210999	0.015055	360.08	<.0001*	.
LINERPN[1Y3555]	0.0372221	0.015038	2.48	0.0150*	1.0035179
IND2[809-1]	-0.180324	0.014912	-12.09	<.0001*	1.0035179

Residual by Predicted Plot



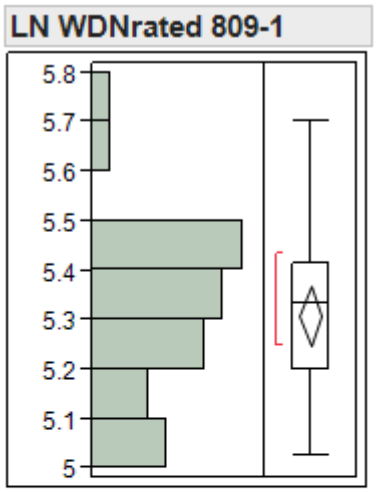
- Applied transformation: LN(WDNrated)
- Tested for statistically significant effects
- Liner means are statistically significantly different
- Oils are also statistically significantly different
- Proposed Correction Factor (CF): add 0.0744448 to LN (WDNrated)
- CF= 5.458322-5.383878= 0.074444
- Standard deviation: RMSE of model on the left, i.e. 0.150728

WDNrated original by Oil
LN(WDNrated) BEFORE CF by Oil
LN(WDNrated) AFTER CF by Oil

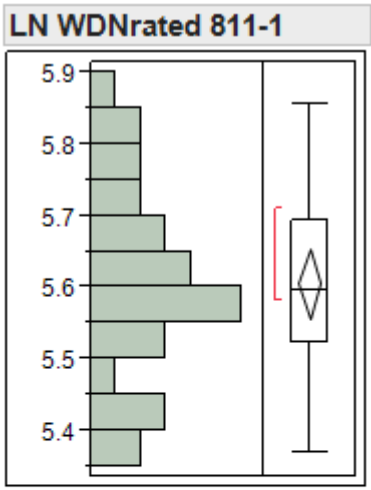


CF= 0.074444

Standard deviation for LN (WDNrated): RMSE



Summary Statistics	
Mean	5.3096709
Std Dev	0.1646309
Std Err Mean	0.0300573
Upper 95% Mean	5.3711451
Lower 95% Mean	5.2481968
N	30



Summary Statistics	
Mean	5.6058809
Std Dev	0.1299333
Std Err Mean	0.024128
Upper 95% Mean	5.6553049
Lower 95% Mean	5.556457
N	29

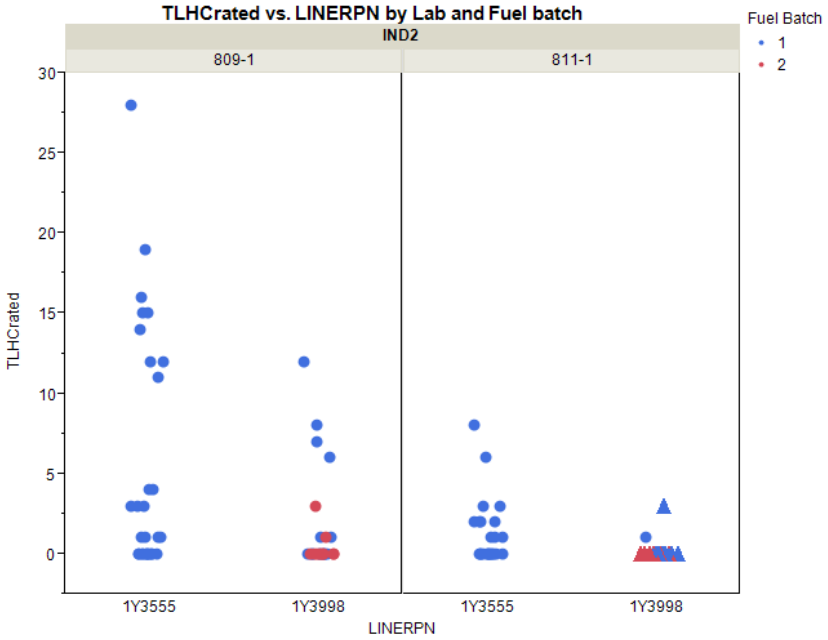
S_{pooled} for New Liner set 809/811= 0.1437

- 809-1
  - STD for Target set= 0.1646
- 811-1
  - STD for Target set= 0.1299
- RMSE for model that includes both liners for oils 809 and 811-1/ 811-2= 0.150728
- # of tests with new liner that do not calibrate:

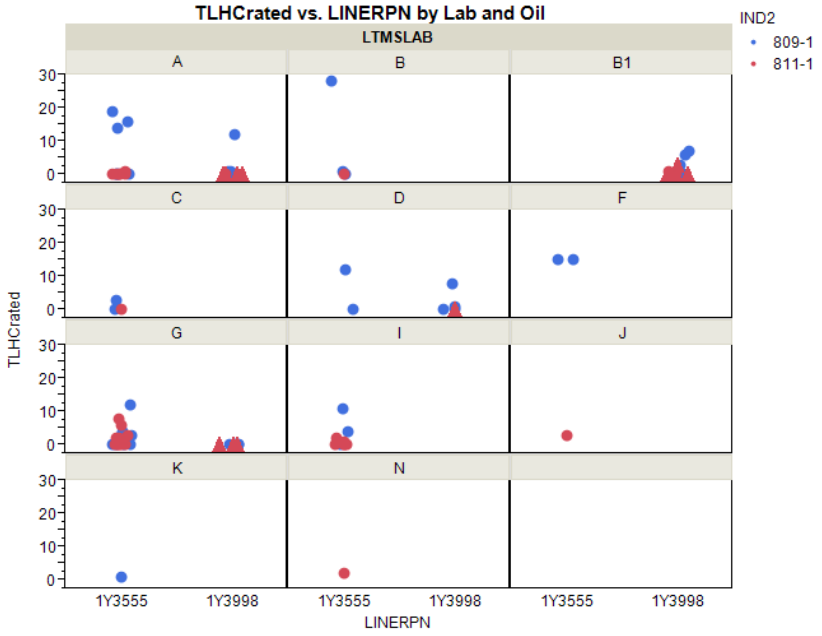
Using RMSE= 0.150728	
809 (25 tests)	
Before	After
1	2
811 (19 tests)	
Before	After
1	2

TLHCrated: Visualizing the data

All Labs by Oil, Liner and Fuel batch



By Lab, Liner and Oil



LN (TLHCrated +1)

Whole Model

Summary of Fit

RSquare	0.184841
RSquare Adj	0.168538
Root Mean Square Error	0.859108
Mean of Response	0.631227
Observations (or Sum Wgts)	103

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	16.735992	8.36800	11.3377
Error	100	73.806716	0.73807	Prob > F
C. Total	102	90.542708		<.0001*

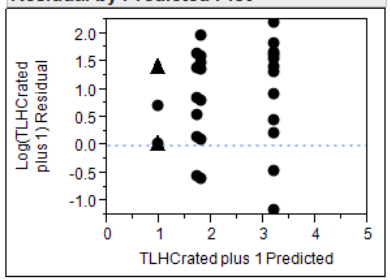
Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	1	1.000895	1.00090	1.3610
Pure Error	99	72.805820	0.73541	Prob > F
Total Error	100	73.806716		0.2462
				Max RSq
				0.1959

Parameter Estimates

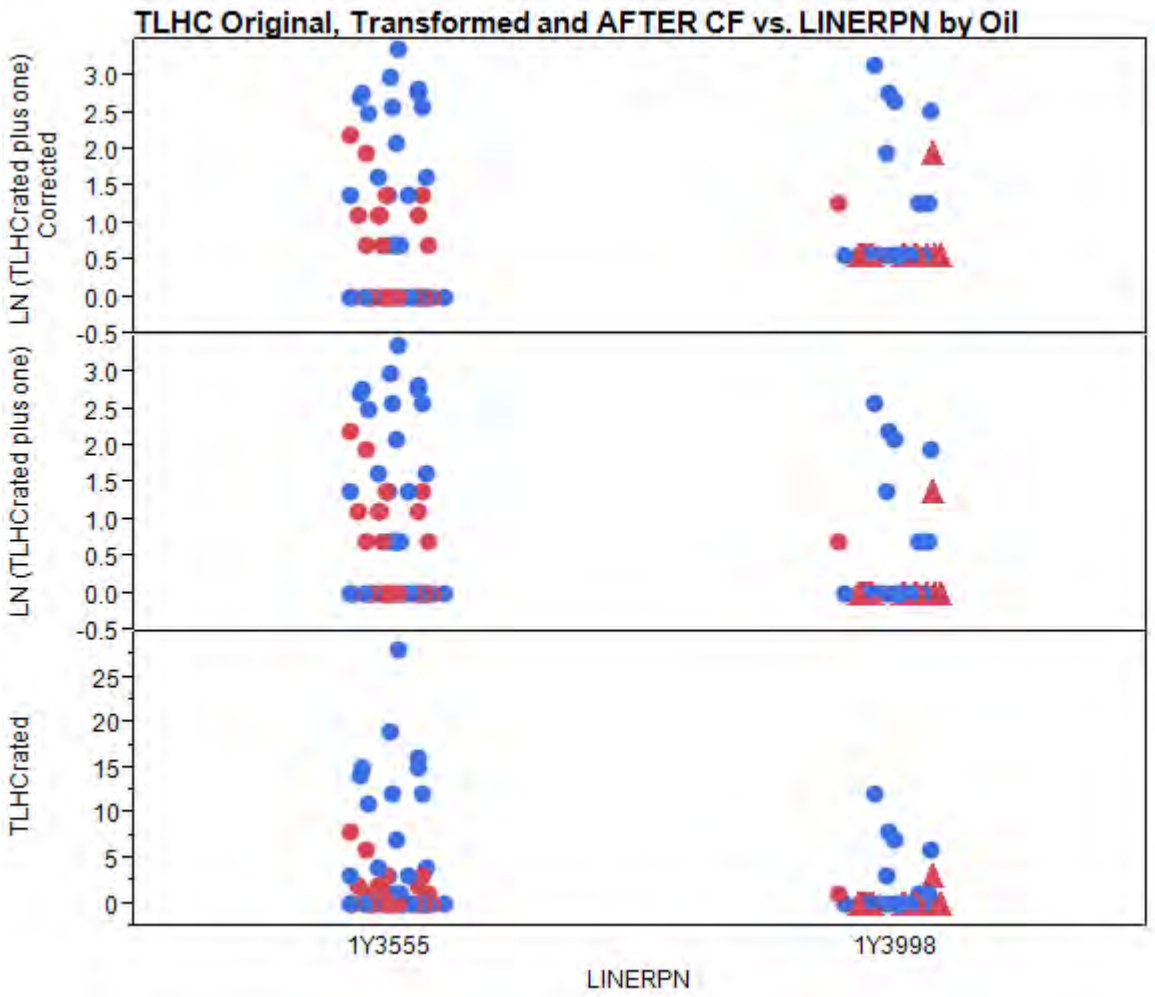
Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	0.5689357	0.08581	6.63	<.0001*	.
LINERPN[1Y3555]	0.2849228	0.085713	3.32	0.0012*	1.0035179
IND2[809-1]	0.3060227	0.084996	3.60	0.0005*	1.0035179

Residual by Predicted Plot



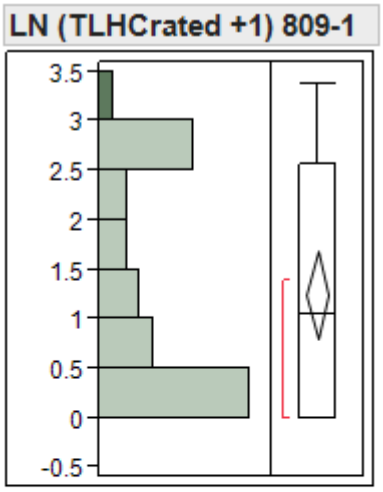
- Applied transformation: LN(TLHCrated+1)
- Tested for statistically significant effects
- Liner means are statistically significantly different
- Oils are also statistically significantly different
- Proposed Correction Factor (CF): add 0.569846 to LN(TLHCrated+1)
- CF= 0.853859-0.284013= 0.569846
- Standard deviation: RMSE of model on the left, i.e. 0.859108

TLHCrated by Oil
LN(TLHCrated +1) BEFORE CF by Oil
LN(TLHCrated +1) AFTER CF by Oil

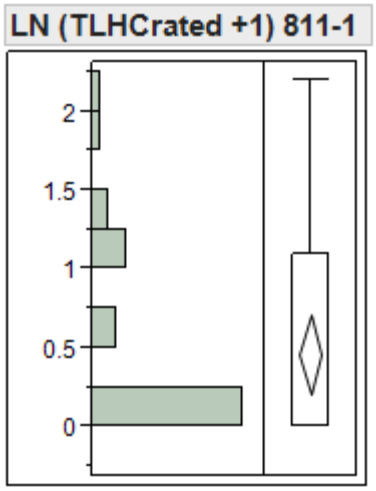


CF= 0.569846

Standard deviation for LN(TLHCrated +1)



Summary Statistics	
Mean	1.2431355
Std Dev	1.1920896
Std Err Mean	0.2176448
Upper 95% Mean	1.688269
Lower 95% Mean	0.7980019
N	30



Summary Statistics	
Mean	0.4617108
Std Dev	0.669355
Std Err Mean	0.1242961
Upper 95% Mean	0.7163199
Lower 95% Mean	0.2071018
N	29

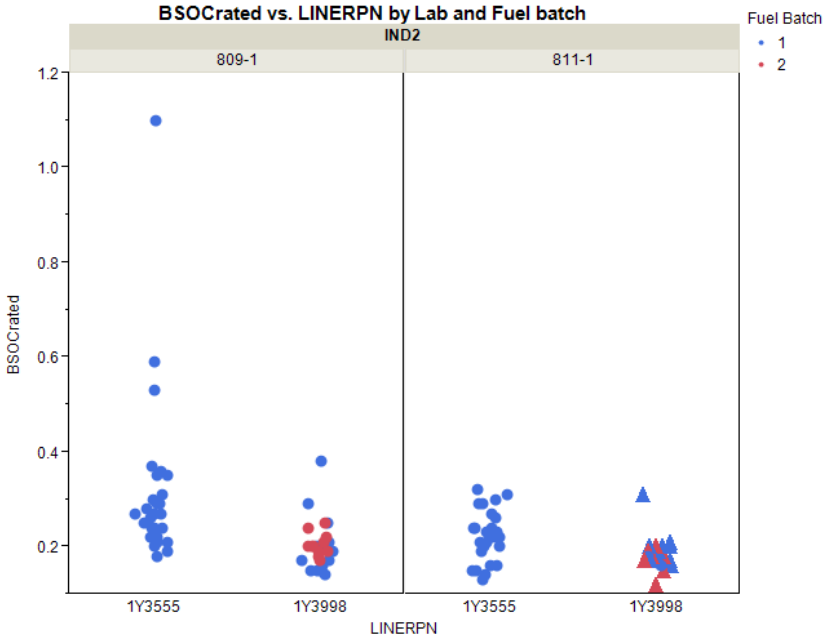
- 809-1
  - STD for Target set= 1.192
- 811-1
  - STD for Target set= 0.66935
- RMSE for model that includes both liners for oils 809 and 811-1/ 811-2= 0.859108
- # of tests with new liner that do not calibrate:

Using RMSE= 0.859108	
809 (25 tests)	
Before	After
0	2
811 (19 tests)	
Before	After
0	0

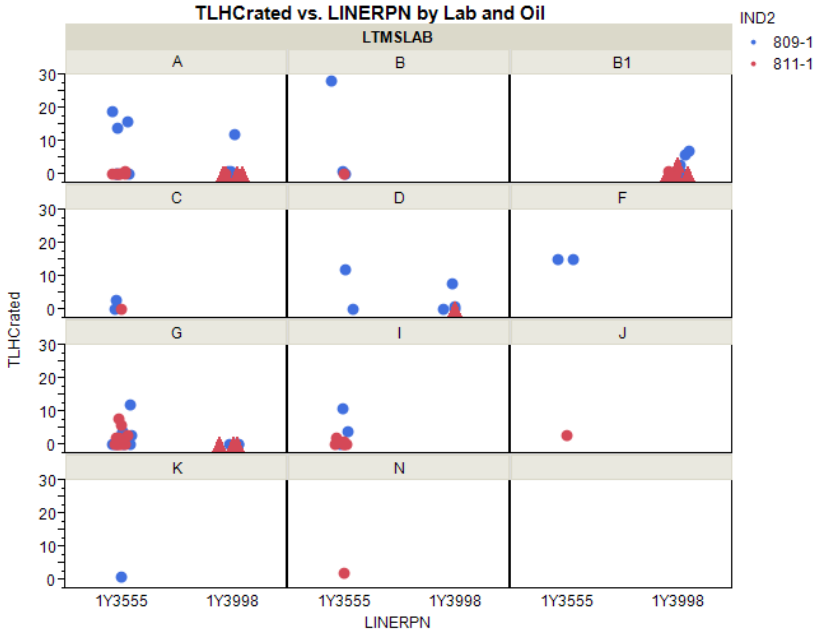
S_{pooled} for New Liner set 809/811= 0.673469

BSOCrated: Visualizing the data

All Labs by Oil, Liner and Fuel batch



By Lab, Liner and Oil



LN (BSOCrated)

Whole Model

Summary of Fit

RSquare	0.251816
RSquare Adj	0.236852
Root Mean Square Error	0.280647
Mean of Response	-1.51176
Observations (or Sum Wgts)	103

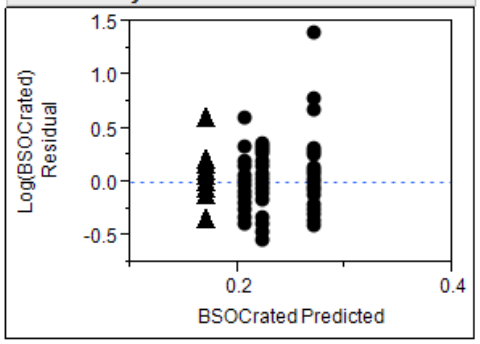
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	2.650923	1.32546	16.8285
Error	100	7.876294	0.07876	Prob > F
C. Total	102	10.527216		<.0001*

Parameter Estimates

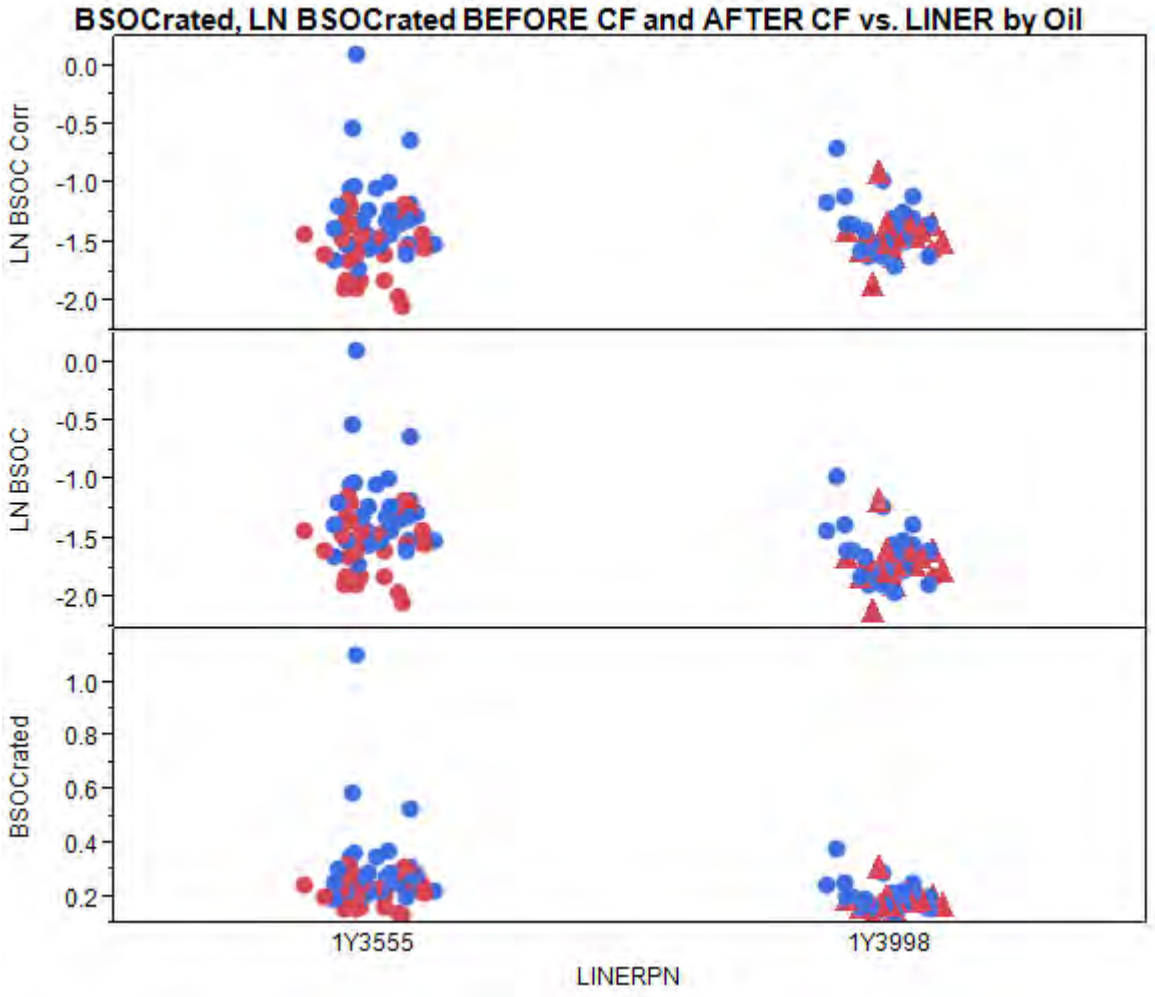
Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	-1.538003	0.028032	-54.87	<.0001*	.
LINERPN[1Y3555]	0.1343998	0.028	4.80	<.0001*	1.0035179
IND2[809-1]	0.0982046	0.027766	3.54	0.0006*	1.0035179

Residual by Predicted Plot



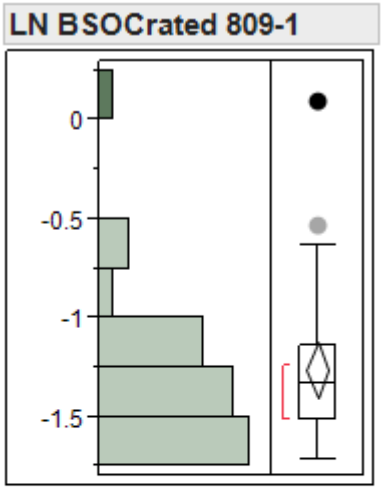
- Applied transformation: LN(BSOCrated)
- Tested for statistically significant effects
- Liner means are statistically significantly different
- Oils are also statistically significantly different
- Proposed Correction Factor (CF): add 0.2688 to LN(BSOCrated)
- CF= -1.4036-(-1.6724)= 0.2688
- Standard deviation: RMSE of model on the left, i.e. 0.280647

BSOCrated by Oil
LN(BSOCrated) BEFORE CF by Oil
LN(BSOCrated) AFTER CF by Oil

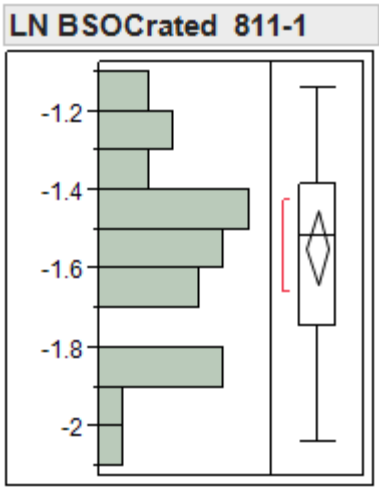


CF= 0.2688

Standard deviation for LN(BSOCrated)



Summary Statistics	
Mean	-1.264208
Std Dev	0.3759706
Std Err Mean	0.0686425
Upper 95% Mean	-1.123818
Lower 95% Mean	-1.404598
N	30



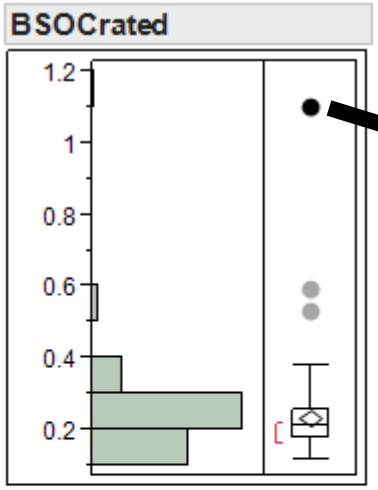
Summary Statistics	
Mean	-1.544419
Std Dev	0.2471592
Std Err Mean	0.0458963
Upper 95% Mean	-1.450405
Lower 95% Mean	-1.638434
N	29

- 809-1
  - STD for Target set= 0.37597
- 811-1
  - STD for Target set= 0.247159
- RMSE for model that includes both liners for oils 809 and 811-1/ 811-2= 0.280647
- # of tests with new liner that do not calibrate:

Using RMSE= 0.2806	
809 (25 tests)	
Before	After
0	1
811 (19 tests)	
Before	After
1	1

S_{pooled} for New Liner set 809/811= 0.208256

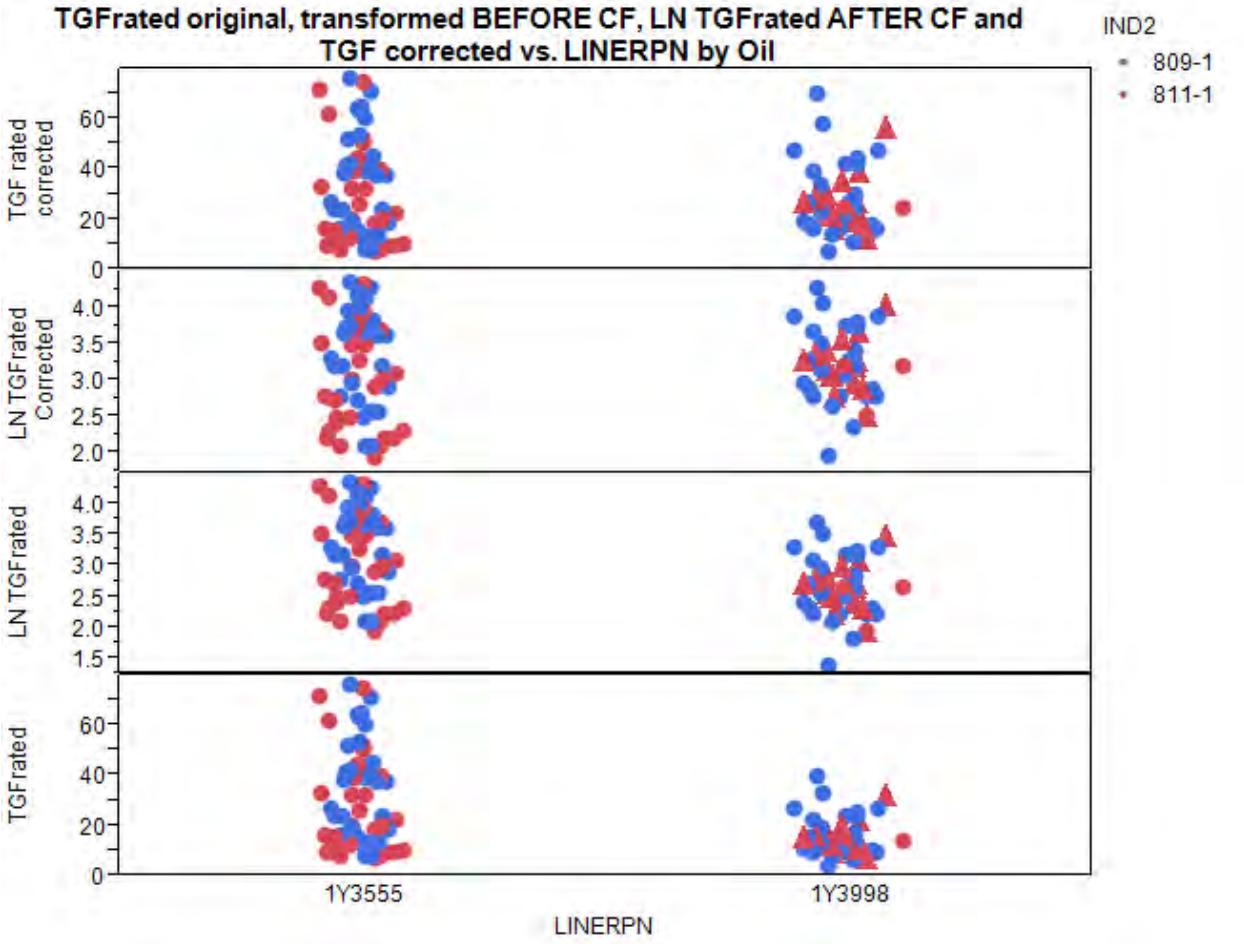
BSOC: additional details



Summary Statistics

Mean	0.2348544
Std Dev	0.112893
Std Err Mean	0.0111237
Upper 95% Mean	0.2569181
Lower 95% Mean	0.2127906
N	103

Transformation for BSOC was identified by temporarily excluding this test value from the analysis


TGFrated original, transformed BEFORE CF, LN TGFrated AFTER CF and TGF corrected vs. LINERPN by Oil
IND2
809-1
811-1
TGF rated corrected
LN TGFrated Corrected
LN TGFrated
TGFrated
1Y3555
1Y3998
LINERPN