1N: Updated Standard Deviations for Alternate Fuel Work New Material added – slides 43 forward (09/01/2020) Material added – slides 26 to 42 (08/13/2020)

Elisa Santos

09/01/2020 - Statistician's Recommendation

08/13/2020

07/23/2020 - Original presentation



Outline



- Issue raised with respect to Top Groove Fill data: reference oils have diverged in severity (09/2016)
 - Parts variation was identified as the root cause
- Plots for TGF: RO809 trending down and RO811 moving up
- TGF Updated Standard deviations: 101 tests (1Y3998)
- Plots Other parameters
- Proposed standard deviations by oil based on liner 1Y3998
- Proposed standard deviation for calculating severity adjustments

Updating standard deviations



- Lubrizol raised an issue see power point presentation
 - Caterpillar 1N TGF Dilemma from September 2016

http://www.astmtmc.cmu.edu/ftp/docs/diesel/CAT/minutes/2016/10.07/1N%20T

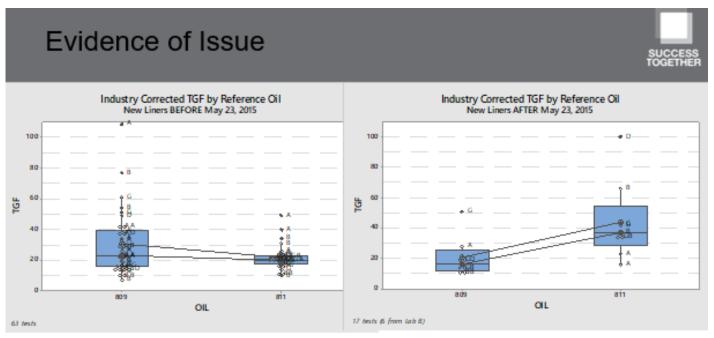
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                        4096875 1R-1808 FilterAnalysis.pdf
12/9/2016 6:10 PM
                          21178 COAT-Task Force Teleconference 10-7-2016.pdf
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- Next four slides will tell you that parts variation was identified as the root cause
- I will proceed with the analysis without excluding any data, assuming that parts variability is part of the test variability
- Please let me know if you have any concerns with anything and I will revise it



Caterpillar 1N TGF Dilemma from September 2016



- Problem so bad that RO 809 and RO 811 have diverged in TGF severity!
 - Historically, 809 with higher TGF than 811
 - Now 811 way higher than 809
 - This is not due to the correction factor, but another issue

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Slide from Lubrizol's presentation

01/10/2017 CAT SP Minutes



All,

I wanted to inform this group of the result of a recent 1N hardware test that we ran as a part of our continuing investigation into the TGF issues we discussed earlier last year. We ran a reference test on oil 811 in our stand 605. If the group recalls, 811 was supposedly the oil that was trending severe and our stand 605 was also supposedly a severe stand. We ran the recent reference test using a piston, rings, and liner from Southwest who had some older parts on hand and, as you might guess, we drastically shifted our results and went very mild with TGF as you can see in the plot below. Before running the test, we analyzed the Southwest parts and compared them against a set from Lubrizol. We found what we believe to be significant differentiation of the top ring face surface finish, as displayed in the second graphic below (the "Minus Major Asperity" values or those that discount a large valley in the Southwest ring). I believe this new information warrants further discussion and should probably be brought up again at a surveillance panel call. If there are any questions or comments, please let me know.

Andrew D. Stevens

Test Engineer, Mechanical Engineering & Testing

The Lubrizol Corporation

[To Parent Directory]

http://www.astmtmc.cmu.edu/ftp/docs/diesel/CAT/minutes/2017/01.10/1N%20TGF%20findings.pdf

www.astmtmc.cmu.edu - /ftp/docs/diesel/CAT/minutes/2017/01.10/

2/20/2017	2:05 PM	111125 1N TGF findings.pdf
2/20/2017	2:05 PM	24361 CAT surveillance panel minutes 1-10-2017.pdf
2/20/2017	2:05 PM	72326 COAT MM Calibration Procedure Rev1 1-11-2017.pd
2/20/2017	2:05 PM	64775 Test Numbering Proposed Changes.pdf

01/10/2017 CAT SP Minutes



1N – Hardware effect on TGF (Lubrizol)

Greg: We sent out data from the last test.

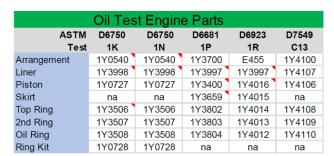
We got old parts from SwRI. Should have been severe. But they went mild. There is a plot that was sent out. (Attached with these minutes)

Greg: Quite a bit difference in the surface profile of the top ring.



- Went back to minutes and found 3/31/2017 CAT O & H Panel Conference Minutes
 - Proper recording of parts data for 1K/1N (specifying serial number, date code, etc and ensuring consistency between labs)
 - Proper recording of parts data will allow for future investigations as needed
 - Example for liners:
 - LINERPN "Liner part number" (Include dash, dash change level) 1Y-3998-03
 - LINERBDC "Liner box date code" Date code on box label (14 characters)
 - LINERDC "Liner date code" day of year year's last digit (Ex. 133-6)
 - LINERSN "Sequence number" 0-99999
 - It also includes a CAT presentation SCOTE Hardware Marking March 31, 2017

Piston, Ring, Liner Part Numbers



From CAT

The current test database with parts data vs. recommended recording – please follow the recommendations

Liners - an example

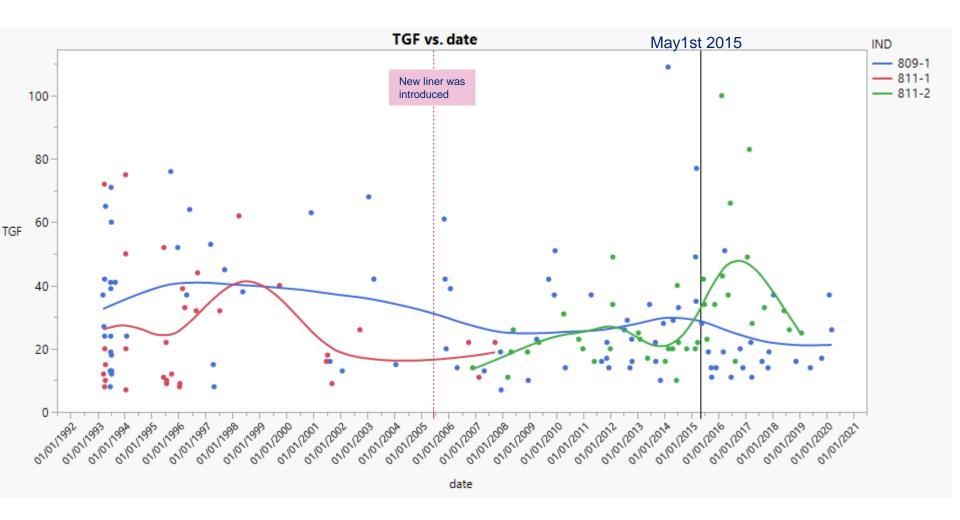
LINERPN – "Liner part number" (Include dash, dash change level) 1Y-3998-03 LINERBDC – "Liner box date code" Date code on box label (14 characters) LINERDC – "Liner date code" day of year - year's last digit (Ex. 133-6) LINERSN – "Sequence number" - 0-99999

Add		•													
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442 D.2871 1/3998 D.OMMOPY15P47 N/A 19727 310714 1225 1/10728		440 0.0577	1Y3998	D05M09Y14P47	N/A		1Y0727		1444	1225	1Y0728				•
448 0.8257 17.3998 565017 D09412Y15R47 11/0727 615 1225 11/0728		441 1.7885	1Y3998	65861	DYM06Y15P47		1Y0727		733	1225	1Y0728				
444 0.8269 1Y-3998 N/A D04M06Y15R47 1Y-0727 615 1225 1Y-0728		442 0.2971	1Y3998	D04M06Y15P47	N/A		1Y0727		256	1225	1Y0728				
445 0.8269 17-9988 N/A D24M08Y15P47 17-0727 615 1225 17-0728		443 0.8457	1Y3998	566017	D09M12Y15P47		1Y0727		310714	1225	1Y0728				
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448 0.2743 11-3998 D13M06Y14P47 N/A 11-0727 125M3191300 N/A 11-0728		446 0.9029	1Y-3998	N/A	D09M12Y15P47		1Y-0727		615	1225	1Y-0728				
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458 0.3886 173998 55581 2235 170727 1225M3191307 N/A 170728		457 1.2115	1Y3998	5-65913	D04M06Y12P47		1Y0727		D07M10Y16P47	1225	1Y0728				
459 0.9038 173998 55974 223 5 170727 1225M3491302 N/A 170728				55581	2235		1Y0727		1225M3191307	N/A	1Y0728				
460 0.5029 1V-3998 65983 223 5 1Y-0727 125M2161620 N/A 1V-0728 NA 1V-0728 N/A N/A 461 0.56 1V3998 6-66145 D09M06Y16P47 1V0727 D25M08Y17P47 016-185-17 1225 1Y0728 N/A 271216A8871L N/A 463 1.4038 1V3998 86990 033-6 D99M06Y17P47 1V-0727 D07M10Y16P47 1857-216-16 1225 1Y-3508-04 8659 N/A 1 1V3998 86990 162 4 D28M11Y16 1Y-0727 D07M10Y16P47 125 1Y-3508-04 8802 271216 A8871 464 0.6346 1Y-3998 6590 162 4 D28M11Y16 1Y-0727 D07M10Y16 M21616 1225 1Y-3508-04 8802 271216 A8871 465 0.9029 1Y3998 6-66202 03-301 D02M11Y16P47 1Y0727 D25M08Y17P47 220412417 1225 1Y0728 N/A 240816A8871L N/A 466 1.5962 1Y3998 6-66206 03-235 D31M08Y16P47 1Y-0727 D25M08Y17P47 231212417 1225 1Y0728 N/A 271216A8871L N/A 467 0.7314 1Y-3998 66244 235 6 D31M08Y16P47 1Y-0727 D25M08Y17P47 1225M1841723 1225 1Y-0728 8843 271216A8871L 8866 1V-0728 0.8457 1Y-3998 6615 133-6 D09M06Y16 1Y-0727-02 D25M08Y17P47 0037-185-17 1225 1Y-0728 8843 271216A8871L 8843 469 0.8457 1Y-3998 6615 133-6 D09M06Y16 1Y-0727-02 D25M08Y17P47 0037-185-17 1225 1Y-0728 8753 240816A8871L 8857															
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Plots - Top Groove Fill (TGF) original unit

TGF Overall trend: 809 trending down and 811 moving up

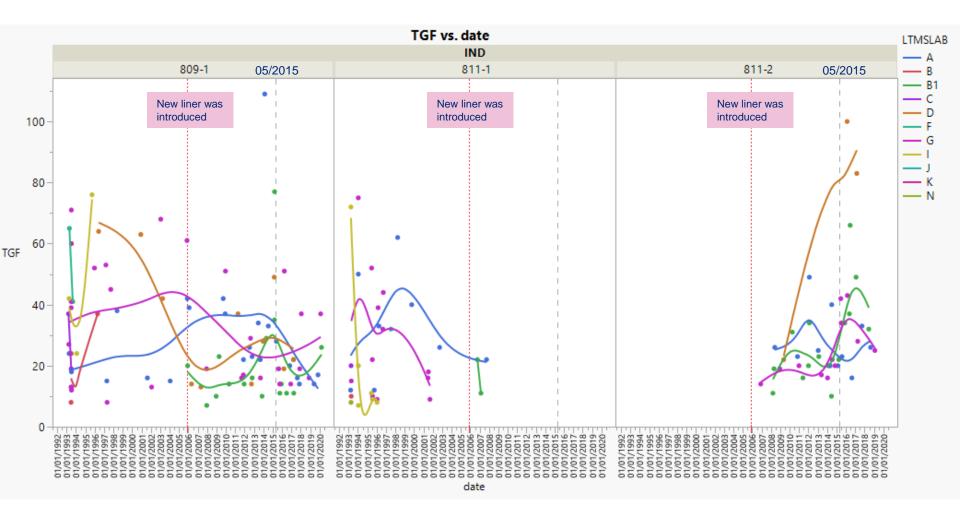




TGF (after CF is applied)

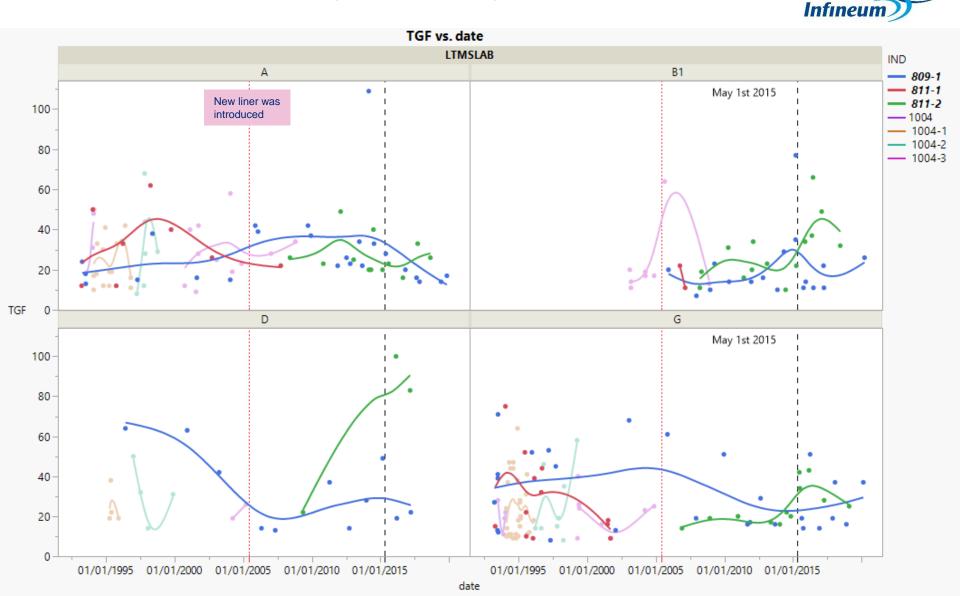


TGF by oil and Lab: 809 trending down and 811 moving up Only Labs A, B1, D and G have data for new liners – 1Y3998



TGF (after CF is applied)

TGF by Lab and Oil: 809 trending down and 811 moving up (current oils highlighted)
Labs are affected differently depending on the parts they get and how the test is run

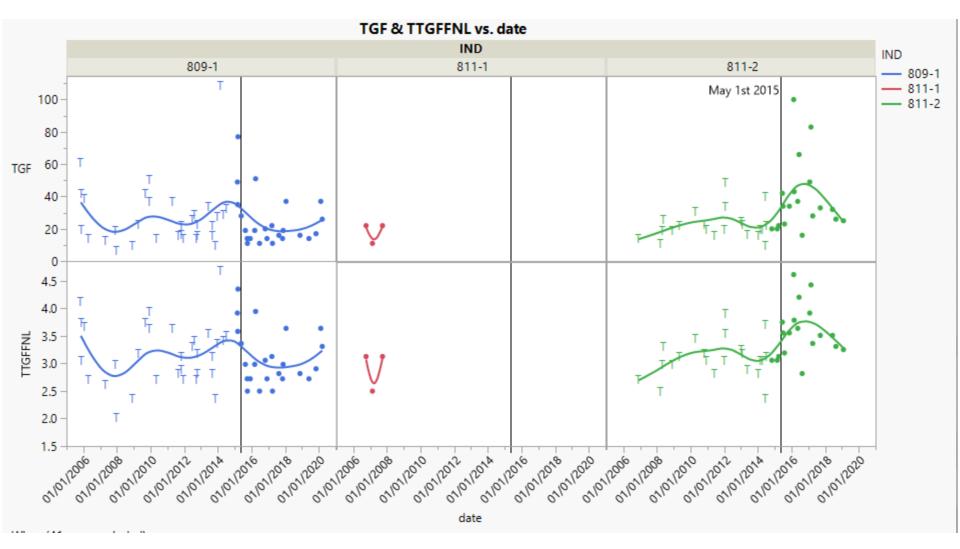


TGF (after CF is applied)

Plots – TGF (original unit) & transformed unit

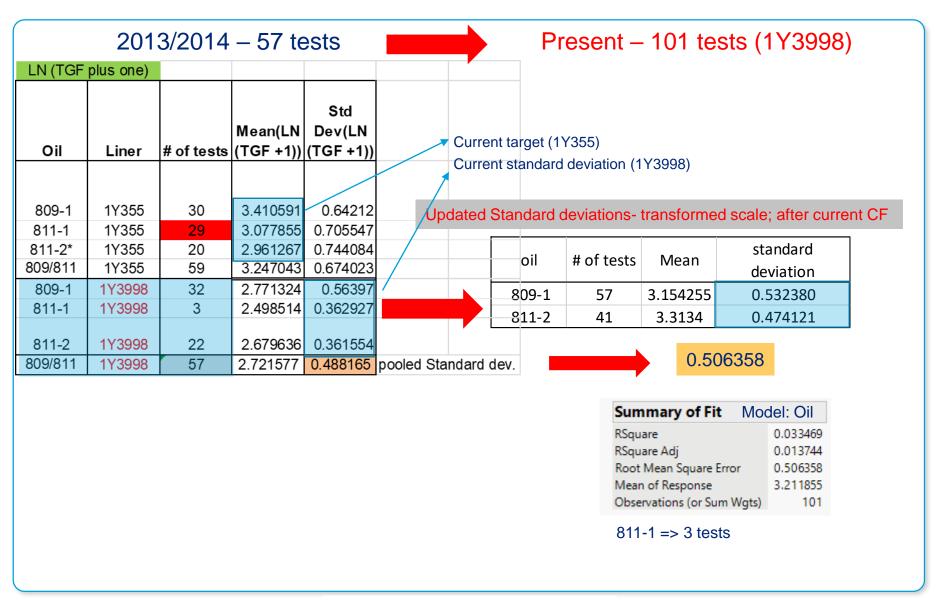
TGF by oil: original unit and transformed unit





Updated Standard deviations: 101 tests (1Y3998)

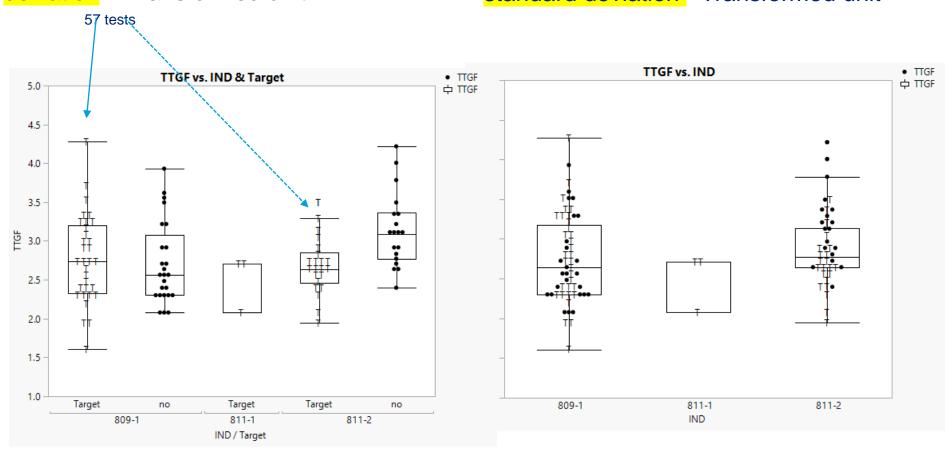






Previous data set (57 tests/ 1Y3998 liner) used for calculating current standard deviation – Transformed unit

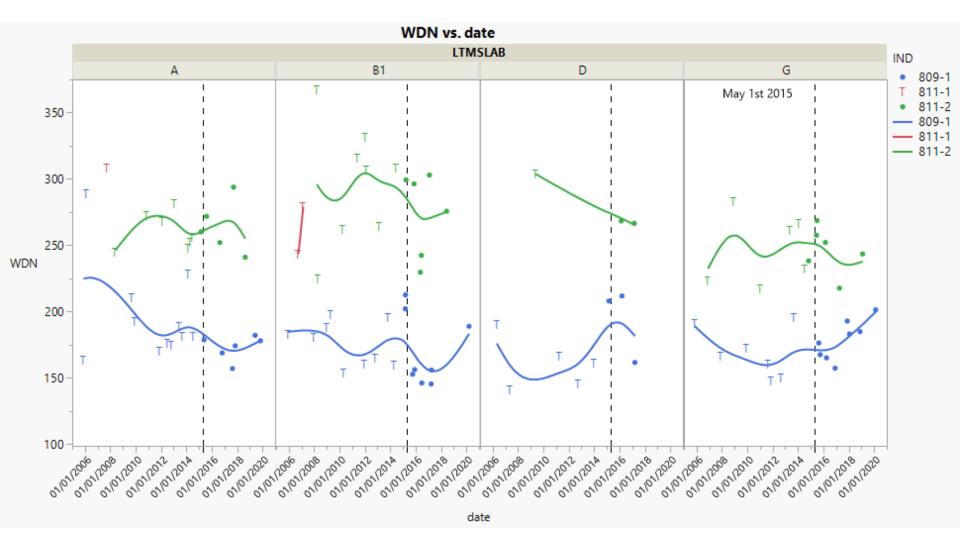
Combined data set (101 tests/ 1Y3998 liner) used for calculating proposed standard deviation - Transformed unit



Plots – Other parameters

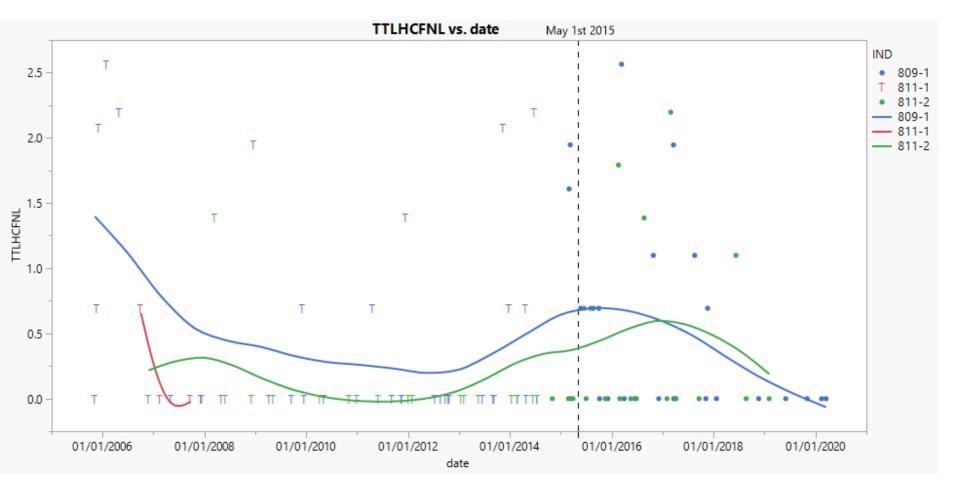
Weighted demerits (1Y3998 liner) over time by Lab and Oil





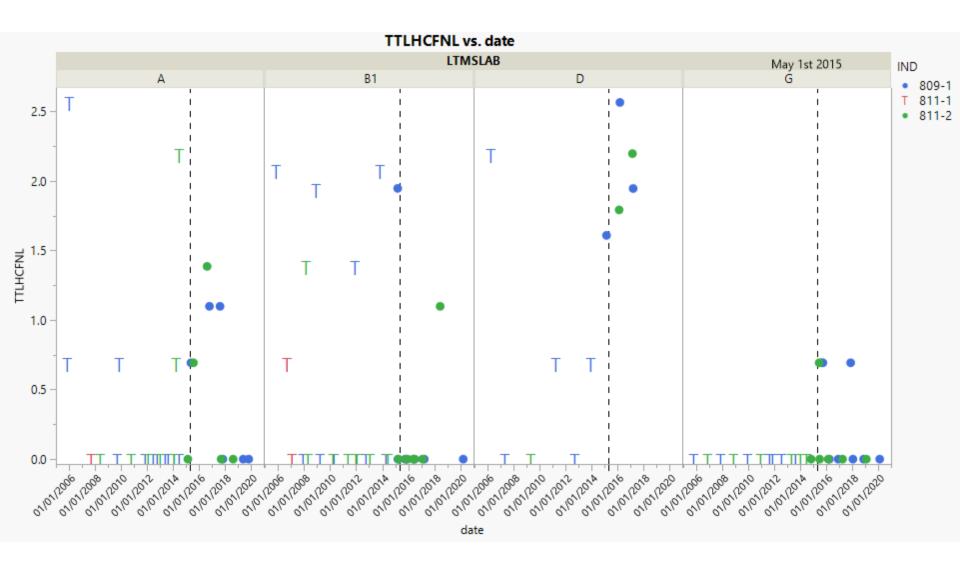
Top Land Heavy Carbon (1Y3998 liner) over time by Oil (transformed unit)



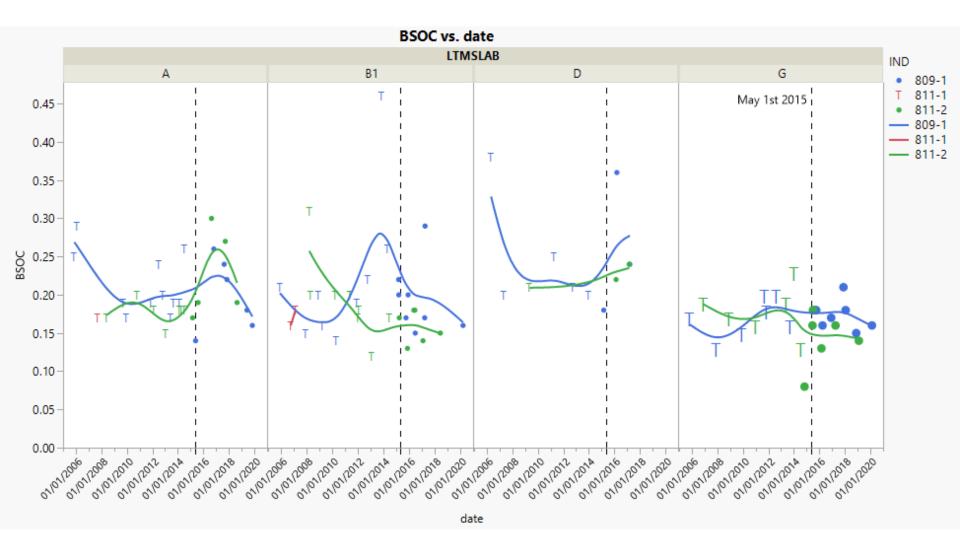




Top Land Heavy Carbon (1Y3998 liner) over time by Lab and Oil Labs: A, B1, D and G



Average Oil Consumption g/kW-h (1Y3998 liner) over time by Lab and Oil



Proposed standard deviations by oil





IND	Liner2	N Rows	Mean(TTGFFNL)	Std Dev(TTGFFNL)
809-1	New	57	3.154254754	0.532380411
811-1	New	3	2.918468	0.362926998
811-2	New	41	3.313400415	0.474120965
IND	Liner2	N Rows	Mean(WDN)	Std Dev(WDN)
809-1	New	57	177.8263158	24.81789048
811-1	New	3	276.9	32.40108023
811-2	New	41	267.5463415	32.22211273
IND	Liner2	N Rows	Mean(TTLHCFNL)	Std Dev(TTLHCFNL)
809-1	New	57	0.492298246	0.789975948
811-1	New	3	0.231	0.400103737
811-2	New	41	0.296	0.627757238
IND	Liner2	N Rows	Mean(BSOC)	Std Dev(BSOC)
809-1	New	57	0.205087719	0.060122577
811-1	New	3	0.17	0.01
811-2	New	41	0.181707317	0.044096623

Proposed standard deviation for calculating severity adjustments



- Exceed EWMA laboratory chart action limit for severity (all parameters noted below)
 - Calculate laboratory Severity Adjustment (SA) for each parameter that exceeds action limit, using the current laboratory EWMA (Zi) as follows:

Weighted Demerits: $SA = (-Z_i) \times (27.1)^1$

Top Groove Fill: $SA = (-Z_i) \times (0.488165)^2$

Top Land Heavy Carbon: $SA = (-Z_i) \times (0.9)^T$



Based on 101 tests on liner 1Y3998, updated to 0.5064

The other two parameters are based on oil 1004-1. Guidance from the SP is needed if there is need to update them.

¹ s based on reference oil 1004-1

² s based on reference oil 811-1 and 811-2 on 1Y-3998 liners

Appendices



	1N Reference Oil Targets												
		Effectiv	e Dates	W	DN	TC	TGF ³		TLHC ⁴		OC		
Oil	n	From ¹	To ²	$\overline{\mathbf{x}}$	s	$\overline{\mathbf{x}}$	s	$\overline{\mathbf{X}}$	s	$\overline{\mathbf{X}}$	s		
809-1	18	3-14-93	12-7-95	196.6	33.3	32.1	18.8	1.386	1.1	0.325	0.215		
	20	12-8-95	12-6-07	198.1	33.1	33.9	20.5	1.363	1.1	0.322	0.204		
	30	12-7-07	1-31-04	> 205.0	34.6	35.3	20.5	1.197	1.213	0.308	0.175		
	30°	2-1-04	***	> 205.0	34.6	3.410591	0.563970	1.197 1.213		0.308	0.175		
810-2	86	2-1-98	12-31-99	270.5	39.3	73.6	11.8	2.632	1.2	0.500	0.407		
	4	1-1-00	***	273.3	45.5	70.8	11.0	2.548	1.3	0.540	0.410		
811-1	10	3-22-93 3-28-96 293.8 38.6		38.6	28.9	26.5	0.262	0.5	0.249	0.051			
	20	3-29-96	12-6-07	281.5	37.4	24.7	21.6	0.366	0.6	0.223	0.052		
	30	12-7-07	1-31-04	273.2	35.5	26.2	19.8	0.454	0.659	0.218	0.053		
	30°	2-1-04	***	273.2	35.5	3.077855	0.362927	0.454	0.659	0.218	0.053		
811-28	20	11-26-06	1-31-04	281.5	37.4	24.7	21.6	0.366	0.6	0.223	0.052		
	20°	2-1-04	***	281.5	37.4	2.961267	0.361554	0.366	0.6	0.223	0.052		
1004	16	6-29-93	***	224.7	37.5	24.8	13.8	0.588	0.8	0.192	0.048		
1004-1	30	2-6-94	***	212.4	27.1	24.7	14.6	0.693	0.9	0.201	0.045		
1004-25		8-11-95	12-10-96	212.3	27.1	24.7	14.6	0.693	0.9	0.201	0.045		
	12	12-11-96	12-21-97	205.9	28.9	31.7	14.8	0.552 0.904		0.206	0.093		
	22	12-22-97	***	204.0	25.7	30.4	16.8	0.490	0.804	0.206	0.075		
1004-3 ⁷		4-17-99	3-13-04	204.0	25.7	30.4	16.8	0.490	0.804	0.206	0.075		
	16	3-14-04	1-31-04	190.7	24.7	23.9	14.6	0.1806	0.3977	0.148	0.038		
	16 ⁹	2-1-04	***	190.7	24.7	3.059337	0.581279	0.1806	0.3977	0.148	0.038		

- 1 Effective for all tests completed on or after this date.
- 2 *** = currently in effect.
- 3 Transformation for TGF is ln(TGF+1).
- 4 Transformation for TLHC is ln(TLHC+1).
- 5 Initial targets based on 1004-1.
- 6 Three runs on 810-1 and five runs on 810-2.

- 7 Initial targets based on 1004-2.
- 8 Initial targets based on 811-1
- Targets valid for 1Y3998 liners only

New Material: to be discussed at SP meeting 8/13/2020

New liner data

Horizontal RED LINE is the current target

Each plot shows the distribution by parameter and oil

The plots shows how far the current target is from the actual mean

TTGFFNL 4.5 3.5 3 2.5 Summary Statistics Mean 3.1542548

Distributions IND= 809-1

Std Dev 0.5323804 Std Err Mean 0.0705155 Upper 95% Mean 3.2955143 Lower 95% Mean 3.0129952 57

300 280 260 240 220 200 180 160 140

WDN

Summary Statistics

Mean 177.82632 Std Dev 24.81789 Std Err Mean 3.2872099 Upper 95% Mean 184,41139 Lower 95% Mean 171.24124 57

WDN

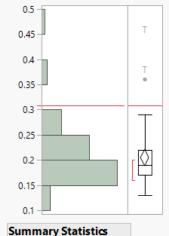
2.5 T 2 1.5 0.5 0

TTLHCFNL

Summary Statistics

TTLHCFNL

Mean 0.4922982 Std Dev 0.7899759 Std Err Mean 0.1046349 Upper 95% Mean 0.7019071 Lower 95% Mean 0.2826894



BSOC

0.2050877 Mean Std Dev 0.0601226 Std Err Mean 0.0079634

Upper 95% Mean 0.2210404 0.1891351 Lower 95% Mean 57

BSOC

Distributions IND= 811-2

TTGFFNL 4.5 3.5 2.5

Summary Statistics

3.3134004 Mean Std Dev 0.474121 Std Err Mean 0.0740453 Upper 95% Mean 3.4630515 Lower 95% Mean 3.1637494 41

350 300 250

Summary Statistics

200

Mean Std Dev Std Err Mean Upper 95% Mean Lower 95% Mean 257,37579

267.54634 32.222113 5.0322486 277.7169

2 1.5 To 0.5 0

Summary Statistics

Mean 0.296 Std Dev 0.6277572 Std Err Mean 0.0980392 Upper 95% Mean 0.4941446 Lower 95% Mean 0.0978554

0.3 0.25 \Diamond 0.15 0.1

Summary Statistics Mean 0.1817073 Std Dev 0.0440966 Std Err Mean 0.0068867 Upper 95% Mean 0.1956259 Lower 95% Mean 0.1677887

Performance you can rely on.



	All data		All data	
809	Mean(TTGFFNL)	811-2	Mean(TTGFFNL)	
Target	3.410591	Target	2.961267	
Mean	3.154255	Mean	3.313400	
Std dev	0.532380	Std dev	0.474121	
S2	0.283429	S2	0.224791	
Mean square		Mean square		
error	0.349137	error	0.348789	
RMSE	0.590878	RMSE	0.590583	

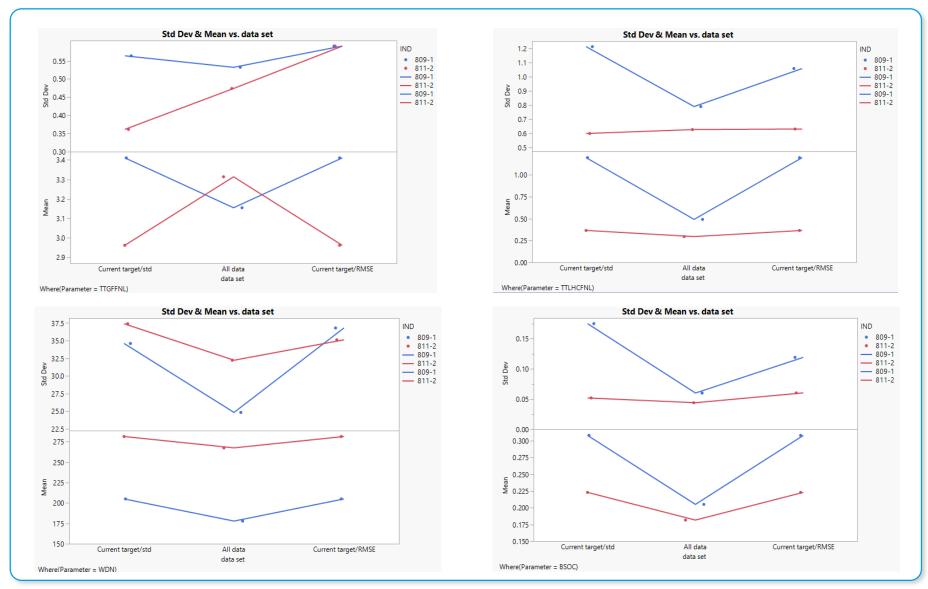
	All data		All data
809	Mean(TTLHCFNL)	811-2	Mean(TTLHCFNL)
Target	1.197	Target	0.366
Mean	0.492298	Mean	0.296
Std dev	0.789976	Std dev	0.627757
S2	0.624062	S2	0.394079
Mean square		Mean square	
error	1.120667	error	0.398979
RMSE	1.058615	RMSE	0.631648

	All data		All data
809	Mean(WDN)	811-2	Mean(WDN)
Target	205	Target	281.5
Mean	177.826316	Mean	267.546341
Std dev	24.817890	Std dev	32.222113
S2	615.927688	S2	1038.264549
Mean square		Mean square	
error	1354.336802	error	1232.969135
RMSE	36.801315	RMSE	35.113660

	All data		All data
809	Mean(BSOC	811-2	Mean(BSOC
Target	0.308	Target	0.223
Mean	0.205088	Mean	0.181707
Std dev	0.060123	Std dev	0.044097
S2	0.003615	S2	0.001945
Mean square		Mean square	
error	0.014206	error	0.003650
RMSE	0.119188	RMSE	0.060412

Comparing Current Target/ Std Deviation with Updated values with "All Data" and RMSE





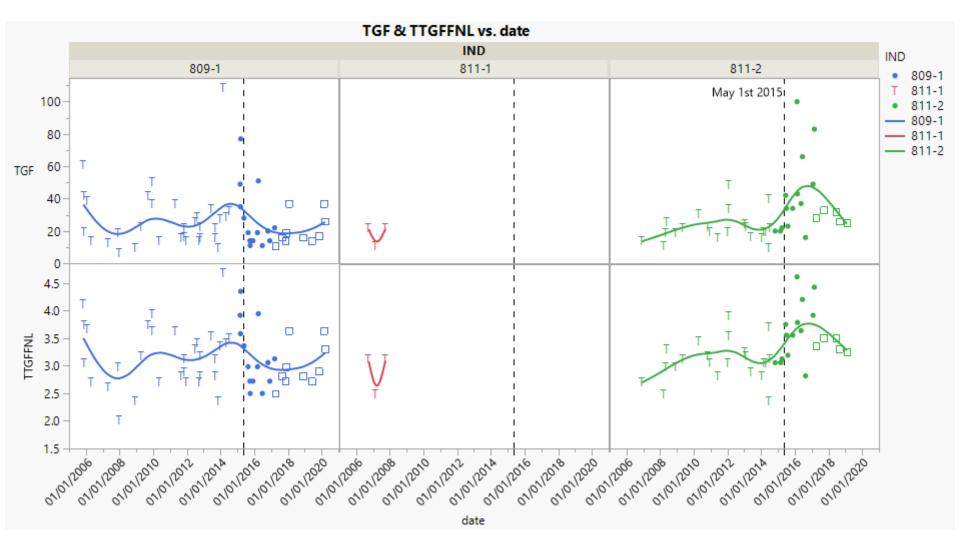


Mean and Standard Deviation By Oil for different subsets of data by parameter

						1	-		Т		1	1		1	1	-
IND					N Rows target	Current target	Current Std Dev	N Rows 04/2017 forward	04/2017 forward Mean		N Rows	2018 forward Mean	forward Std		excl D1 811-2 Mean	excl D1 811-2 Std Dev
809-1	New	uata 57	` ′	` ′							2010 11 W	3.172206				
						3.410591	0.30397	7 10	3.003/32	0.555551	0	3.1/2200	0.41323	3/	3.154254754	0.532560411
811-1	New	3				2.061267	0.261554		2 200076	0.117269	2	2.250162	0.135400	20	2.251461760	0.204261070
811-2	New	41	3.313400415	5 0.474120965	20	2.961267	0.361554	, 3	3.389976	0.117268	3	3.358163	0.135408	39	3.251461769	0.394261078
	1						1	N Rows						N Rows		
İ		N Rows all			N Rows			04/2017			N Rows			excl D1		
IND			Mean(WDN)		target			forward			2018 frw			811-2		
809-1	New	57	, ,	` '		205	34.6		179.73		6	186 2833333	8.129555133	_	177.8263158	24.81789048
811-1	New	37	276.9			, 203	34.0	10	1/3./3	14.47020	J	180.2033333	8.129555155	3,	177.0203130	24.81703040
811-2	New	41				281.5	37.4		254.28	30.263295	2	252 222222	19.41039241	39	267.5538462	33.05852741
011-7	INCAA	71	207.3403413	32.22211273		, 201.3	37.4		234.20	30.203233	,	233,333333	19.41039241	33	207.3330-02	33.03032771
	1					+		N Rows	-					N Rows		
		N Rows all			N Rows			04/2017			N Rows			excl D1		
IND			Mean(TTLHCFNL)	Std Dev(TTLHCFNL)				forward			2018 frw			811-2		
809-1	New	57		` '		1.197	7 1.213		0.1792		6	0	0	-	0.492298246	0.789975948
811-1	New	3	0.231						3.2.3.2	0.232.22		-			0.132=55=15	0.7002.22.22
811-2	New	41				0.366	0.6	5	0.2198	0.491488	3	0.366333333	0.634507946	39	0.208897436	0.503029286
0== =	110					-					-	0,22222	0.11			
						1		N Rows						N Rows		
		N Rows all			N Rows			04/2017			N Rows			excl D1		
IND	Liner2	data	Mean(BSOC)	Std Dev(BSOC)	target			forward			2018 frw			811-2		
809-1	New	57	0.205087719	9 0.060122577	30	0.308	0.175	10	0.195	0.044783	6	0.165	0.012247449	57	0.205087719	0.060122577
811-1	New	3	0.17	7 0.01												
811-2	New	41	0.181707317	7 0.044096623	20	0.223	0.052	2 5	0.182	0.052631	3	0.16	0.026457513	39	0.179230769	0.043732718
															1	

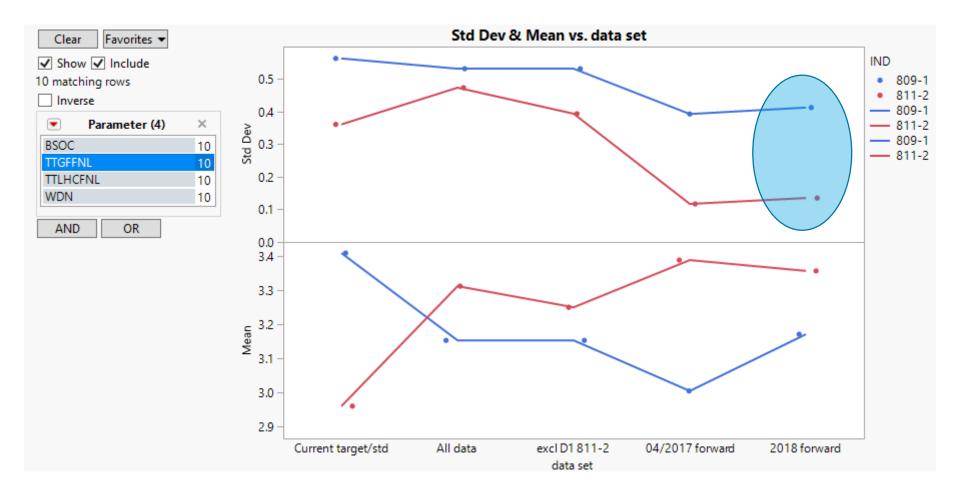
04/2017 forward: symbol □





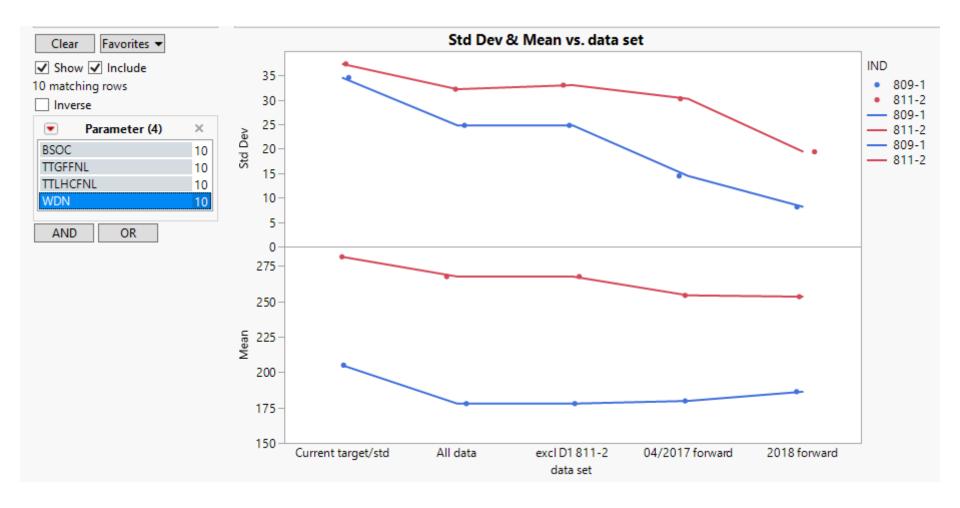
TTGFFNL: Mean standard deviation for different datasets





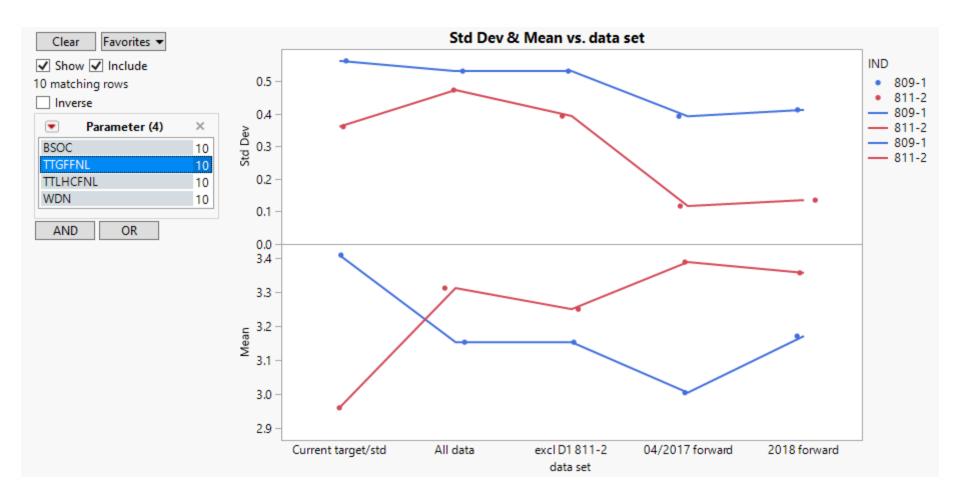
WDN: Mean standard deviation for different datasets





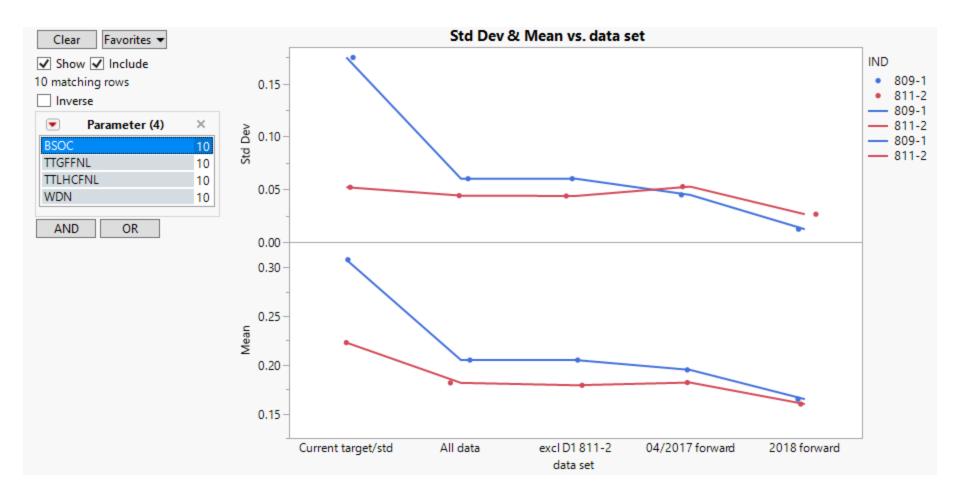
TTLHCFNL: Mean standard deviation for different datasets





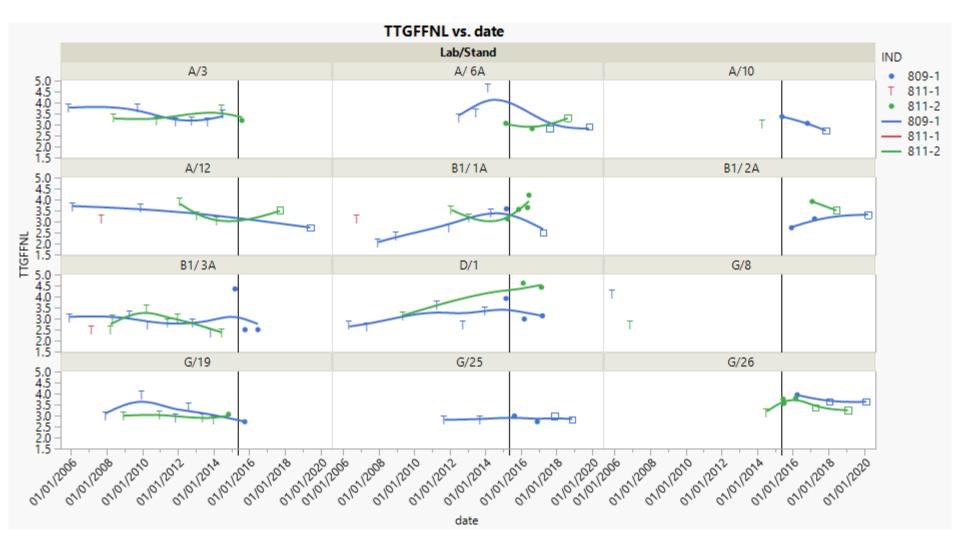
BSOC: Mean standard deviation for different datasets





Additional plots by Lab

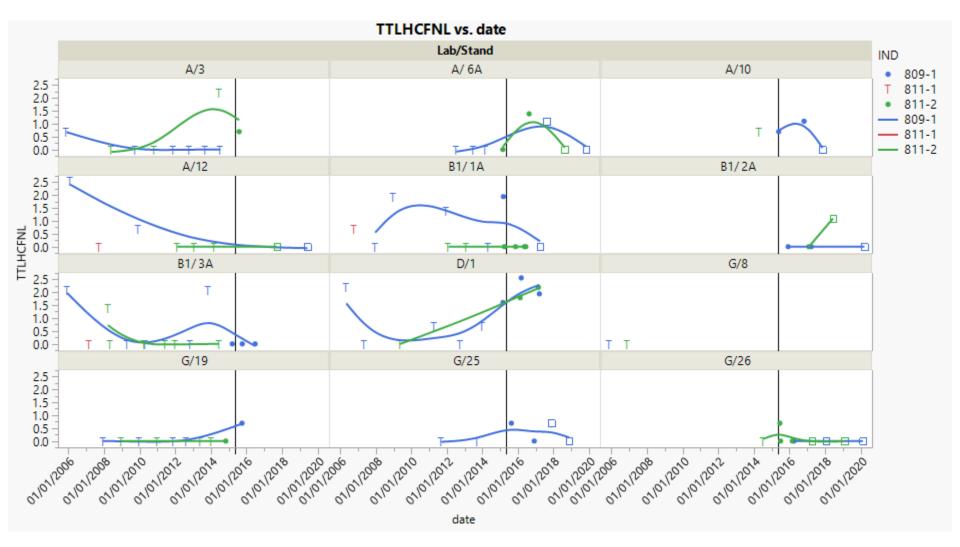




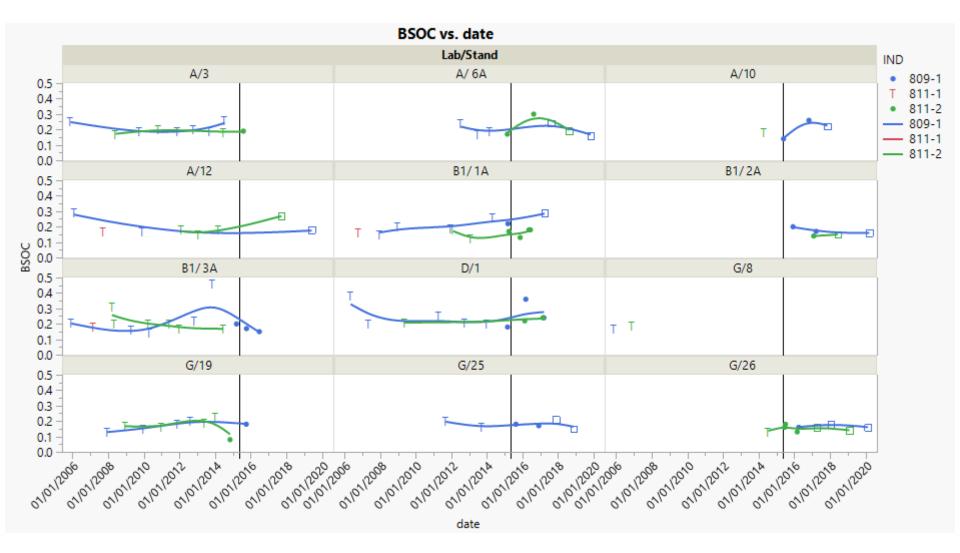






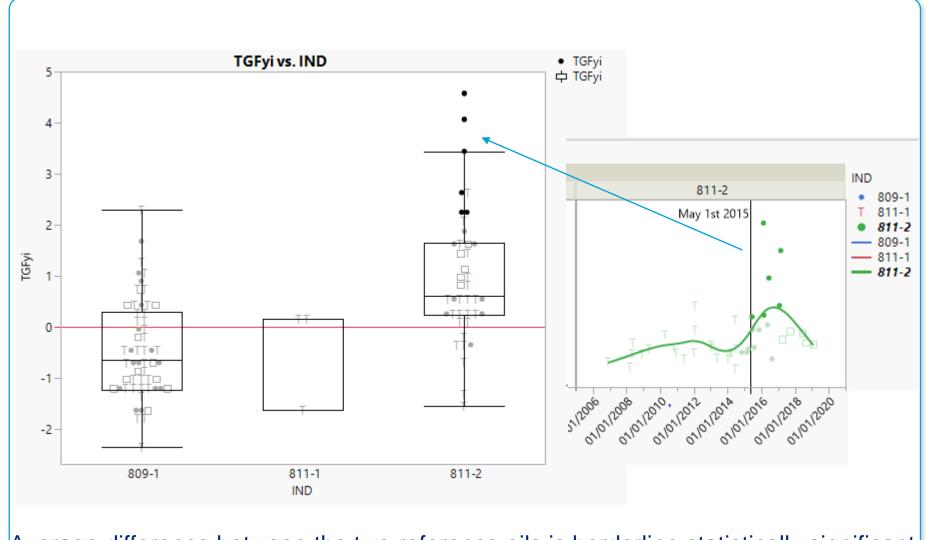






Highlighted tests correspond to 811-2 right after May 1st 2015





Average difference between the two reference oils is borderline statistically significant

1N Statistician's meeting: 08/20/2020

Led by Elisa (Infineum)
Thanks to Jo (Chevron), Kevin (LZ), Martin (IAR), Sean (TMC),
Todd (Afton), Travis (SwRI)

Statisticians and Sean Moyer (TMC) met to brainstorm a path forward

- Investigation: This situation requires an investigation. Labs would examine hardware, understand the problem. SP would work on a solution. If investigation is not a viable option...
- Do Nothing has been adopted before
 - Currently there are no Severity alarms. Yi window seems ok
 - Precision alarms: currently, none, but EWMA is still very close to warning line
 - No labs failing calibration
 - Thought about the ref. oils severity: Assuming that one oil is "right" and the other oil is "wrong", on average the impact is still undetectable
- For the *alternate fuel work*, we could offer most recent standard deviation: would need to select "right subset"
 - Could also update standard deviation to include bias and propose asymmetric bands
- In the end, the statisticians agree that there are too many problems
 - Further direction from the SP for a mathematical or practical solution may eliminate the symptoms but do not address the root cause
- Also, small number of registered tests by year: not worth the effort

Recommendation



- The statisticians agree that, no matter what standard deviation we agree on, it will be based on many assumptions, including the fact that the parts that caused the high variability are not available anymore. We have no way to know if this is true or false
- Small number of registered tests by year: not worth the effort
 - Based on the low number of 1N tests run over the last three years total of 18 tests, there is very low economical incentive in adopting the alternate fuel for the 1N
- Final recommendation: abandon the idea of using an alternate fuel for the 1N

Infineum confidential information.

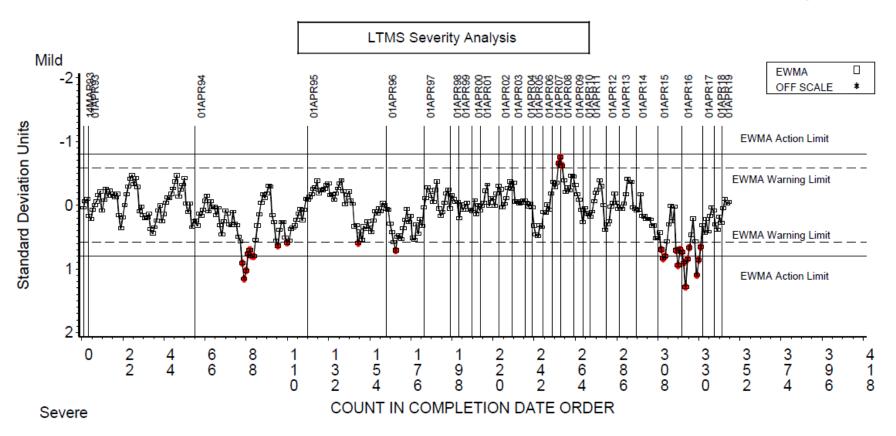
Given in confidence to xxxxxx under agreement xxxxxxx



CATERPILLAR 1N INDUSTRY OPERATIONALLY VALID DAT



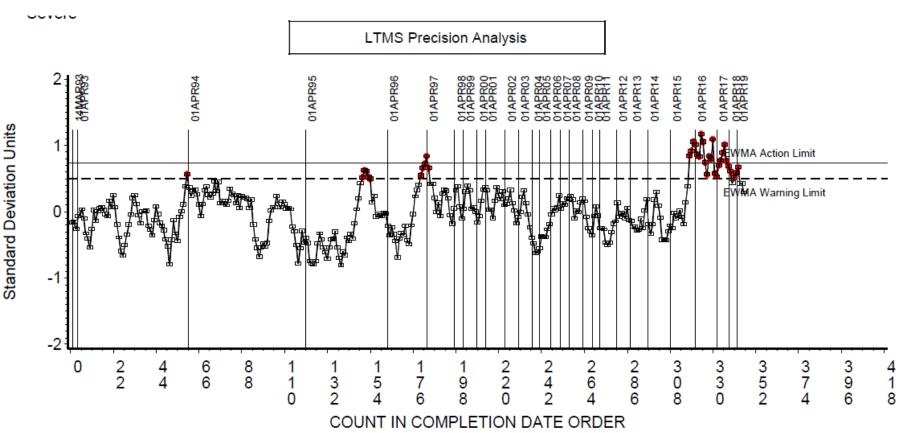
FINAL CORRECTED TGF



45



TGF Precision



If the oils remain separated as they are now we would expect a regular on going series of precision alarms or near the alarm limit depending, in part, on the order oils are assigned.

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