CAT Test Surveillance Panel Meeting
May 13, 2014
Peoria, IL

The meeting began at 8:35 am. The Attendance is shown in **Attachment 1**.

1N Correction Factor Analysis

Elisa Santos presented her analysis (**Attachment 2**). Elisa explained the reasoning for a data transformation and asked if there were any questions about it. She is trying to address the change in test performance (reduced mean and variability) associated with the liner change. During a lengthy discussion the following were noted:

- The panel asked Elisa to:
  - Calculate weighted averages for target data set (both oils), old liners. Calculate weighted averages for new liners; compare the differences.
  - Calculate pooled standard deviations for old target data set and pooled standard deviation for the new liner data set.

- The ACC proactive monitoring plots appear to demonstrate the same severity change seen in the reference data.

- The panel should consider pursuing a new technology reference oil but perhaps only after the severity issued have been resolved.

At this point in the meeting, the discussion was paused to allow Elisa to run the analysis requested - with the intent of resuming the discussion later in the day.

1K Test Fuel TAN Specification

The last few batches of SDTF (fuel used in the 1K) have missed the TAN specification. This is due to the crude source and is expected to continue. Mike Wendling of Haltermann indicated that typically the copper corrosion has been of bigger concern rather than TAN. The recent batches have not had any problems meeting the copper corrosion spec. After discussion it was generally agreed to that: the spec would not be changed and that approval of future batches with TAN variances would be handled by panel e-ballot and that this issue would remain an item of concern at future panel meetings.

Action Item - for any batch above the TAN specification, send an email ballot for batch approval - J. Gutzwiller.

C13 Pre-Test Ring Cleaning Procedure

The ring cleaning procedure was updated in late 2013, but so far has not appeared to produce the desired severity change (from mild to back on target). The labs expressed a desire to use Ensolv rather than pentane. It was moved and seconded (Moritz, McCord) to change the C13 test method by removing the referenced cleaning document and noting that Ensolv, followed by a pentane rinse has been found to work. The motion was approved unanimously.

Action Item - TMC to issue appropriate information letter.

Permanent Surveillance Panel Secretary

The official secretary of record is Addison Schweitzer who no longer attends panel business. Martin Thompson of SwRI volunteered to begin duties as panel secretary, starting with the next meeting.

Update on Supply of Reference Oils

Jeff Clark presented Sean Moyer's update on the supply of reference oils; the update is show in **Attachment 3**.

Test Parts Supply

- C13
    - There are quality control concerns (rotating bushing) for Batch R4702 of the 1Y4106 piston. Hind Abi-Akar of CAT requested that labs quarantine those pistons and report back how many have been affected. CAT will advise labs if /when to return the pistons for validation. Future batches will all be fully inspected.
        - **ACTION ITEM** - labs are to report to CAT the number of Batch R4702 pistons in their inventories.
    - Liner Seal 104-3560 (O-ring) is susceptible to bore distortion and is currently used in the C13 test. It has been replaced in current production (with 437-1409). It was moved (McCord, Moritz) to move to the 437-1409 liner seal for all engines built on or after May 14, 2014. This motion passed unanimously.
        - **ACTION ITEM** - CAT to change the 1Y-4116 soft kit accordingly.
        - **ACTION ITEM** - TMC to update the parts list maintained on the website.

- There have been problems getting turbo charger from dealers and those possibly having different shaft seals. Is there a possibility having a CAT approved turbo rebuilder?
  - **ACTION ITEM** - CAT will investigate rebuild possibilities and long term availability of the current C13 turbos.

- The question was asked if the block can be bought separately.The test procedure specifically states an engine arrangement. Mark Jarrett of CAT stated that he believed short blocks should be available. The panel will consider a list of engine arrangement components that could be purchased separately.

- Jim Moritz brought liners (with and without machining marks) to show differences in id surface finish and showed the surface finish results (**Attachment 4**) of the different liners. Jim's quick analysis shows a significant difference.
  - **ACTION ITEM** - CAT will investigate.

- 1P

  - Liners - a new date code has been observed. The question was asked if this was a new batch of liners.
    - **ACTION ITEM** - CAT will investigate.

- 1K/1N - Jade Katinas reviewed current parts supply issues.

  - There are currently no 1Y-3998 liners in stock. CAT is working to resolve.
  - Water pump - several components are not currently available. CAT is working to resolve. In the long term, Jade noted that it would be best to replace the mechanical pump with an electrical pump. CAT is working on the long term solution that they'd like in place for PC-11.
  - Cooling Heat exchanger - currently two are available from Grainger. CAT's long term recommendation is to modernize the heat exchanger.
  - Oil Pump - CAT is looking to modernize the oil pump used for the test.
    - **ACTION ITEM** - CAT will organize a hardware task force to help address the component modernization issue

Resumption of 1N Analysis

Elisa presented the calculations she had been asked for earlier in the meeting (**Attachment 2a**). The general consensus was that the test is in need of correction by some method, though what the method should be is not certain at

this time. The mean difference approach appeared problematic. Remaining possibilities include (but not limited to) the transforms and a multiplicative factor.

ACTION ITEM: Elisa was asked to summarize and apply two options for future consideration: transforms and multiplicative correction. It was noted that the SA standard deviation needs to be included in the discussion.

ACTION ITEM: Interested parties are encouraged to take the results of Elisa's summary and apply to their data to gage the scope / impact of the transforms and corrections.

Test Procedure Clean Ups

Jim Moritz noted that SCOTE procedures have the wrong auxiliary oil pump flow rates. His suggested fix was to specify the pump, motor speed, and line sizes.

ACTION ITEM: Jim Moritz will draft some wording to handle this issue.

C13 Aeration Test

Mark Cooper asked about if this surveillance panel needs to address CJ-4 limits to replace the EOAT. Martin Thompson commented that this will be part of the C13 Aeration development.

The meeting adjourned at 4:25 p.m.

ATTACHMENT 1

NAME	COMPANY
JIM GUTZWILLER	INFINEUM
Jim McCord	SwRI
Martin Thompson	SwRI
Jade Katinas	Cat
Mark Jaroff	CAT
MATTHEW BOWDEN	OH TECHNOLOGIES
Mark Cooper	Chevron Oronite
Jeff Clark	TMC
Greg Seman	Lubrizol
Andrew Stevens	Lubrizol
Michael Conrad	Lubrizol
Bob Salgueiro	Infineum
ELISA SANTOS	Infineum
Mike Alessi	ExxonMobil
JIM MORITZ	INTERTEK
Adam Roig	Intertek
Ahind AK Aher	Caterpillar

Via Teleconference

Bob Campbell	Afton
Zach Bishop	TEI
Sean Mayer	TMC
Kevin O'Malley	Lubrizol
Mike Wendling	Halterman

ATTACHMENT 2

Second part

May 13th 2014

Elisa Santos

For CAT Surveillance Panel

Infineum

Mean and Standard deviations by Parameter

LN(TLHC rated plus one)

Oil	Liner	# of tests	Mean(LN(TLHC rated plus one))	Std Dev(LN(TLHC rated plus one))
809-1	1Y355	30	1.197	1.213
809-1	1Y3998	30	0.50086	0.83375
811-2	1Y355	30	0.366	0.6
811-2	1Y3998	19	0.109444	0.347585
811*	1Y3998	22	0.12603	0.3473

TGF

Oil	Liner	# of tests	Mean(LN(TLHC rated plus one))	Std Dev(LN(TLHC rated plus one))
809-1	1Y355	30	35.3	20.5
809-1	1Y3998	30	17.700	13.2305
811-2	1Y355	30	24.7	21.6
811-2	1Y3998	19	14.42105	5.59082
811*	1Y3998	22	14.04545	5.4114

WDN

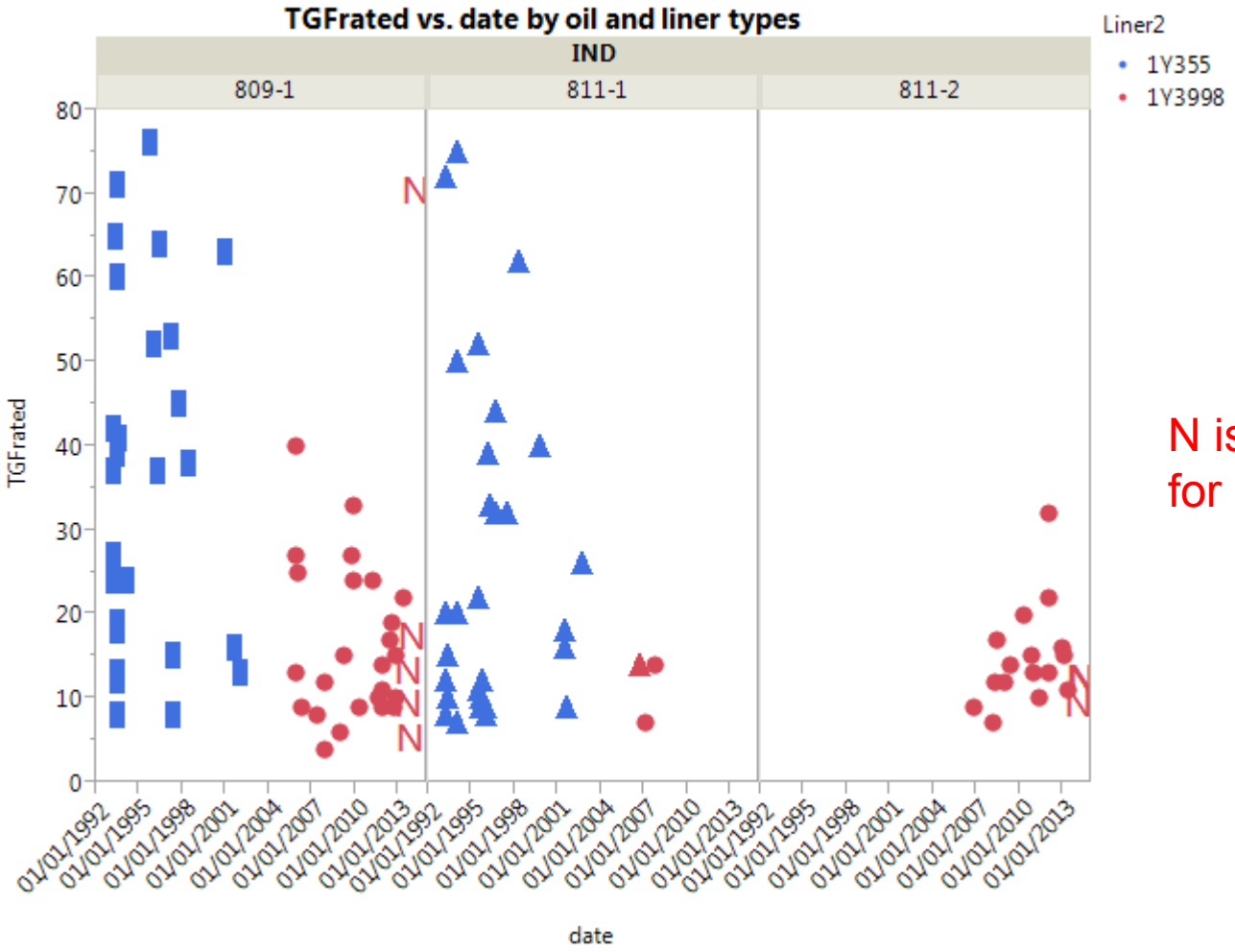
Oil	Liner	# of tests	Mean(LN(TLHC rated plus one))	Std Dev(LN(TLHC rated plus one))
809-1	1Y355	30	205	34.6
809-1	1Y3998	30	179.62000	28.80947
811-2	1Y355	30	281.5	37.4
811-2	1Y3998	19	273.47368	38.41626
811*	1Y3998	22	273.94091	36.9650

Average Oil Consumption

Oil	Liner	# of tests	Mean(LN(TLHC rated plus one))	Std Dev(LN(TLHC rated plus one))
809-1	1Y355	30	0.308	0.175
809-1	1Y3998	30	0.20867	0.06720
811-2	1Y355	30	0.223	0.052
811-2	1Y3998	19	0.18895	0.03784
811*	1Y3998	22	0.18636	0.0358

* 3 tests with 811-1 and 19 with 811-2

Reasoning for data transformation



N is the symbol for recent data

Reasoning for data transformation

- To achieve constant variance
- To reduce mean/variance relationship: the larger the mean, the larger the variability
- Looking at a plot of the residuals versus fitted values helps assess potential lack of constant variance
- The logarithm and square root transformations are commonly used for positive data, and the reciprocal transformation can be used for non-zero data. These are particular cases of Box-Cox transformations
- Failing to address this issue may result in inappropriate estimates and inferences

TGF

Summary of Fit

RSquare	0.311045
RSquare Adj	0.226684
Root Mean Square Error	0.608679
Mean of Response	2.933958
Observations (or Sum Wgts)	111

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	16.392150	1.36601	3.6870
Error	98	36.308043	0.37049	Prob > F
C. Total	110	52.700193		0.0001*

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	10	7.147397	0.714740	2.1569
Pure Error	88	29.160646	0.331371	Prob > F
Total Error	98	36.308043		0.0279*
				Max RSq
				0.4467

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	2.9414086	0.12317	23.88	<.0001*	.
LTMSLAB[A]	0.1511641	0.161489	0.94	0.3515	1.6487705
LTMSLAB[B]	-0.444756	0.302251	-1.47	0.1444	1.2129106
LTMSLAB[B1]	-0.350302	0.210971	-1.66	0.1000	1.8853631
LTMSLAB[C]	-0.040413	0.34086	-0.12	0.9059	1.2430968
LTMSLAB[D]	0.0616868	0.241458	0.26	0.7989	1.3468136
LTMSLAB[F]	0.6662855	0.411929	1.62	0.1090	1.3698833
LTMSLAB[G]	-0.016569	0.150083	-0.11	0.9123	1.5555451
LTMSLAB[I]	-0.155044	0.221792	-0.70	0.4862	1.2511907
LTMSLAB[J]	0.3487958	0.567762	0.61	0.5404	1.740148
LTMSLAB[K]	0.8166504	0.566789	1.44	0.1528	1.7341881
Liner2[1Y355]	0.2559085	0.074563	3.43	0.0009*	1.6590447
IND2[809-1]	0.080377	0.061361	1.31	0.1933	1.1206312

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	10	10	6.2411824	1.6846	0.0950
Liner2	1	1	4.3641912	11.7795	0.0009*
IND2	1	1	0.6357103	1.7159	0.1933

Least Squares Means Table

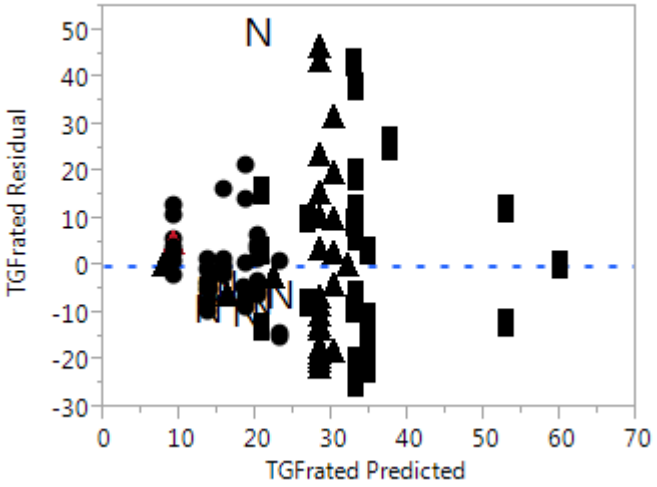
Level	Least Sq Mean	Std Error	Mean
1Y355	3.1973171	0.12209990	3.19651
1Y3998	2.6855001	0.16294889	2.63606

Least Squares Means Table

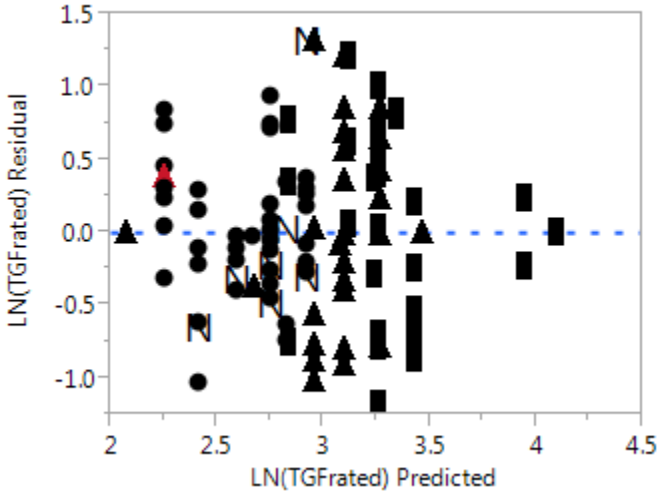
Level	Least Sq Mean	Std Error	
809-1	3.0217856	0.13305746	3.
811	2.8610316	0.14201247	2.

Residuals before transformation

Residual by Predicted Plot

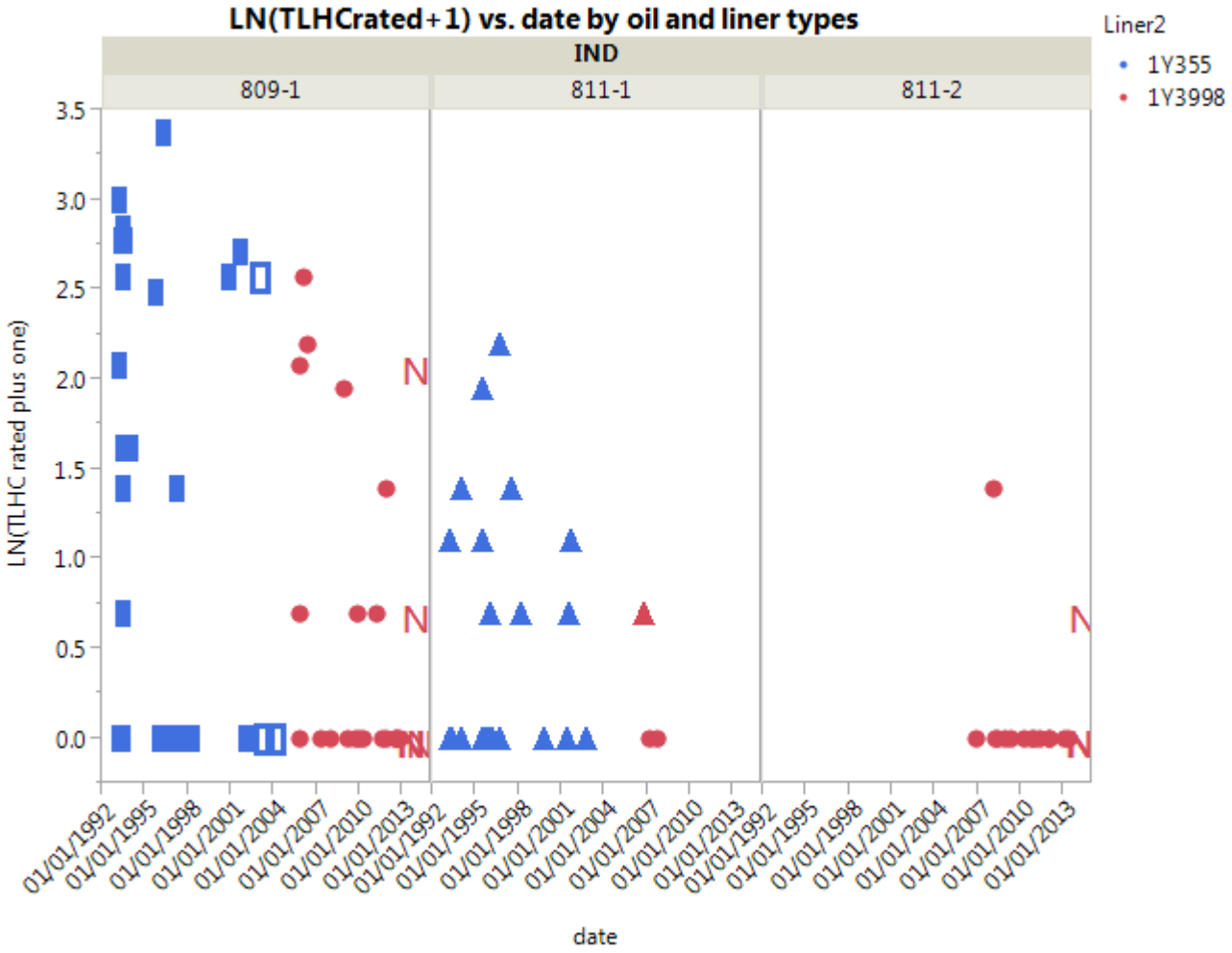


Residual by Predicted Plot

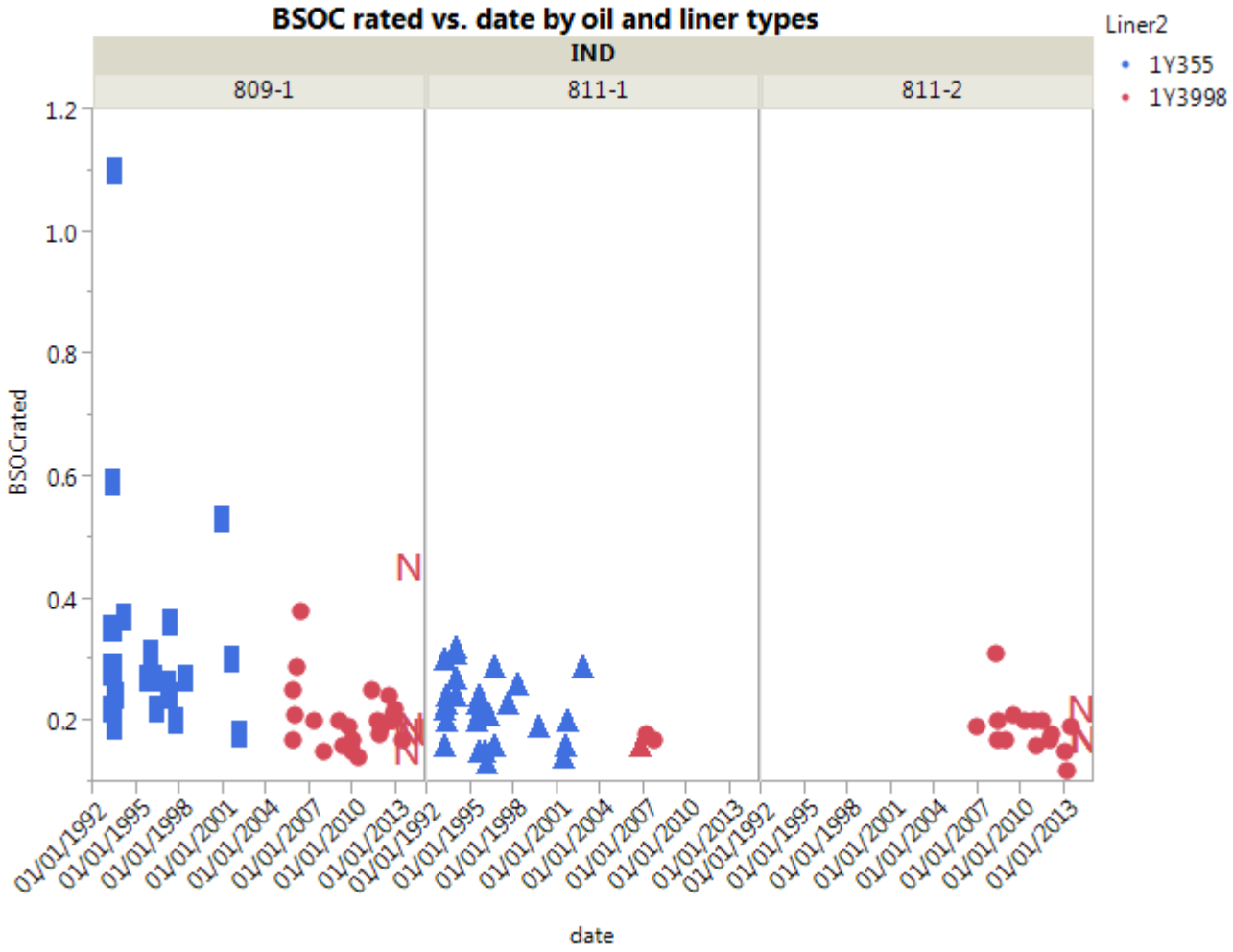


Residuals after transformation

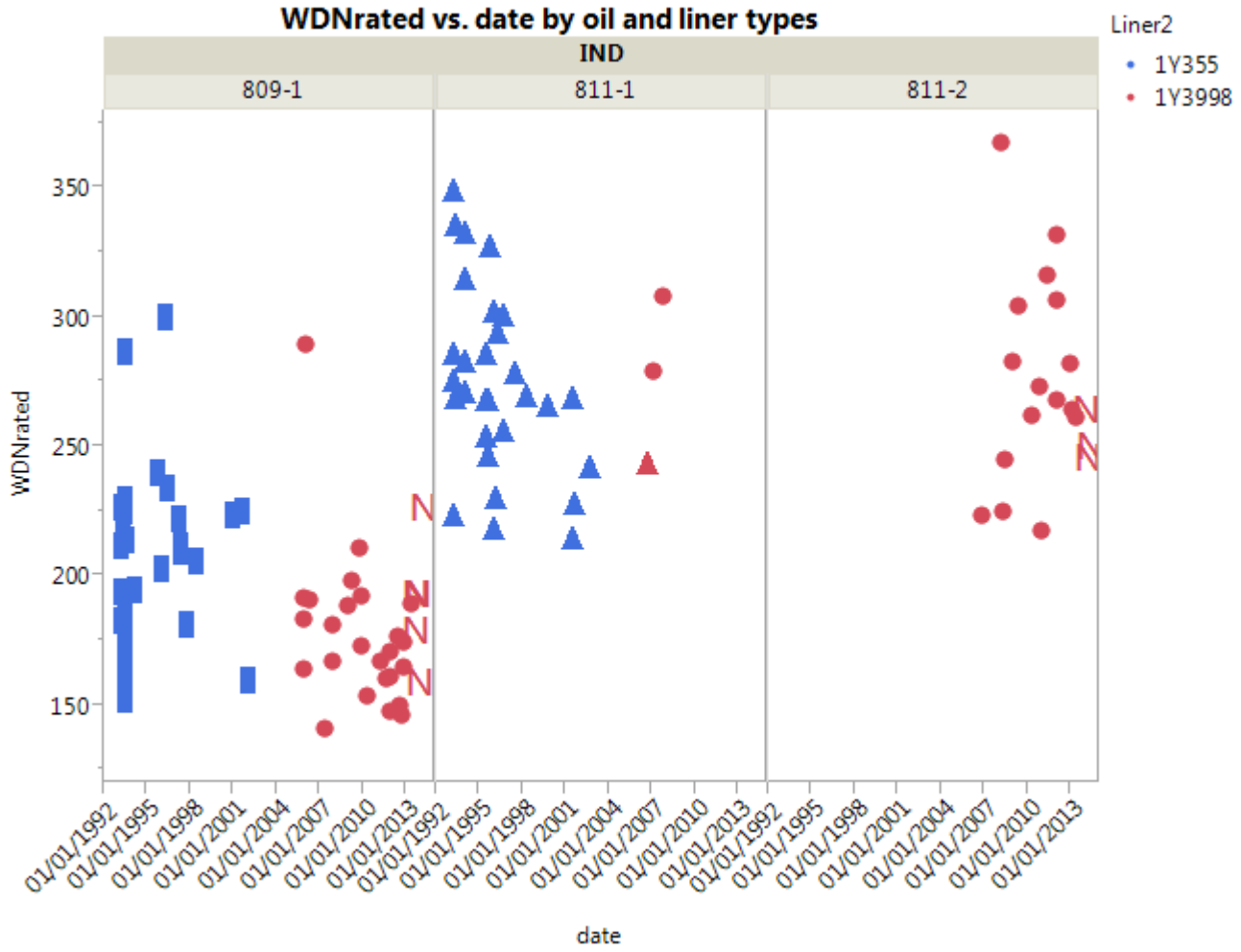
LN(TLHCrated +1)



BSOC: Oil Consumption



WDN



Summary of Correction Factors and Standard Deviations by Parameter

Parameter	Previous sample size 809/1Y3555 809/1Y3998 811/1Y3555 811/1Y3998	Target Labs	Current Labs	Transformation	Lab effect	Oil effect	Liner effect	Previous Correction Factor to be added to the transformed values	Most recent Correction Factor to be added to the transformed values	Previous Standard deviation: RMSE	Most recent Standard deviation: RMSE	Previous New Liner Standard Deviation: Pooled 809/811	Most recent New Liner Standard Deviation: Pooled 809/811-2	Most recent Correction on original scale
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	0.511817	0.632151	0.608679	0.49	0.530791	9.80
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	0.097107	0.150728	0.146344	0.1437	0.142317	21.82
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	0.690769	0.859108	0.830756	0.673469	0.68934	0.691
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	0.3128	0.280647	0.277815	0.208256	0.235224	0.068

WDN

Summary of Fit

RSquare	0.654442
RSquare Adj	0.612129
Root Mean Square Error	0.146344
Mean of Response	5.410441
Observations (or Sum Wgts)	111

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	3.9748885	0.331241	15.4666
Error	98	2.0988155	0.021416	Prob > F
C. Total	110	6.0737040		<.0001*

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	10	0.2925301	0.029253	1.4252
Pure Error	88	1.8062854	0.020526	Prob > F
Total Error	98	2.0988155		0.1825
				Max RSq
				0.7026

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	5.4144218	0.029613	182.84	<.0001*	.
LTMSLAB[A]	0.0444537	0.038827	1.14	0.2550	1.6487705
LTMSLAB[B]	0.0522252	0.07267	0.72	0.4741	1.2129106
LTMSLAB[B1]	0.053277	0.050723	1.05	0.2961	1.8853631
LTMSLAB[C]	-0.070754	0.081952	-0.86	0.3901	1.2430968
LTMSLAB[D]	-0.010102	0.058053	-0.17	0.8622	1.3468136
LTMSLAB[F]	0.0876694	0.099039	0.89	0.3782	1.3698833
LTMSLAB[G]	-0.040009	0.036084	-1.11	0.2702	1.5555451
LTMSLAB[I]	0.0041736	0.053325	0.08	0.9378	1.2511907
LTMSLAB[J]	-0.015585	0.136506	-0.11	0.9093	1.740148
LTMSLAB[K]	0.1314054	0.136272	0.96	0.3373	1.7341881
Liner2[1Y355]	0.0485533	0.017927	2.71	0.0080*	1.6590447
IND2[809-1]	-0.18095	0.014753	-12.27	<.0001*	1.1206312

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	10	10	0.2528734	1.1807	0.3131
Liner2	1	1	0.1570986	7.3354	0.0080*
IND2	1	1	3.2219179	150.4410	<.0001*

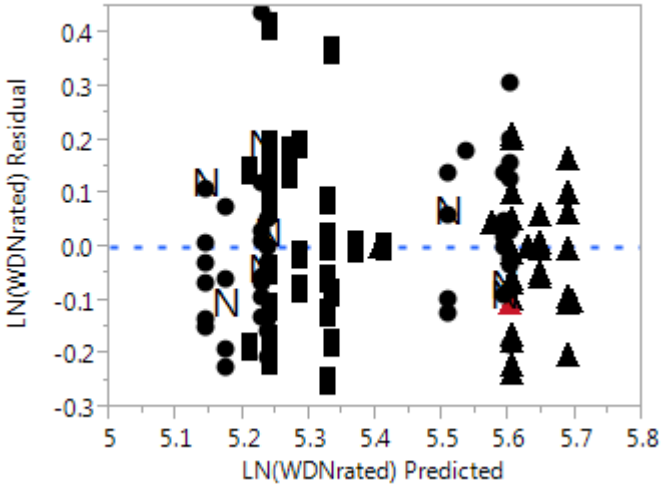
Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
1Y355	5.4629751	0.02935628	5.45527
1Y3998	5.3658685	0.03917753	5.35958

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
809-1	5.2334715	0.03199079	5.24482
811	5.5953721	0.03414383	5.60529

Residual by Predicted Plot



Residuals after transformation

BSOC: Oil Consumption

Summary of Fit

RSquare	0.331104
RSquare Adj	0.249199
Root Mean Square Error	0.277815
Mean of Response	-1.51487
Observations (or Sum Wgts)	111

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	3.744053	0.312004	4.0425
Error	98	7.563729	0.077181	Prob > F
C. Total	110	11.307782		<.0001*

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	10	0.6083434	0.060834	0.7697
Pure Error	88	6.9553855	0.079038	Prob > F
Total Error	98	7.5637289		0.6573
				Max RSq
				0.3849

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	-1.533581	0.056217	-27.28	<.0001*	.
LTMSLAB[A]	0.0538943	0.073707	0.73	0.4664	1.6487705
LTMSLAB[B]	-0.167944	0.137954	-1.22	0.2264	1.2129106
LTMSLAB[B1]	0.049896	0.096292	0.52	0.6055	1.8853631
LTMSLAB[C]	-0.198728	0.155576	-1.28	0.2045	1.2430968
LTMSLAB[D]	0.1888141	0.110207	1.71	0.0898	1.3468136
LTMSLAB[F]	0.3097292	0.188014	1.65	0.1027	1.3698833
LTMSLAB[G]	-0.098	0.068501	-1.43	0.1557	1.5555451
LTMSLAB[I]	0.0515488	0.101231	0.51	0.6117	1.2511907
LTMSLAB[J]	-0.002373	0.259139	-0.01	0.9927	1.740148
LTMSLAB[K]	-0.140013	0.258695	-0.54	0.5896	1.7341881
IND2[809-1]	0.0900994	0.028006	3.22	0.0018*	1.1206312
Liner2[1Y355]	0.1563783	0.034032	4.60	<.0001*	1.6590447

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	10	10	1.1176288	1.4481	0.1709
IND2	1	1	0.7988022	10.3497	0.0018*
Liner2	1	1	1.6296230	21.1143	<.0001*

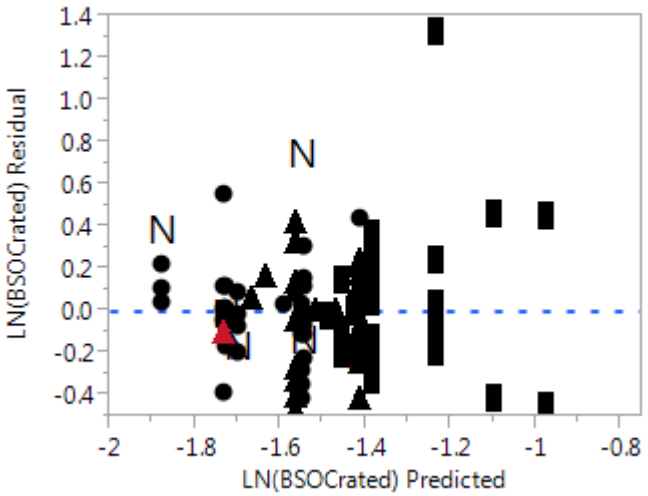
Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
809-1	-1.443482	0.06073035	-1.4343
811	-1.623681	0.06481761	-1.6097

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
1Y355	-1.377203	0.05572908	-1.4019
1Y3998	-1.689960	0.07437345	-1.6430

Residual by Predicted Plot



Residuals after transformation

LN(TLHC rated +1)

Summary of Fit

RSquare	0.28517
RSquare Adj	0.19764
Root Mean Square Error	0.830756
Mean of Response	0.616956
Observations (or Sum Wgts)	111

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	26.982031	2.24850	3.2580
Error	98	67.635302	0.69016	Prob > F
C. Total	110	94.617333		0.0006*

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	10	5.293378	0.529338	0.7472
Pure Error	88	62.341924	0.708431	Prob > F
Total Error	98	67.635302		0.6783
				Max RSq
				0.3411

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	0.7347216	0.168108	4.37	<.0001*	.
LTMSLAB[A]	-0.245355	0.220409	-1.11	0.2684	1.6487705
LTMSLAB[B]	-0.208767	0.412528	-0.51	0.6139	1.2129106
LTMSLAB[B1]	0.1905494	0.287944	0.66	0.5097	1.8853631
LTMSLAB[C]	-0.713856	0.465223	-1.53	0.1281	1.2430968
LTMSLAB[D]	-0.009129	0.329554	-0.03	0.9780	1.3468136
LTMSLAB[F]	1.4049386	0.562222	2.50	0.0141*	1.3698833
LTMSLAB[G]	-0.313415	0.204841	-1.53	0.1292	1.5555451
LTMSLAB[I]	-0.330246	0.302713	-1.09	0.2780	1.2511907
LTMSLAB[J]	0.5937328	0.774911	0.77	0.4454	1.740148
LTMSLAB[K]	-0.674503	0.773583	-0.87	0.3854	1.7341881
Liner2[1Y355]	0.3453843	0.101767	3.39	0.0010*	1.6590447
IND2[809-1]	0.2875443	0.083748	3.43	0.0009*	1.1206312

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
LTMSLAB	10	10	9.9411197	1.4404	0.1741
Liner2	1	1	7.9494925	11.5184	0.0010*
IND2	1	1	8.1358935	11.7885	0.0009*

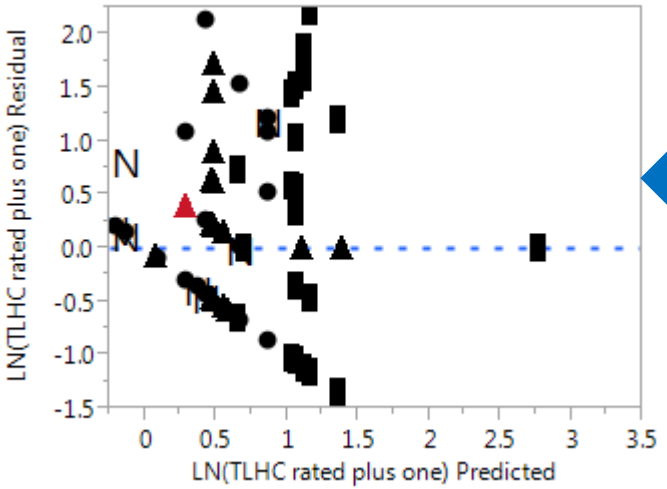
Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
1Y355	1.0801058	0.16664818	0.859045
1Y3998	0.3893373	0.22240098	0.342278

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
809-1	1.0222659	0.18160363	0.871999
811	0.4471773	0.19382588	0.316906

Residual by Predicted Plot



Residuals after transformation

The best transformation is the inverse, but LN is the one being used right now. I decided to keep it

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

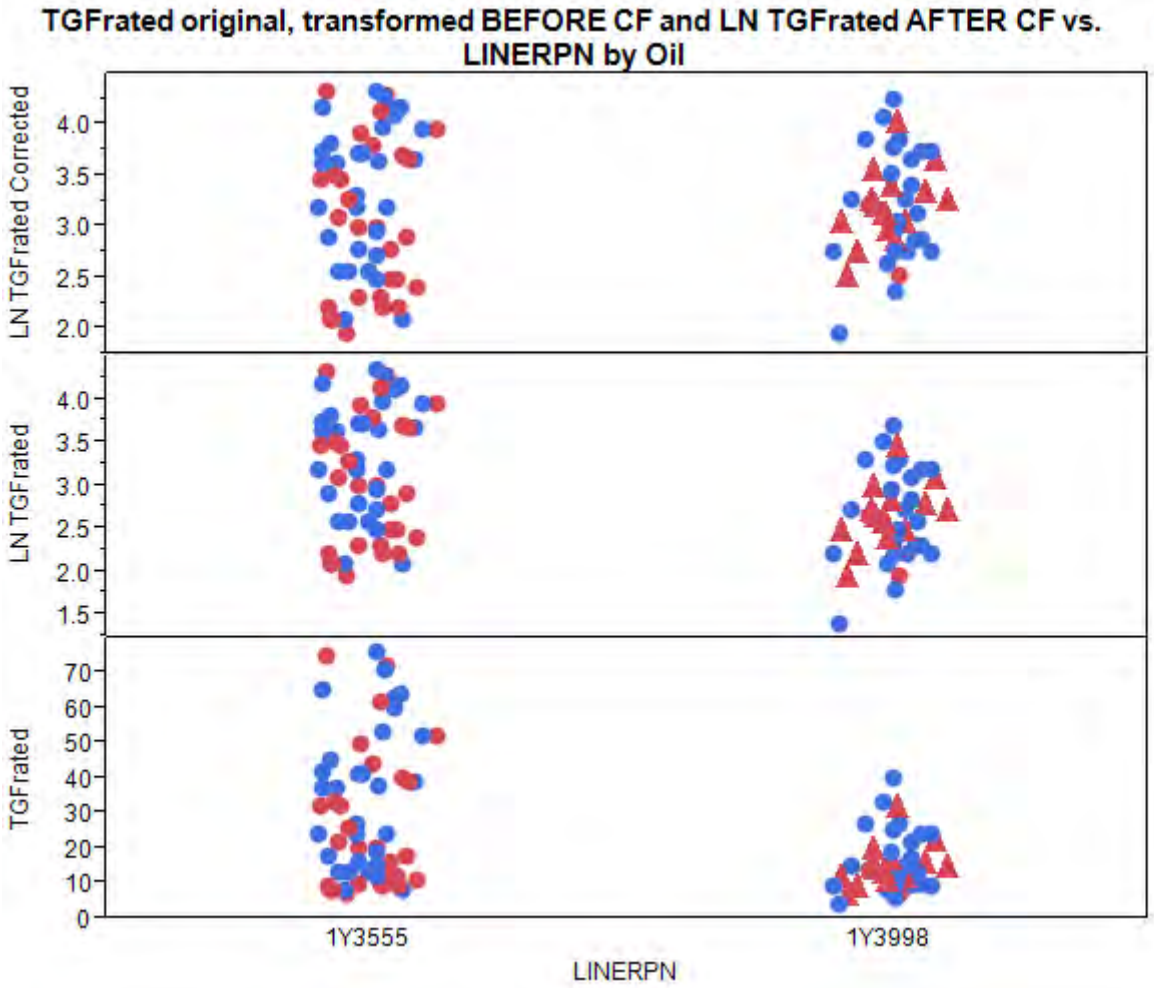
Summary of Correction Factors and Standard Deviations by Parameter

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

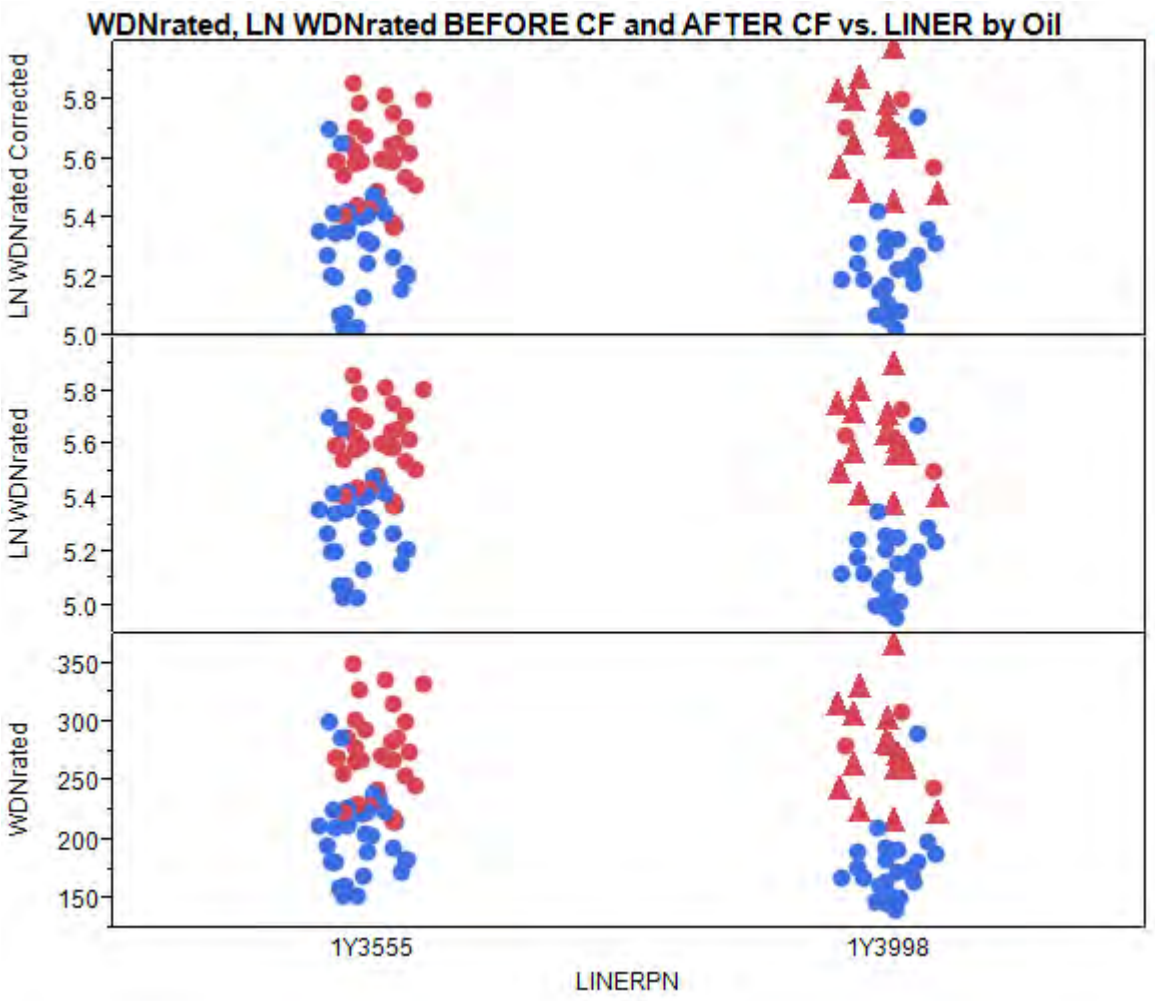
There is no evidence of Fuel Batch effect: Before and After introducing new batch in March 20th 2011

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



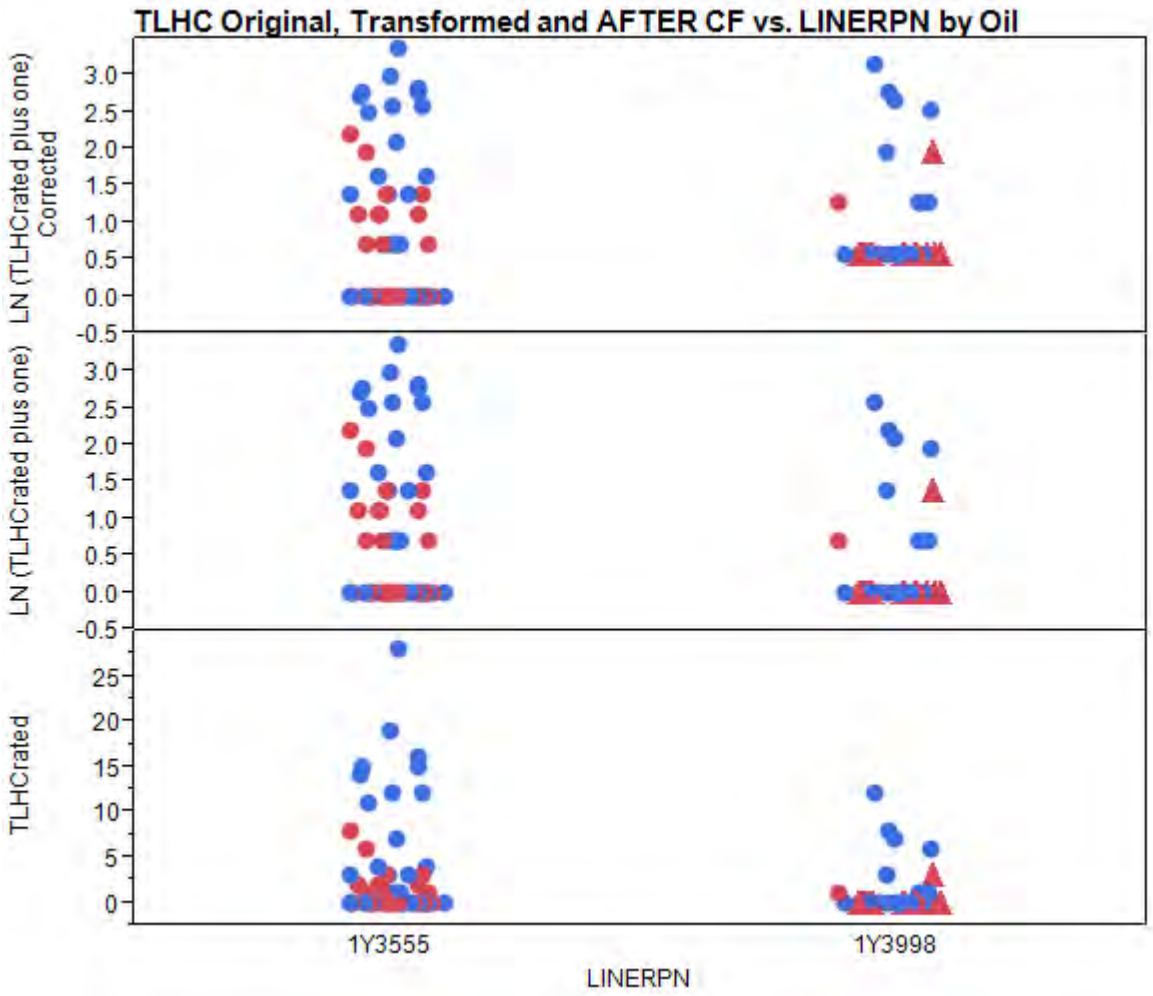
CF= 0.56569

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



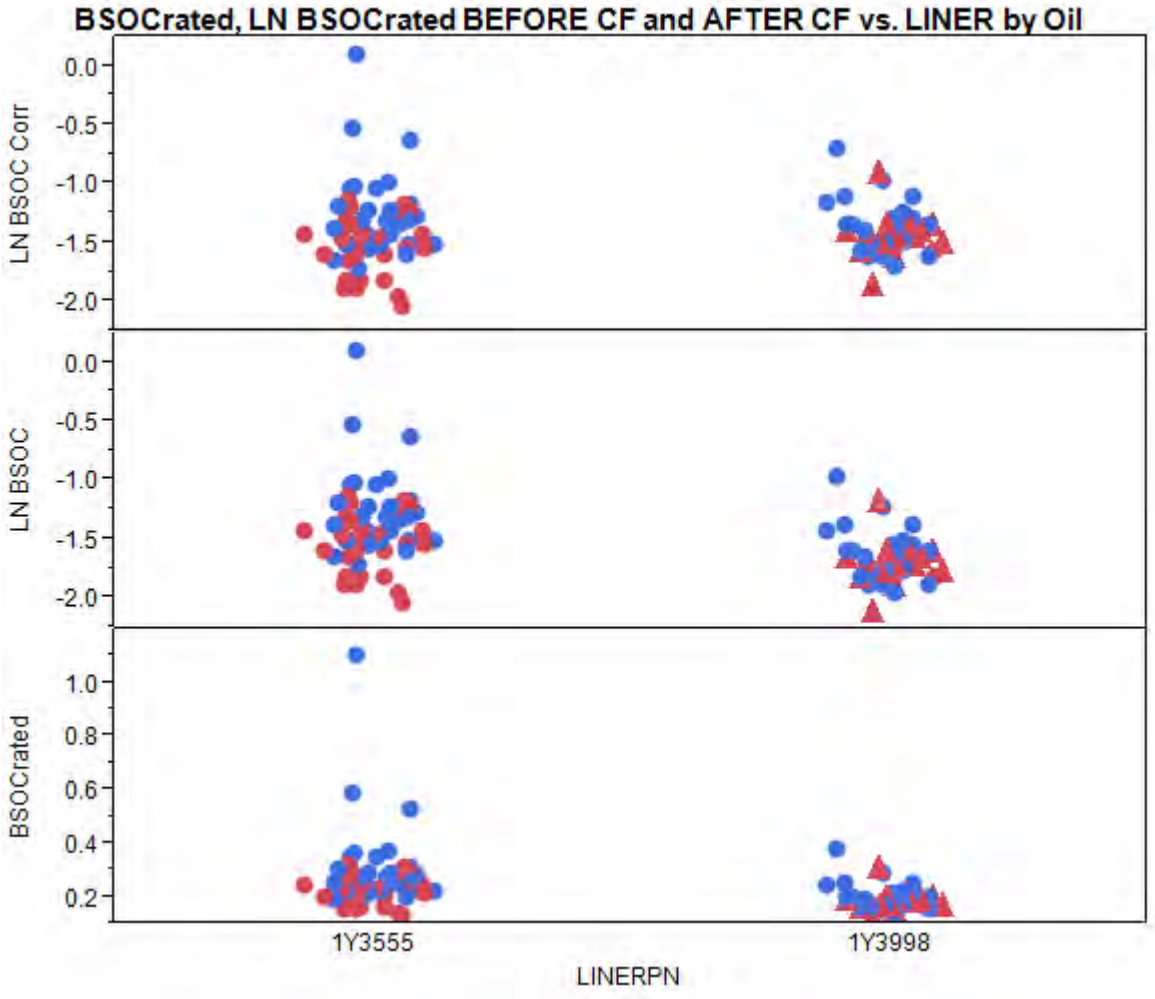
CF= 0.074444

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

Final count

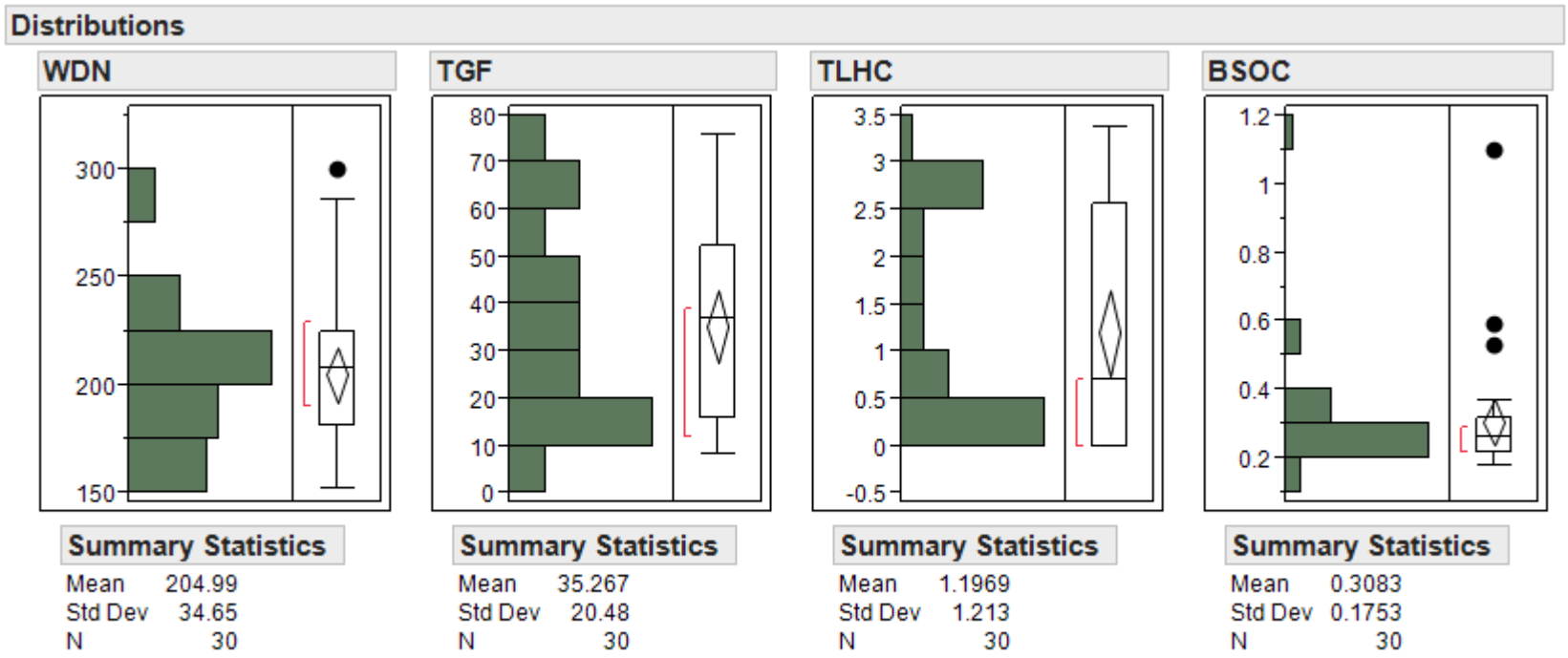
Oil	Liner	n sample size
809-1	1Y3555	30
809-1	1Y3998	25
811-1	1Y3555	29
811-1	1Y3998	19

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

	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



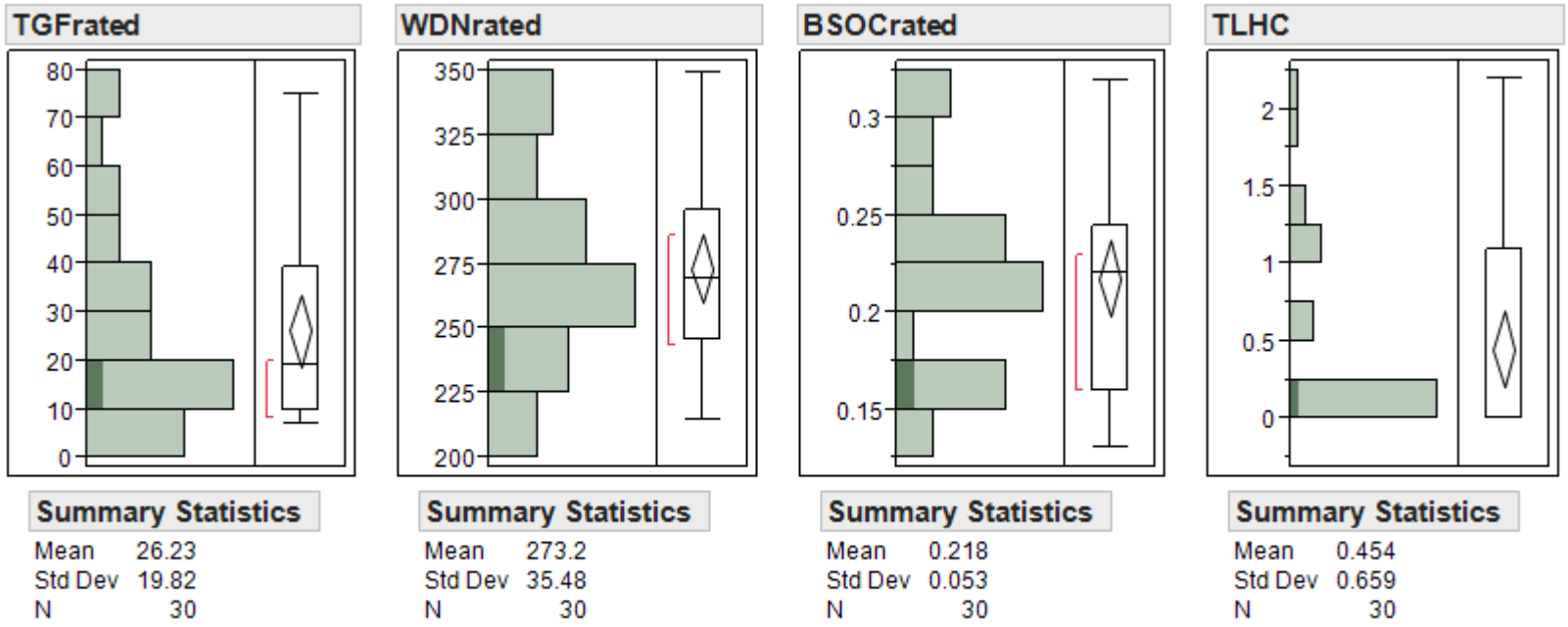
17349: liner is missing but assumed is 1Y3555

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

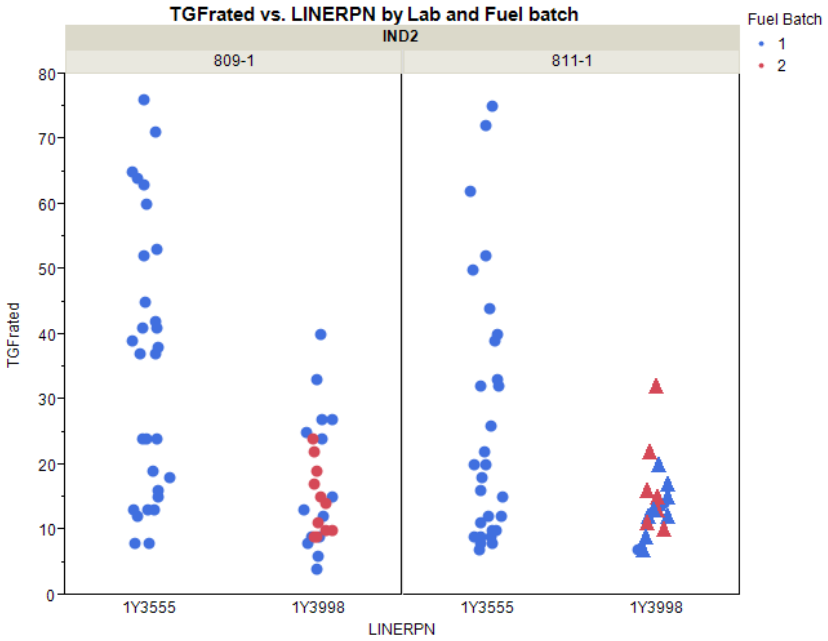
Chart = Yes; N=30*; from 03/22/1993 to 10/03/2006



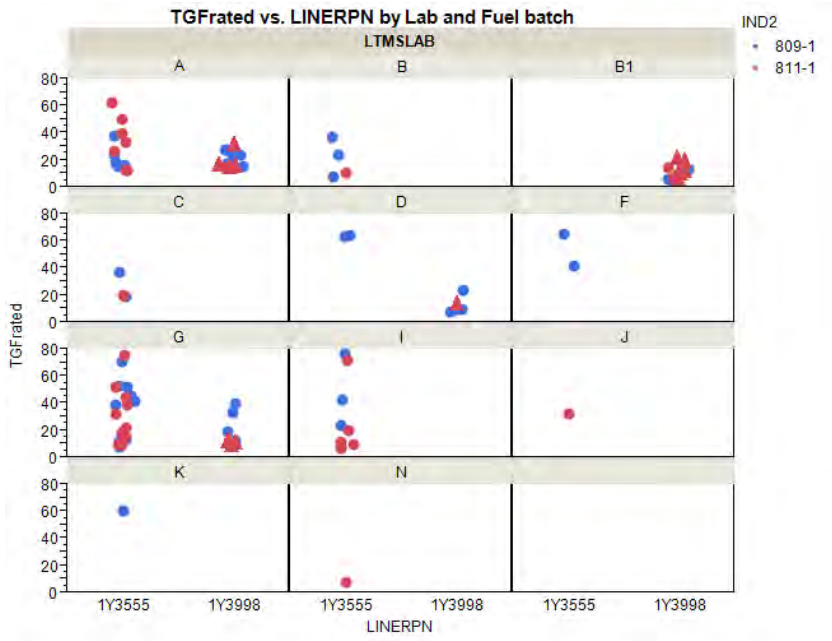
*Test 24229 10/03/2006 was included in the above target calculations to reproduce the LTMS table, but because it has the new liner will be in the analysis as having the new liner

TGFrated: Visualizing the data by Oil and Fuel Batch

All Labs by Oil, Liner and Fuel batch

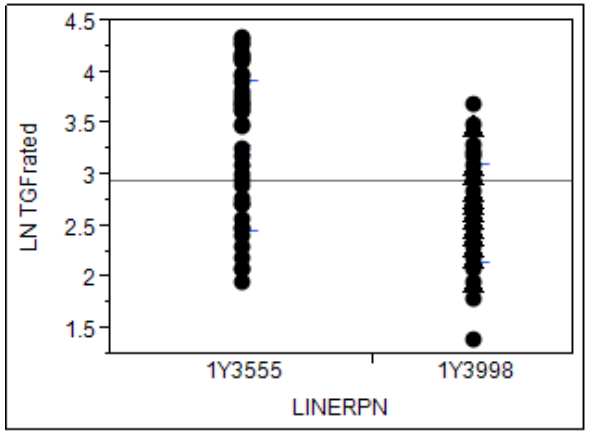


By Lab, Liner and Oil



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

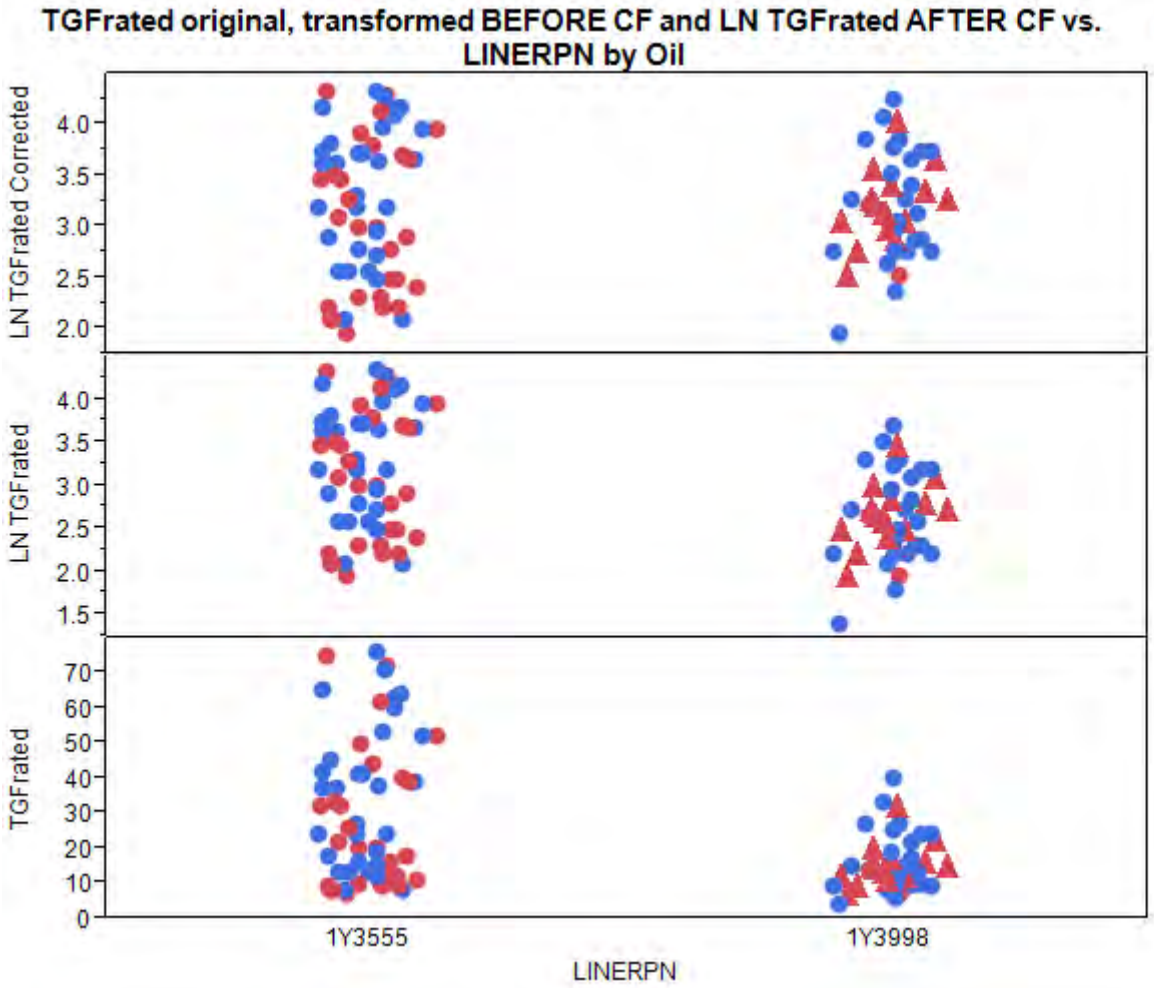
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	8.065538	8.06554	20.1833
Error	101	40.361079	0.39961	Prob > F
C. Total	102	48.426617		<.0001*

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

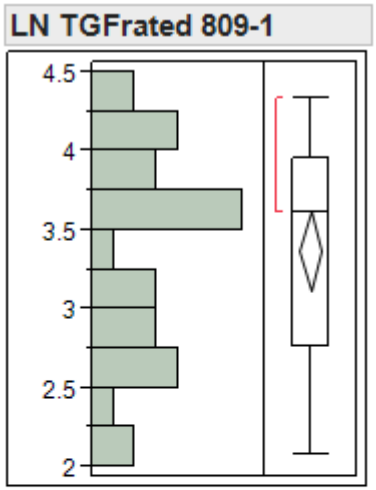
- Applied transformation: LN(TGFrated)
- Tested for statistically significant effects
- Means by liner group are statistically significantly different
- Standard deviations by liner group are also statistically significantly different. The sample size is large and able to detect small differences, not 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

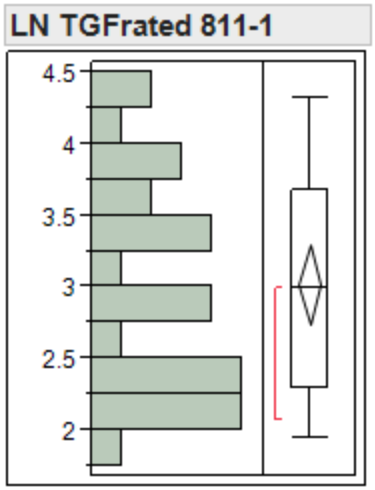


CF= 0.56569

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

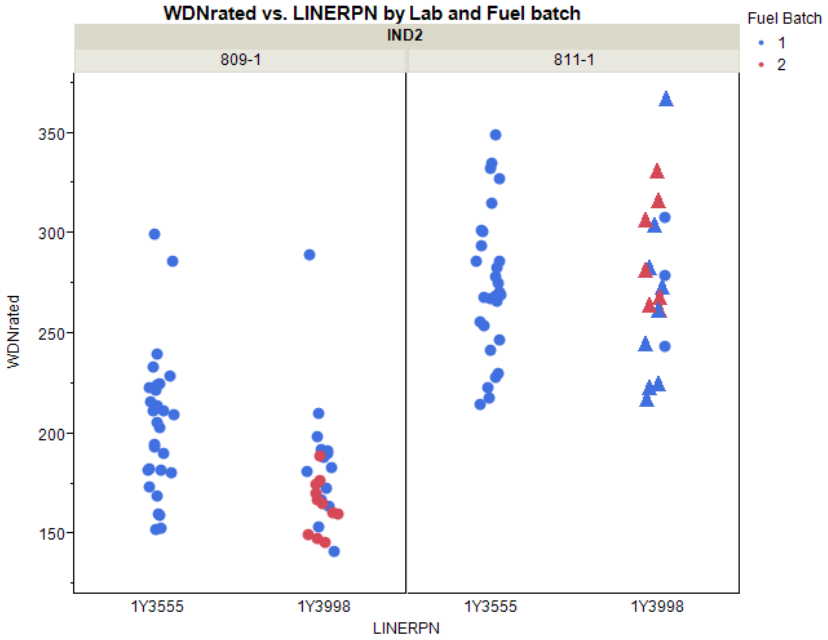
S_{pooled} for New Liner set 809/811= 0.49

- 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

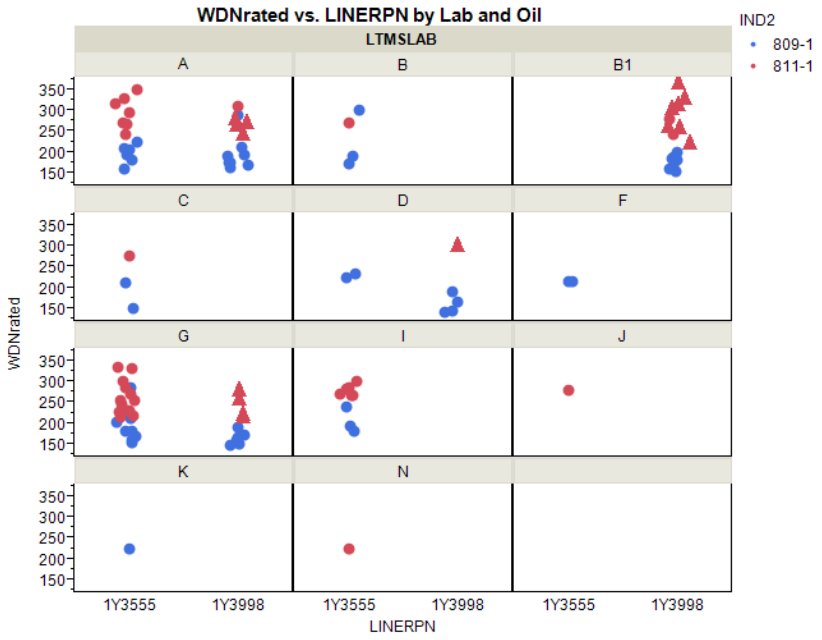
Using RMSE= 0.632	
809 (25 tests)	
Before	After
0	1
811 (19 tests)	
Before	After
0	0

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

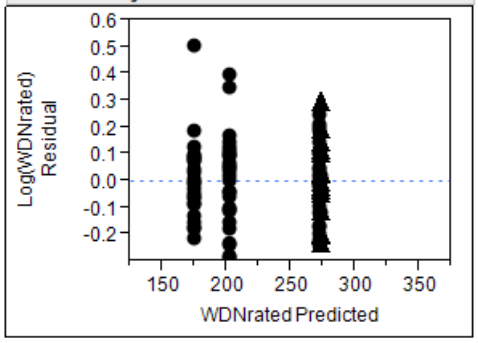
Analysis of Variance

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

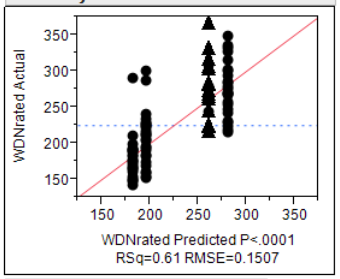
Levels not connected by same letter are significantly different.

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

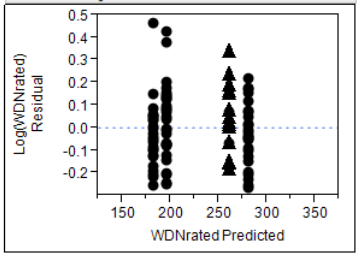
Analysis of Variance

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

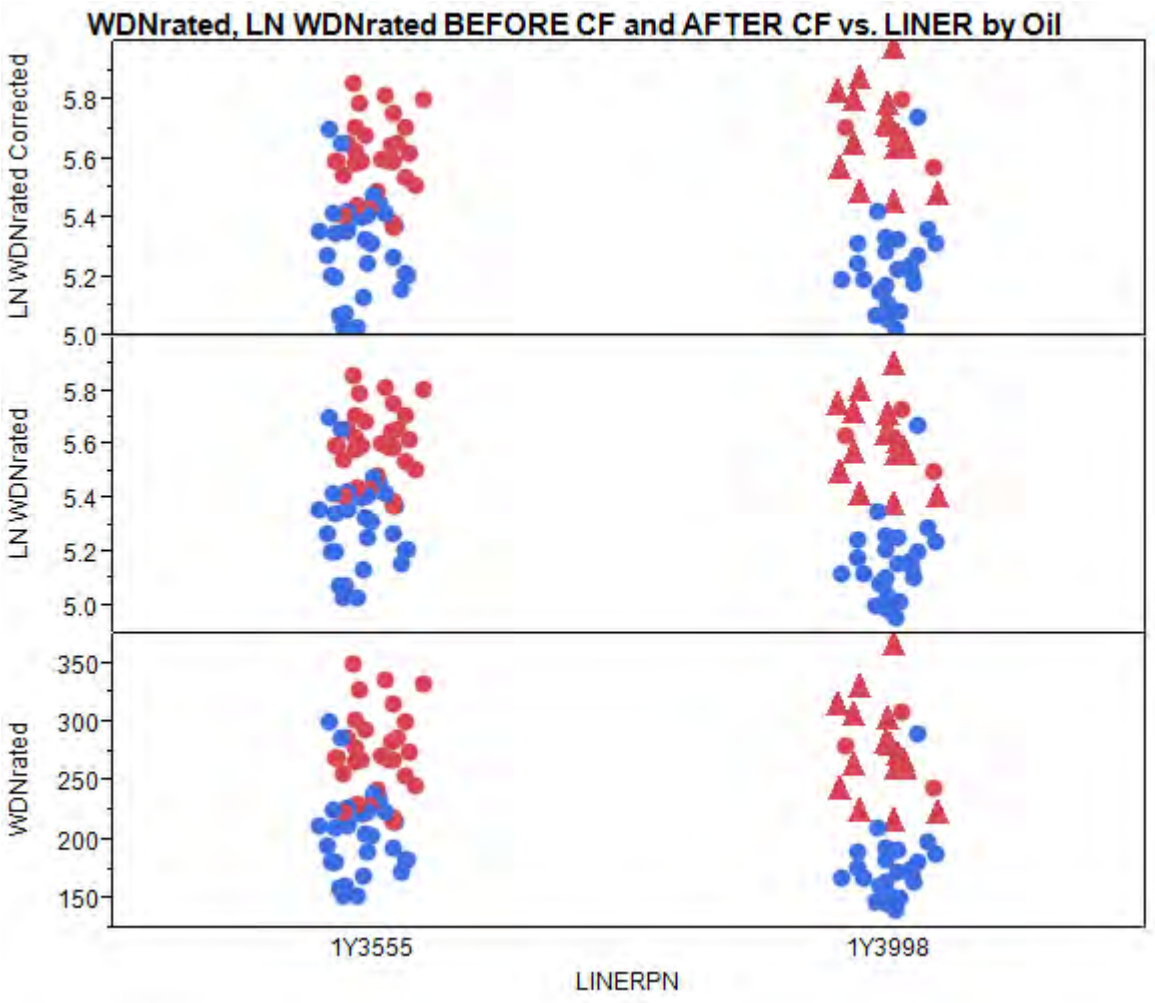
Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	5.4210999	0.015055	360.08	<.0001*	.
LINERPN[1Y3555]	0.0372221	0.015038	2.48	0.0150*	1.0035179
IND2[809-1]	-0.180324	0.014912	-12.09	<.0001*	1.0035179

Residual by Predicted Plot



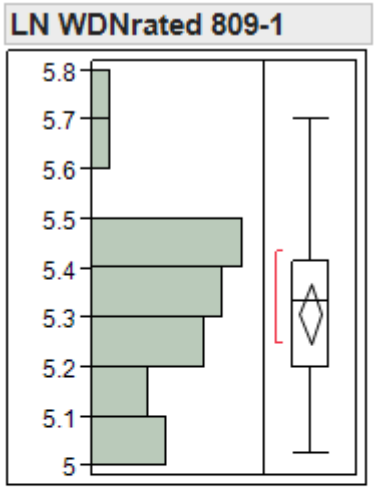
- Applied transformation: LN(WDNrated)
- Tested for statistically significant effects
- Liner means are statistically significantly different
- Oils are also statistically significantly different
- Proposed Correction Factor (CF): add 0.0744448 to LN (WDNrated)
- CF= 5.458322-5.383878= 0.074444
- Standard 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

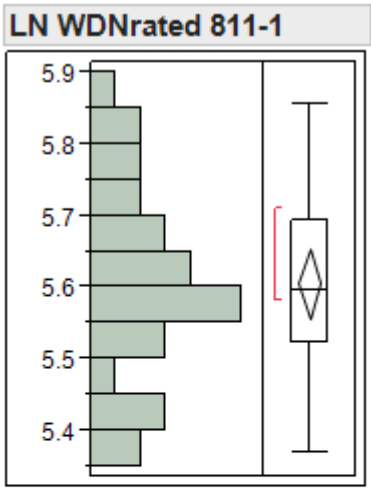


CF= 0.074444

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

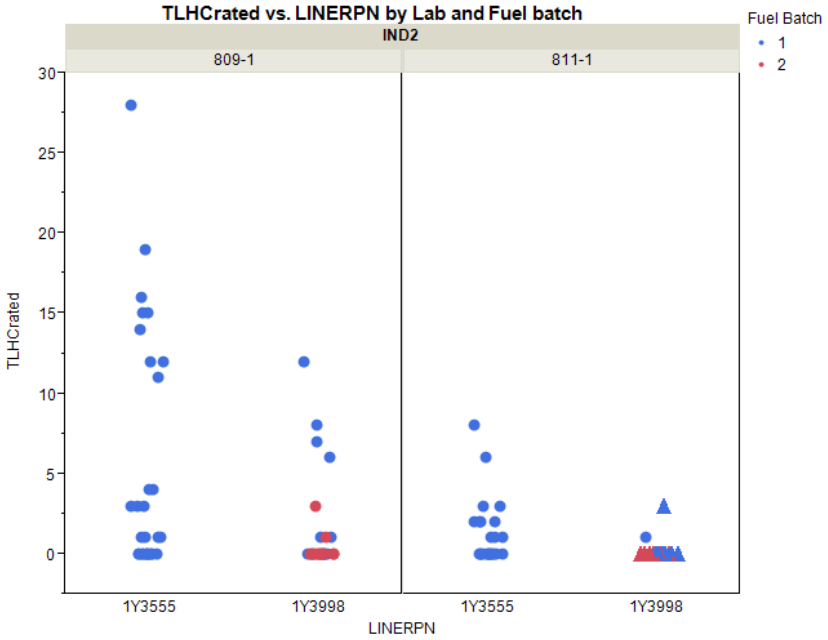
- 809-1
  - STD for Target set= 0.1646
- 811-1
  - STD for Target set= 0.1299
- RMSE for model that includes both liners for oils 809 and 811-1/ 811-2= 0.150728
- # of tests with new liner that do not calibrate:

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

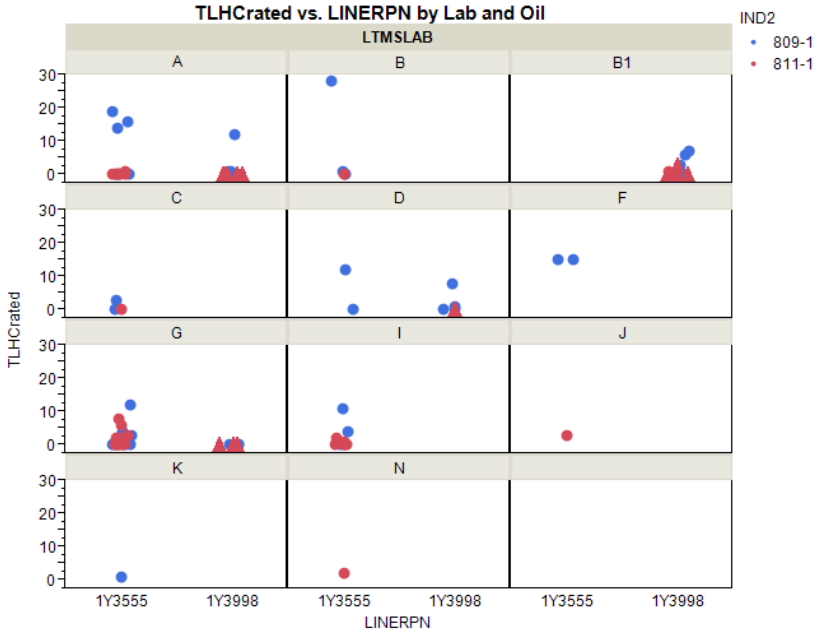
S_{pooled} for New Liner set 809/811= 0.1437

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*

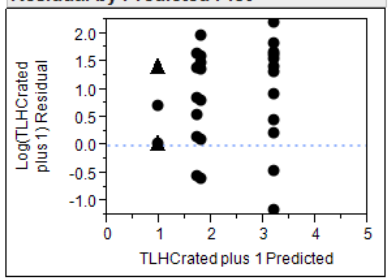
Lack Of Fit

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

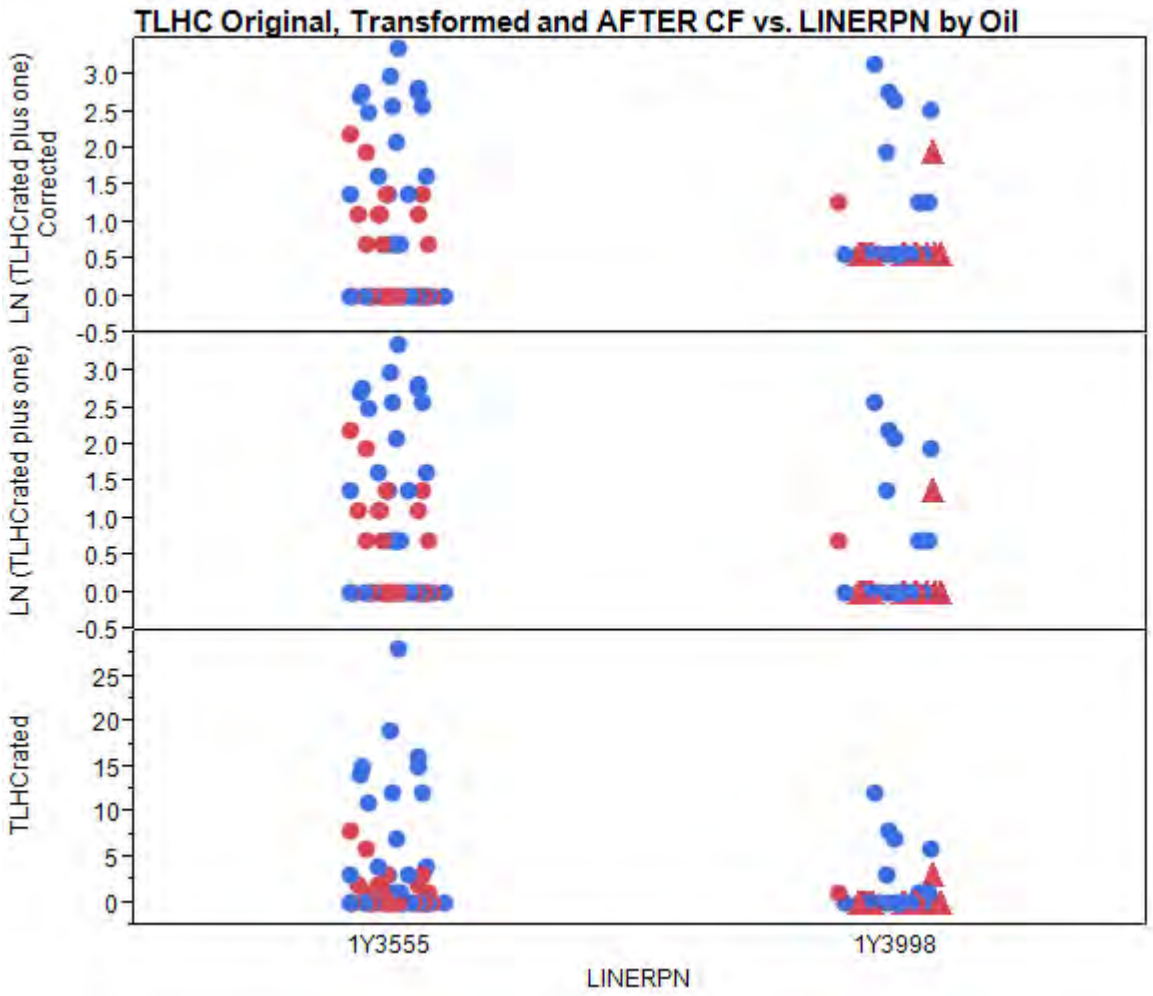
Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	0.5689357	0.08581	6.63	<.0001*	.
LINERPN[1Y3555]	0.2849228	0.085713	3.32	0.0012*	1.0035179
IND2[809-1]	0.3060227	0.084996	3.60	0.0005*	1.0035179

Residual by Predicted Plot



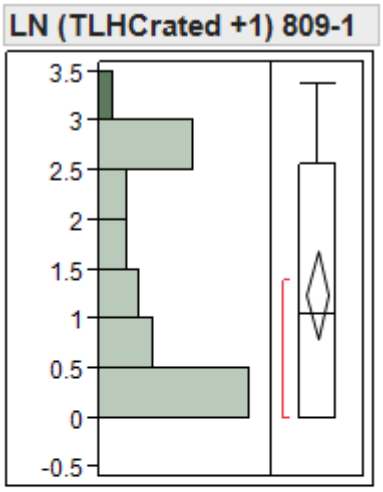
- Applied transformation: LN(TLHCrated+1)
- Tested for statistically significant effects
- Liner means are statistically significantly different
- Oils are also statistically significantly different
- Proposed Correction Factor (CF): add 0.569846 to LN(TLHCrated+1)
- CF= 0.853859-0.284013= 0.569846
- 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

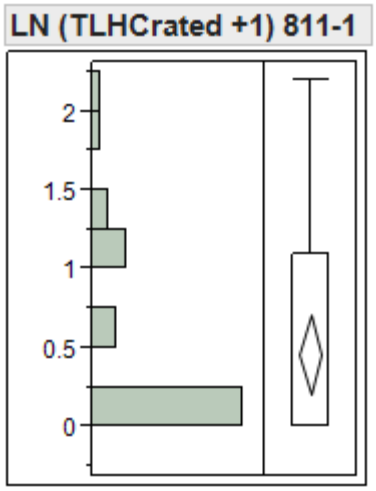


CF= 0.569846

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

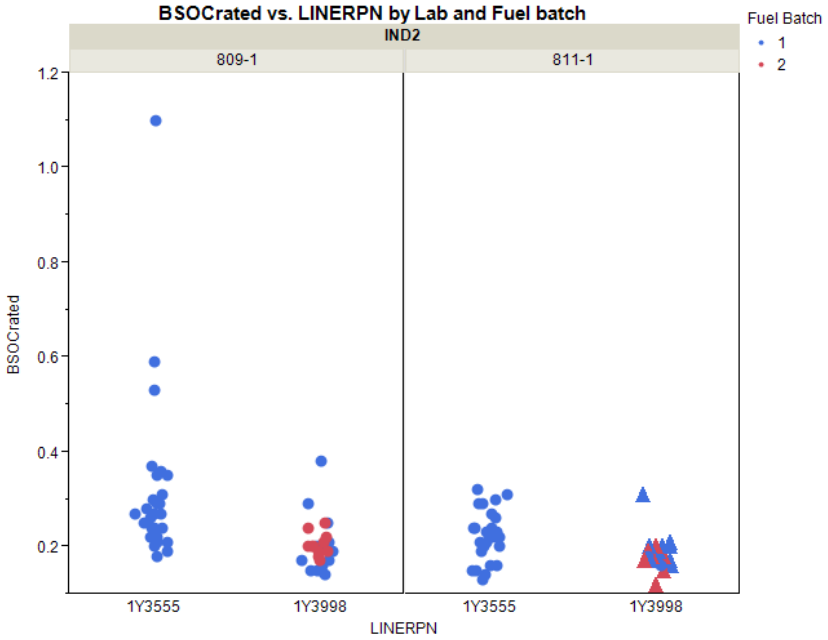
- 809-1
  - STD for Target set= 1.192
- 811-1
  - STD for Target set= 0.66935
- RMSE for model that includes both liners for oils 809 and 811-1/ 811-2= 0.859108
- # of tests with new liner that do not calibrate:

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

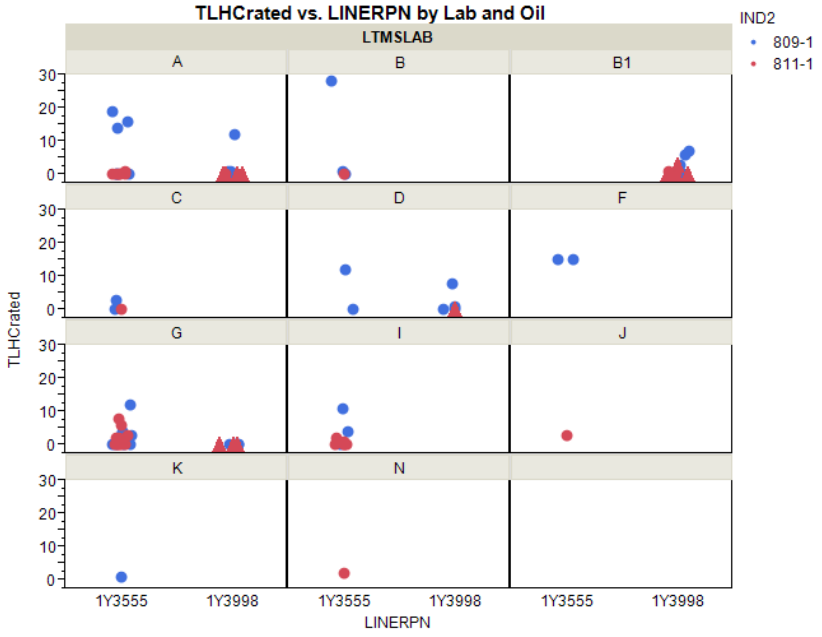
S_{pooled} for New Liner set 809/811= 0.673469

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

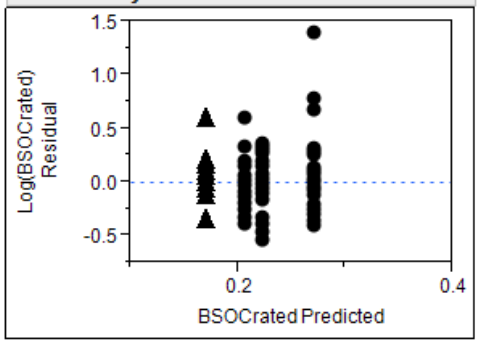
Analysis of Variance

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

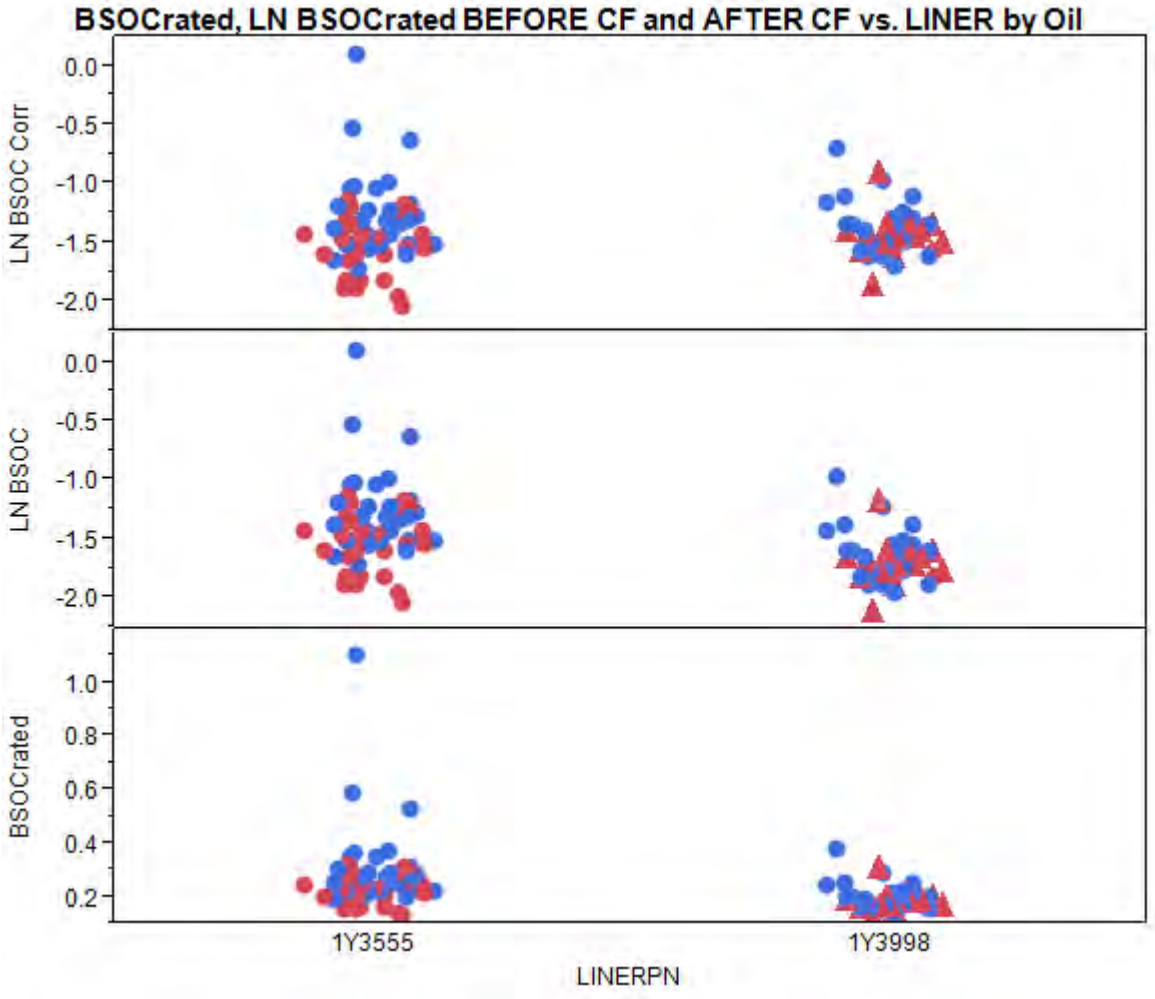
Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	-1.538003	0.028032	-54.87	<.0001*	.
LINERPN[1Y3555]	0.1343998	0.028	4.80	<.0001*	1.0035179
IND2[809-1]	0.0982046	0.027766	3.54	0.0006*	1.0035179

Residual by Predicted Plot



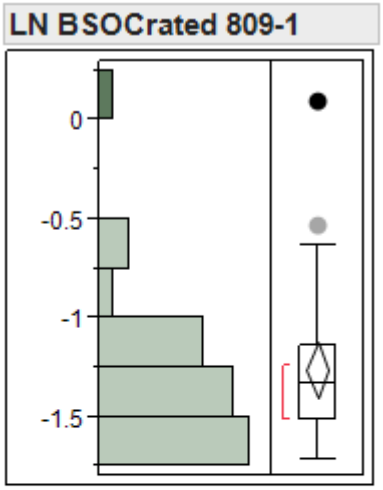
- Applied transformation: LN(BSOCrated)
- Tested for statistically significant effects
- Liner means are statistically significantly different
- Oils are also statistically significantly different
- Proposed Correction Factor (CF): add 0.2688 to LN(BSOCrated)
- CF= -1.4036-(-1.6724)= 0.2688
- Standard 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

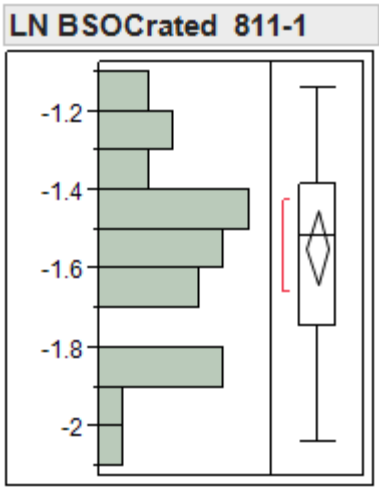


CF= 0.2688

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



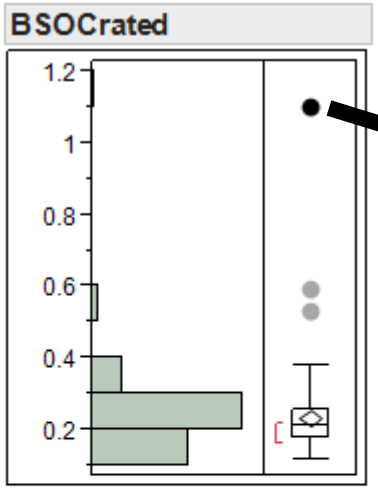
Summary Statistics	
Mean	-1.544419
Std Dev	0.2471592
Std Err Mean	0.0458963
Upper 95% Mean	-1.450405
Lower 95% Mean	-1.638434
N	29

- 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

ATTACHMENT 2a

LN(TLHC rated plus one)

Oil	Liner	# of tests	Mean(LN(TLHC rated plus one))	Std Dev(LN(TLHC rated plus one))
809-1	1Y355	30	1.197	1.213
809-1	1Y3998	30	0.50086	0.83375
811-2	1Y355	30	0.366	0.6
811-2	1Y3998	19	0.109444	0.347585
811*	1Y3998	22	0.12603	0.3473

TGF

Oil	Liner	# of tests	Mean(TGF)	Std Dev(TGF)
809-1	1Y355	30	35.3	20.5
809-1	1Y3998	30	17.700	13.2305
811-2	1Y355	30	24.7	21.6
811-2	1Y3998	19	14.42105	5.59082
811*	1Y3998	22	14.04545	5.4114

WDN

Oil	Liner	# of tests	Mean(WDN)	Std Dev(WDN)
809-1	1Y355	30	205	34.6
809-1	1Y3998	30	179.62000	28.80947
811-2	1Y355	30	281.5	37.4
811-2	1Y3998	19	273.47368	38.41626
811*	1Y3998	22	273.94091	36.9650

Average Oil Consumption

Oil	Liner	# of tests	Mean(BSOC)	Std Dev(BSOC)
809-1	1Y355	30	0.308	0.175
809-1	1Y3998	30	0.20867	0.06720
811-2	1Y355	30	0.223	0.052
811-2	1Y3998	19	0.18895	0.03784
811*	1Y3998	22	0.18636	0.0358

* 3 tests with 811-1 and 19 with 811-2

LN(TLHC rated plus one)

Oil	Liner	# of tests	Mean(LN(TLHC rated plus one))	Std Dev(LN(TLHC rated plus one))			
809-1	1Y355	30	1.243135454	1.192089561	1.197	1.213	Blue is published TMC value
811-1	1Y355	29	0.461710833	0.669355	0.454	0.659	Blue is published TMC value
809/811	1Y355	59	0.83558668	0.984214998			
809-1	1Y3998	30	0.50086	0.83375			
811-1	1Y3998	3	0.23105	0.4002			
811-2	1Y3998	19	0.109444292	0.347585486	**MEAN DIFFERENCE**		
809/811	1Y3998	52	0.342277673	0.679949237	**0.493309**		

TGF

Oil	Liner	# of tests	Mean(TGF)	Std Dev(TGF)			
809-1	1Y355	30	35.3	20.5			
811-1	1Y355	29	26.655	20.036	26.2	19.8	Blue is published TMC value
809/811	1Y355	59	31.05084746	20.27348183			
809-1	1Y3998	30	17.700	13.2305			
811-1	1Y3998	3	11.66666667	4.041451884			
811-2	1Y3998	19	14.42105263	5.590823727	**MEAN DIFFERENCE**		
809/811	1Y3998	52	16.15384615	10.75857346	**14.897**		

WDN

Oil	Liner	# of tests	Mean(WDN)	Std Dev(WDN)			
809-1	1Y355	30	205	34.6			
811-1	1Y355	29	274.2448276	35.65532004	273.2	35.5	
809/811	1Y355	59	239.0355932	35.12236548			
809-1	1Y3998	30	179.62	28.80947402			
811-1	1Y3998	3	276.9	32.40108023			
811-2	1Y3998	19	273.4736842	38.41625585	**MEAN DIFFERENCE**		
809/811	1Y3998	52	219.525	32.80548885	**19.51059**		

Average Oil Consumption

Oil	Liner	# of tests	Mean(BSOC)	Std Dev(BSOC)			
809-1	1Y355	30	0.308	0.175			
811-1	1Y355	29	0.219655172	0.052541328	0.218	0.053	
809/811	1Y355	59	0.264576271	0.130143076			
809-1	1Y3998	30	0.20867	0.06720			
811-1	1Y3998	3	0.17	0.01			
811-2	1Y3998	19	0.18895	0.0378	**MEAN DIFFERENCE**		
809/811	1Y3998	52	0.199230769	0.056591197	**0.065346**		

ATTACHMENT 3

Test Monitoring Center

http://astmtmc.cmu.edu

A Program of ASTM International

CAT Tests' Reference Oil Inventories

May 2014

Reference Oil Inventory Estimated Life

Oil	Tests	Original Blend Amount	Quantity Shipped in last 6 months	TMC Inventory	Lab Inventory	Estimated Life
809-1	1K, 1N	9134	50	2388	126	5+ years
811-2	1K, 1N	1732	30	1194	50	5+ years
822-1	1R, T-10A, T-11	560	0	16	56	~.25 years
822-2	1R, T-10A, T-11	4386	280	4106	196	5+ years
831-1	C13, ISB	1300	0	0	51	~ .5 years
831-2	C13, ISB	880	90	612	235	5+ years
873-2	1M-PC	1650	10	177	50	5+ years
1005-3	1P, 1R, EOAT, RFWT, T-8/E	2000	7	8	150	~ 1 year
1005-4	1P, 1R, EOAT, RFWT, T-8/E	2000	296	1023	401	2.5 years

Reference Oil Reblends

- 1005-4 Re-blend being pursued

ATTACHMENT 4

"Line"

Liner		*Rpk* (uin)	*Rvk* (uin)	*Vo* (uin*uin)/uin
	Thrust	14.2	70.4	5.19
1	Front	20.2	81.5	5.53
	Anti-thrust	20.0	79	5.22
	Rear	19.1	63.9	4.45
	Thrust	17.5	88	6.44
2	Front	17.1	62.6	4.47
	Anti-thrust	20.5	80.6	6.24
	Rear	15.8	101.5	6.70
	Thrust	10.4	68.6	4.51
3	Front	18.5	104.4	6.97
	Anti-thrust	10.0	79.5	5.83
	Rear	9.3	78.2	5.66

	Rpk (uin)	*Rvk* (uin)	*'o* (uin*uin)/uin
T-TEST	0.0042714	0.0000054	0.0000004
Line average	16.050	79.850	5.601
Line Stdev	4.142	13.186	0.872
No-Line average	20.858	104.817	7.906
No-Line Stdev	4.014	7.708	0.799

"No line"

Liner		*Rpk* (uin)	*Rvk* (uin)	*Vo* (uin*uin)/uin
	Thrust	18.8	96.2	6.88
1	Front	15.3	94.3	7.26
	Anti-thrust	16.1	109.3	8.91
	Rear	18.7	113.2	7.39
	Thrust	23.6	102.0	7.90
2	Front	28.8	108.0	8.31
	Anti-thrust	27.1	101.0	7.94
	Rear	20.5	116.2	9.04
	Thrust	20.8	92.0	6.81
3	Front	19.3	108.1	9.12
	Anti-thrust	21.8	111.0	7.75
	Rear	19.5	106.5	7.56