1N: Updated Standard Deviations
A discussion

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07 23 2020

Performance you can rely on.

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%20TGF%209_21_2016.pdf

www.astmtmc.cmu.edu - /ftp/docs/diesel/CAT/minutes/2016/10.07/

[To Parent Directory]

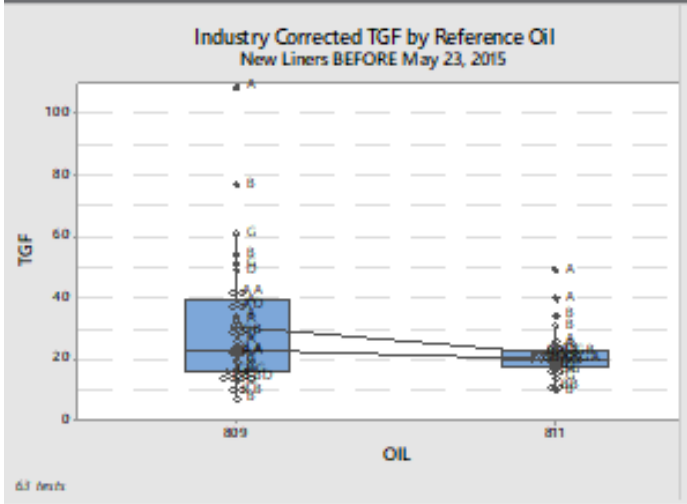
1/10/2017	8:48 AM	410023	1N TGF 9 21 2016.pdf
12/9/2016	6:10 PM	4096875	1R-1808 FilterAnalysis.pdf
1/10/2017	8:49 AM	21178	COAT-Task Force Teleconference 10-7-2016.pdf

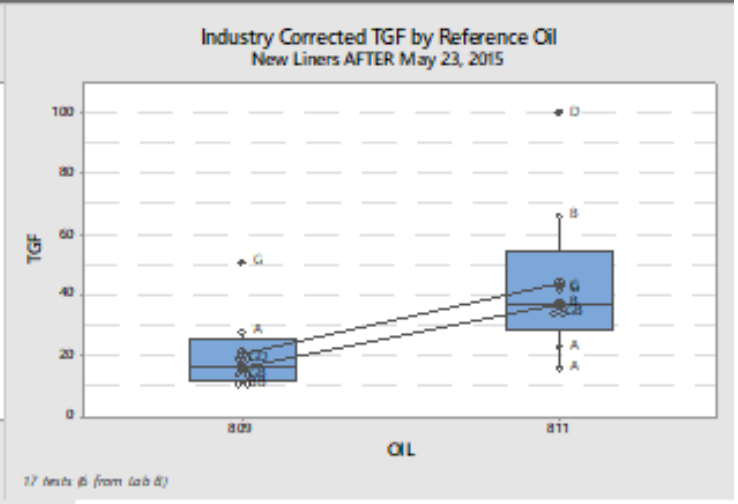
- Next four slides will tell you that parts variation was identified as the root cause
- I will proceed with the analysis without excluding any data, assuming that parts variability is part of the test variability
- Please let me know if you have any concerns with anything and I will revise it

Caterpillar 1N TGF Dilemma from September 2016

Evidence of Issue

SUCCESS TOGETHER





- 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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Lubrizol

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

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/

[To Parent Directory]

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.pdf
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

Oil Test Engine Parts					
ASTM Test	D6750 1K	D6750 1N	D6681 1P	D6923 1R	D7549 C13
Arrangement	1Y0540	1Y0540	1Y3700	E455	1Y4100
Liner	1Y3998	1Y3998	1Y3997	1Y3997	1Y4107
Piston	1Y0727	1Y0727	1Y3400	1Y4016	1Y4106
Skirt	na	na	1Y3659	1Y4015	na
Top Ring	1Y3506	1Y3506	1Y3802	1Y4014	1Y4108
2nd Ring	1Y3507	1Y3507	1Y3803	1Y4013	1Y4109
Oil Ring	1Y3508	1Y3508	1Y3804	1Y4012	1Y4110
Ring Kit	1Y0728	1Y0728	na	na	na

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

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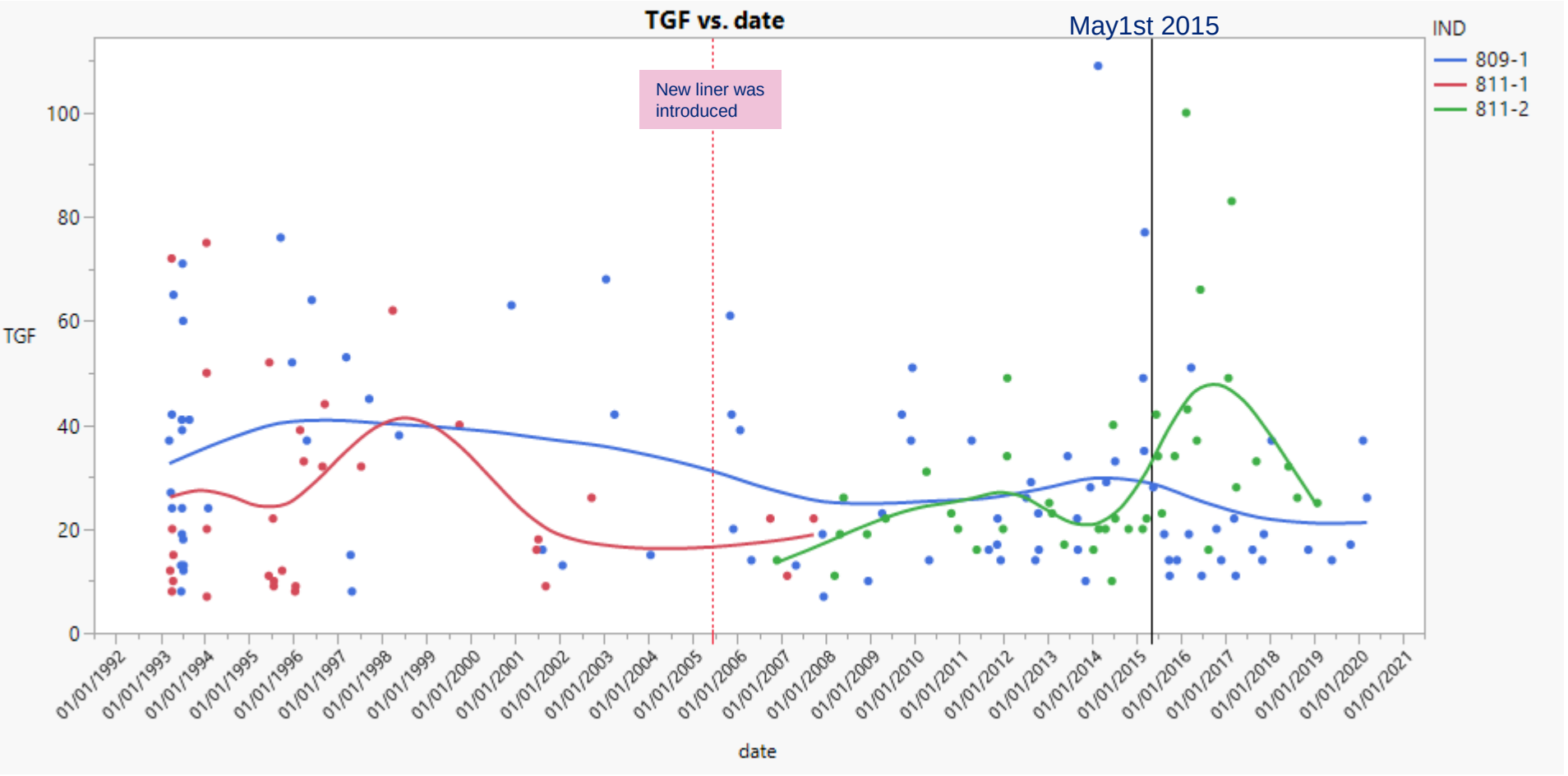
	SOCyi	LINERPN	LINERSN	LINERDC	LINERBDC	PISTPN	PISTSNBDC	PISTDC	PISTIC	RINGPN	RINGSN	RINGBDC	RINGSC	DWNOCR
440	0.0577	1Y3998	D05M09Y14P47	N/A		1Y0727		1444	1225	1Y0728				0
441	1.7885	1Y3998	65861	DYM06Y15P47		1Y0727		733	1225	1Y0728				4
442	0.2971	1Y3998	D04M06Y15P47	N/A		1Y0727		256	1225	1Y0728				1
443	0.8457	1Y3998	566017	D09M12Y15P47		1Y0727		310714	1225	1Y0728				5
444	0.8269	1Y-3998	N/A	D04M06Y15P47		1Y-0727		615	1225	1Y-0728				0
445	0.8269	1Y-3998	N/A	D24M08Y15P47		1Y-0727		615	1225	1Y-0728				3
446	0.9029	1Y-3998	N/A	D09M12Y15P47		1Y-0727		615	1225	1Y-0728				0
447	1.4808	1Y3998	D13M06Y14P47	N/A		1Y0727		1225M2561202	N/A	1Y0728				2
448	0.2743	1Y-3998	D13M06Y14P47	N/A		1Y-0727		1225M3191300	N/A	1Y-0728				6
449	0.7886	1Y3998	6-65171	D09M06Y16P47		1Y0727		10515	1225	1Y0728				3
450	-1.76	1Y-3998	N/A	D09M12Y15P47		1Y-0727		615	1225	1Y-0728				0
451	1.0192	1Y-3555G	N/A	D13M06Y14P47		1Y-0727		114	1225	1Y-0728				0
452	1.5962	1Y-3998	N/A	D04M06Y15P47		1Y-0727		615	1225	1Y-0728				0
453	0.3269	1Y3998	D09M06Y16P47	3		1Y0727		2136	1225	1Y0728				2
454	0.3886	1Y3998	D09M06Y16P47	1396		1Y0727		2133	1225	1Y0728				2
455	0.7886	1Y-3998	N/A	D09M06Y16P47		1Y-0727		615	1225	1Y-0728				0
456	0.1029	1Y-3998	N/A	D09M12Y15P47		1Y-0727		1016	1225	1Y-0728				0
457	1.2115	1Y3998	5-65913	D04M06Y12P47		1Y0727		D07M10Y16P47	1225	1Y0728				2
458	0.3886	1Y3998	55581	2235		1Y0727		1225M3191307	N/A	1Y0728				7
459	0.9038	1Y3998	55974	223 5		1Y0727		1225M3491302	N/A	1Y0728				3
460	0.5029	1Y-3998	65983	223 5		1Y-0727		1225M2161620	N/A	1Y-0728				2
461	-0.56	1Y3998	6-66145	D09M06Y16P47		1Y0727		D07M10Y16P47	1225	1Y0728	N/A		N/A	1
462	0.7314	1Y3998	66236	235-6	D31M08Y16P47	1Y0727	D25M08Y17P47	0016-185-17	1225	1Y0728	N/A	271216A8871L	N/A	0
463	1.4038	1Y3998	86990	033-6	D09M06Y17P47	1Y-0727	D07M10Y16P47	1857-216-16	1225	1Y-3508-04	B659	N/A	T	2
464	0.6346	1Y-3998	65690	162 4	D28M11Y16	1Y-0727	D07M10Y16	M21616	1225	1Y-3508-04	B802	271216	A8871	1
465	0.9029	1Y3998	6-66202	03-301	D02M11Y16P47	1Y0727	D25M08Y17P47	220412417	1225	1Y0728	N/A	240816A8871L	N/A	2
466	1.5962	1Y3998	6-66206	03-235	D31M08Y16P47	1Y0727	D25M08Y17P47	231212417	1225	1Y0728	N/A	271216A8871L	N/A	2
467	0.7314	1Y-3998	66244	235 6	D31M08Y16P47	1Y-0727	D25M08Y17P47	1225M1841723	1225	1Y-0728	B866	271216A8871L	B866	3
468	4.2885	1Y-3998	66232	235-6	D31M08Y16P47	1Y-0727-02	D25M08Y17P47	1225M1941721	1225	1Y-0728	B843	271216A8871L	B843	1
469	0.8457	1Y-3998	66115	133-6	D09M06Y16	1Y-0727-02	D25M08Y17P47	0037-185-17	1225	1Y-0728	B753	240816A8871L	B357	1
470	0.8457	1Y-3998-03	62239	235-6	D31M08Y16P47	1Y-0727-02	D25M08Y17P47	2325-184-17	1225	1Y-0728-04	B714	271216A8871L	T	4
471	0.8457	1Y3998-03	66316	301-6	D02M11Y16P47	1Y0727	D25M08Y17P45	184178303	1225	1Y0728		D13M01Y17P47	B607	2

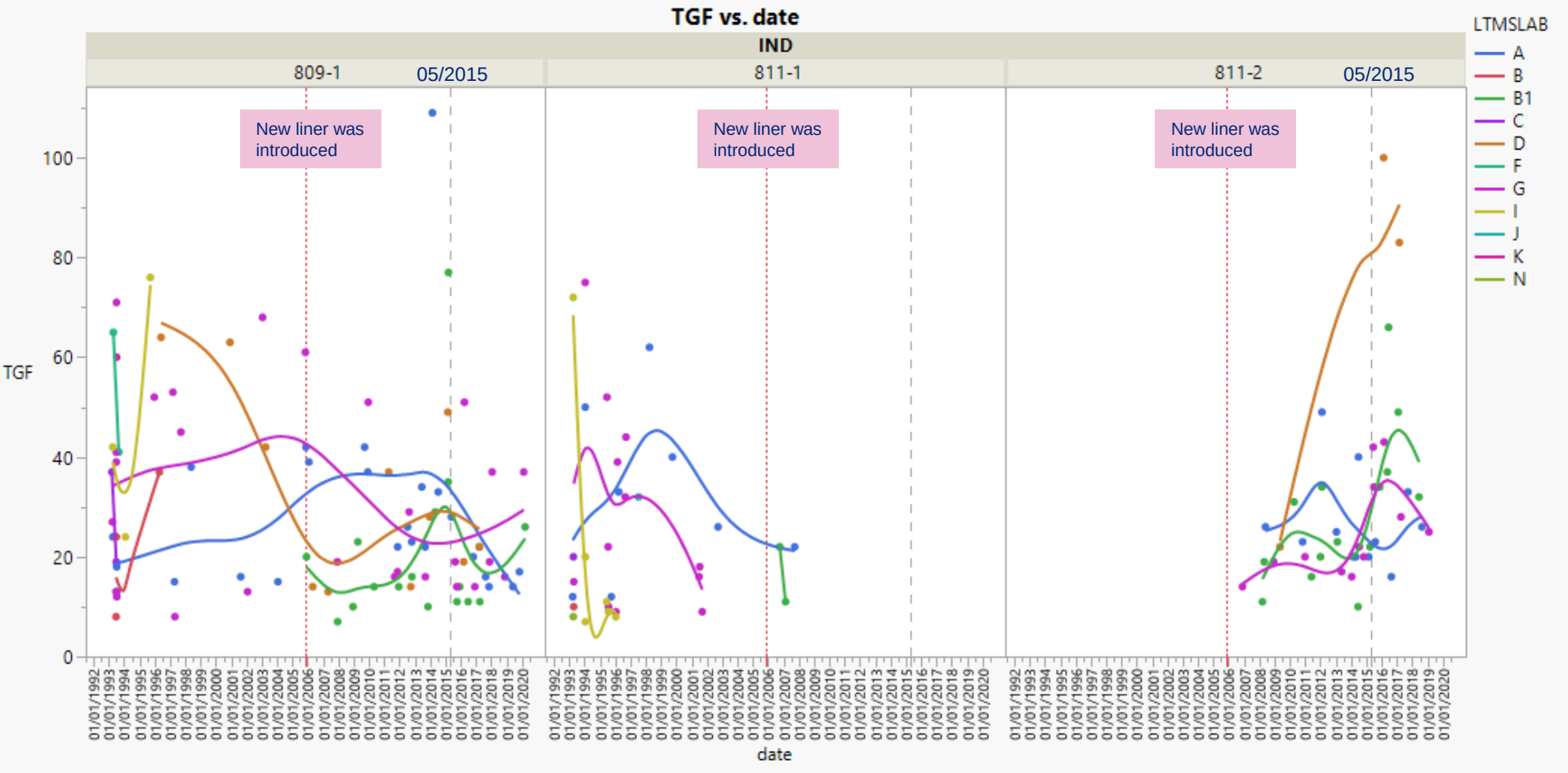
Plots – Top Groove Fill (TGF) original unit

TGF Overall trend: 809 trending down and 811 moving up



TGF (after CF is applied)

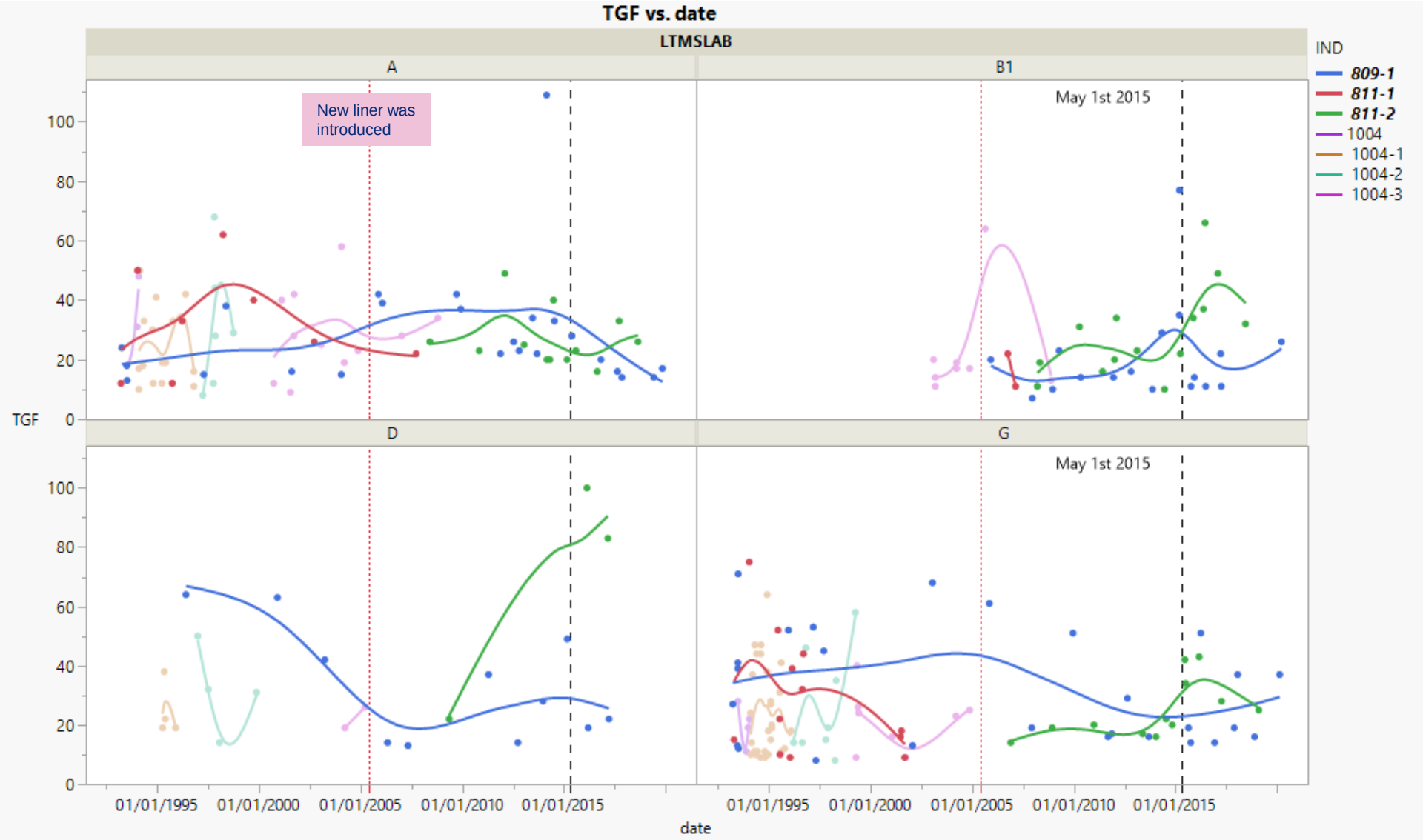
TGF by oil and Lab: 809 trending down and 811 moving up
Only Labs A, B1, D and G have data for new liners – 1Y3998



TGF (after CF is applied)

TGF by Lab and Oil: 809 trending down and 811 moving up (current oils highlighted)

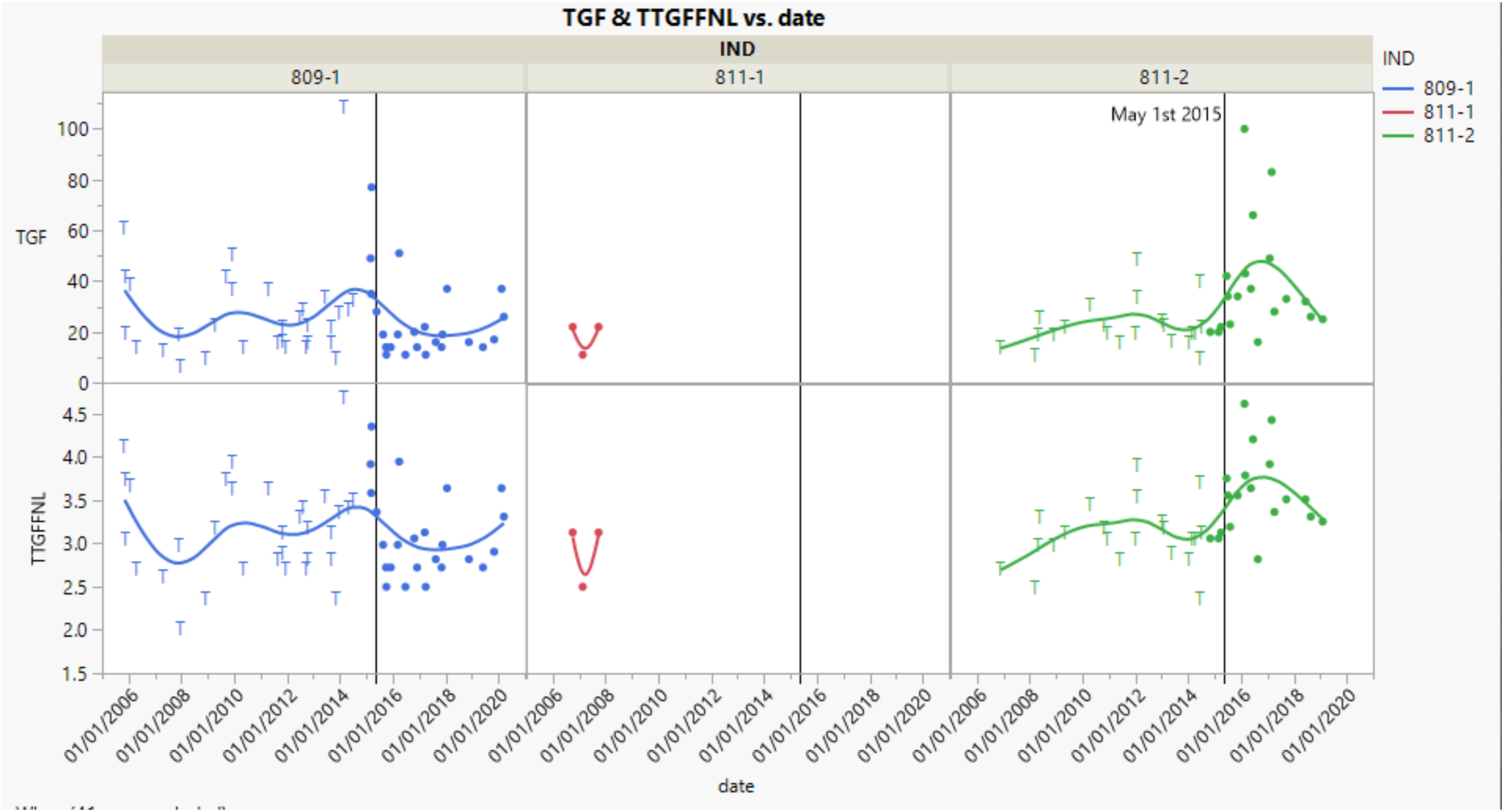
Labs are affected differently depending on the parts they get and how the test is run



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)

2013/2014 – 57 tests

Present – 101 tests (1Y3998)

LN (TGF plus one)

Oil	Liner	# of tests	Mean(LN (TGF +1))	Std Dev(LN (TGF +1))	
809-1	1Y355	30	3.410591	0.64212	
811-1	1Y355	29	3.077855	0.705547	
811-2*	1Y355	20	2.961267	0.744084	
809/811	1Y355	59	3.247043	0.674023	
809-1	1Y3998	32	2.771324	0.56397	
811-1	1Y3998	3	2.498514	0.362927	
811-2	1Y3998	22	2.679636	0.361554	
809/811	1Y3998	57	2.721577	0.488165	pooled Standard dev.

Current target (1Y355)

Current standard deviation (1Y3998)

Updated Standard deviations- transformed scale; after current CF

oil	# of tests	Mean	standard deviation
809-1	57	3.154255	0.532380
811-2	41	3.3134	0.474121

0.506358

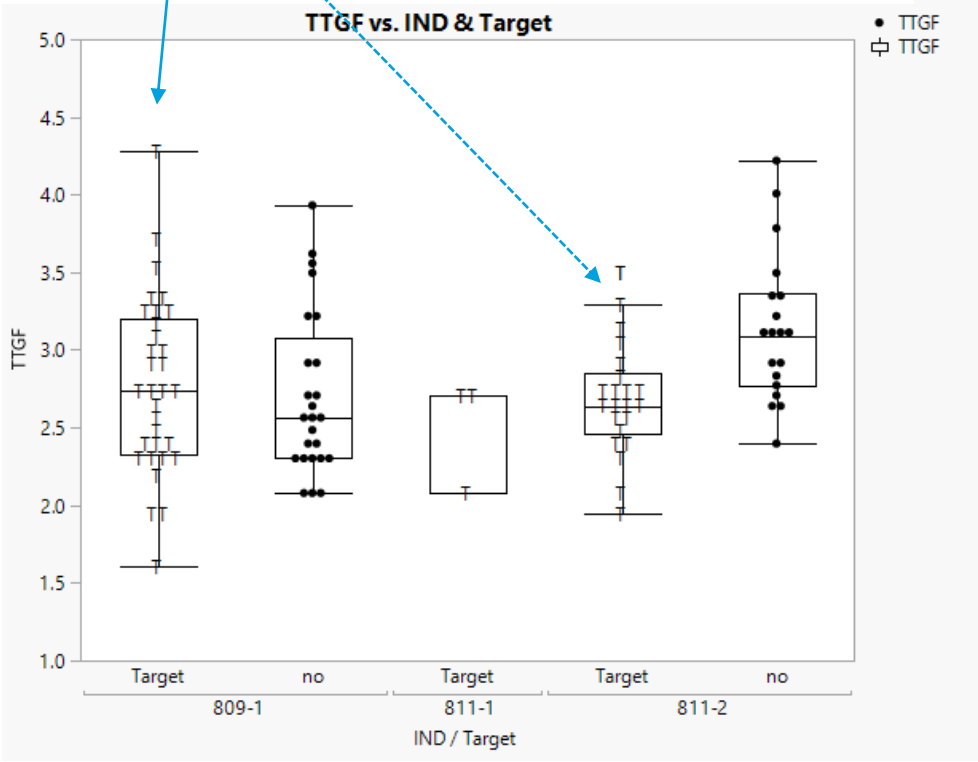
Summary of Fit	Model: Oil
RSquare	0.033469
RSquare Adj	0.013744
Root Mean Square Error	0.506358
Mean of Response	3.211855
Observations (or Sum Wgts)	101

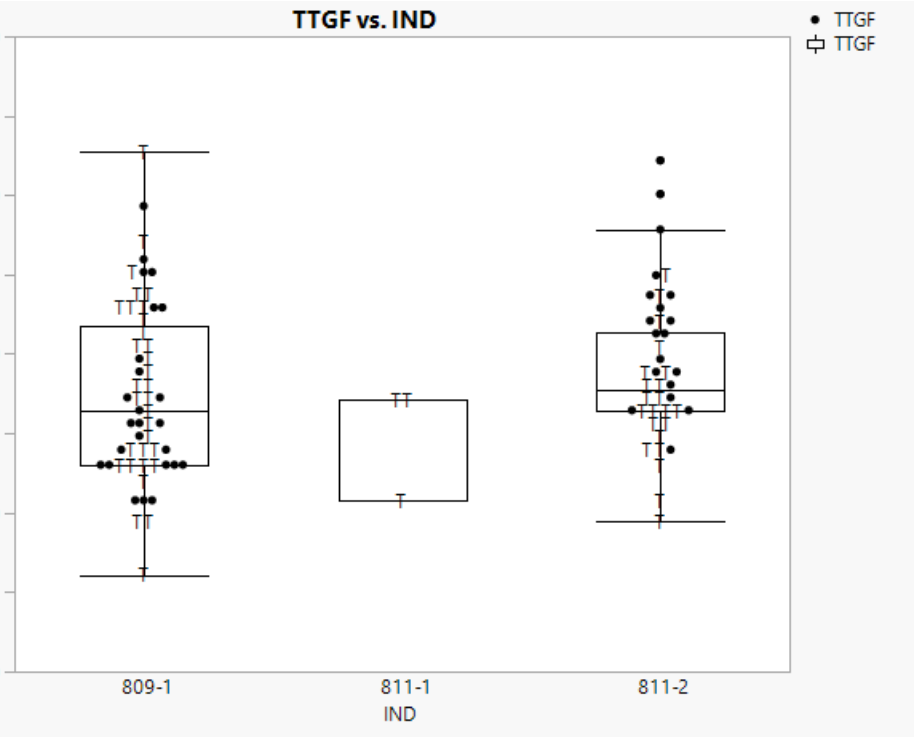
811-1 => 3 tests

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

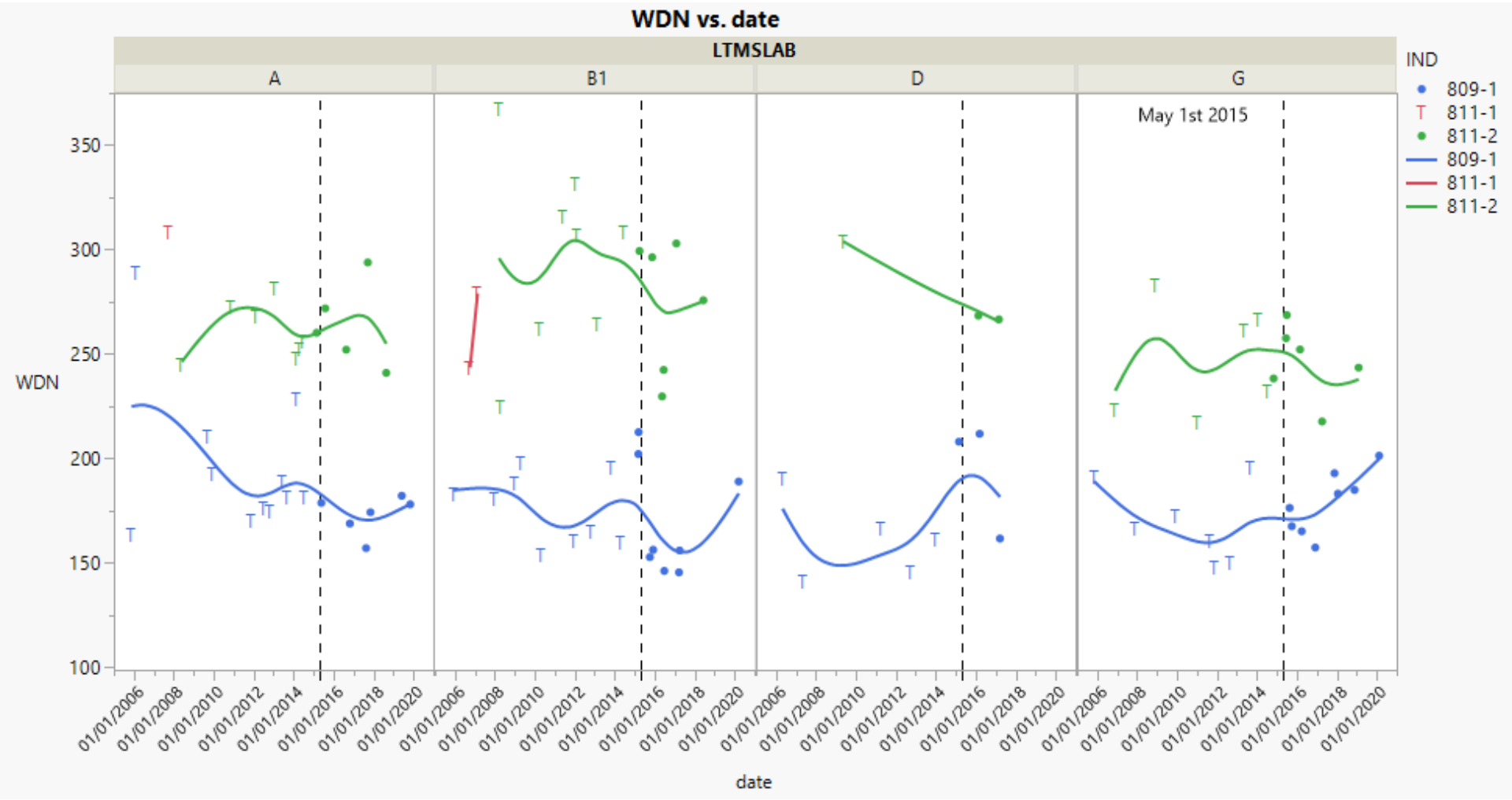
57 tests



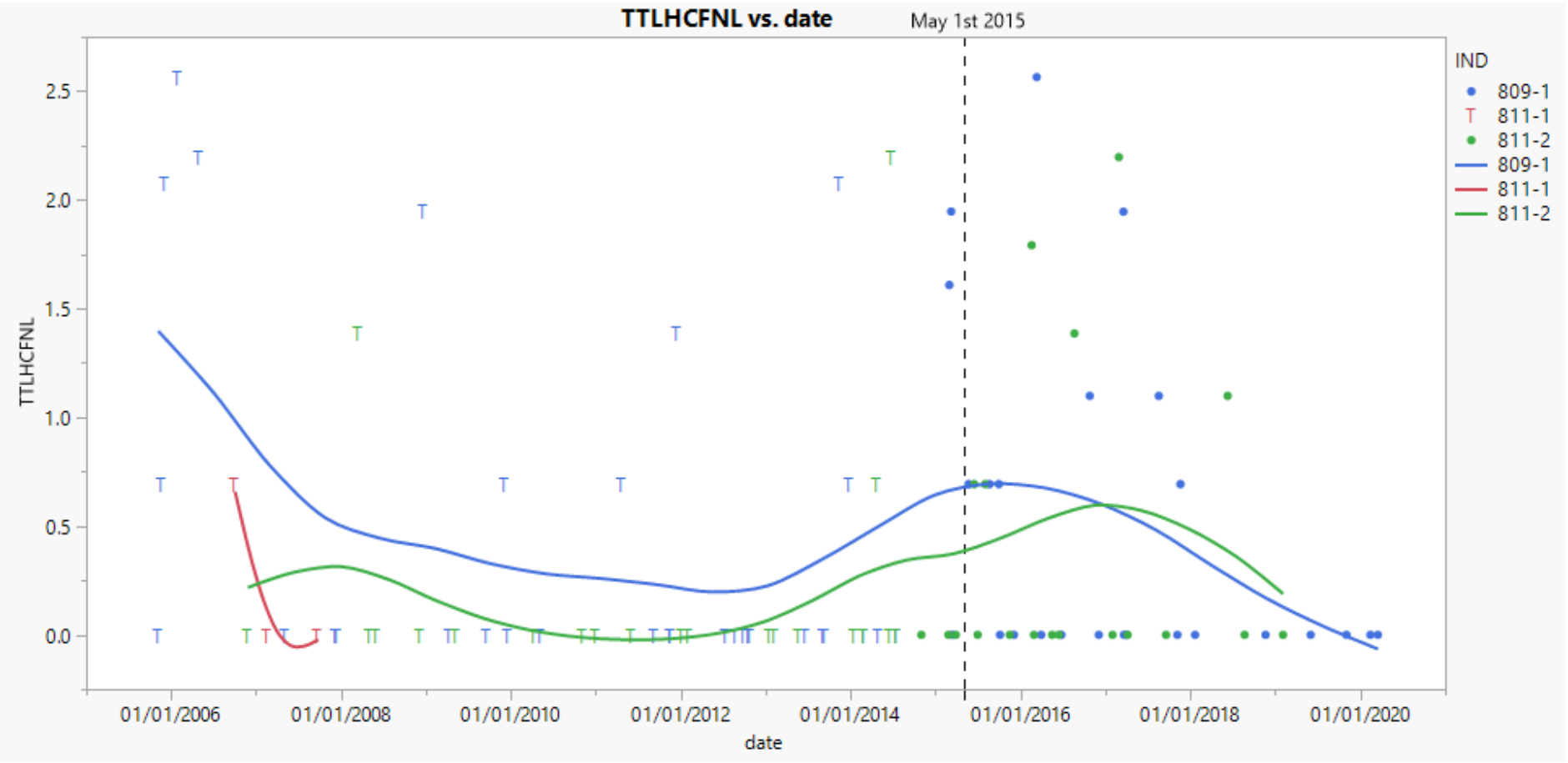


Plots – Other parameters

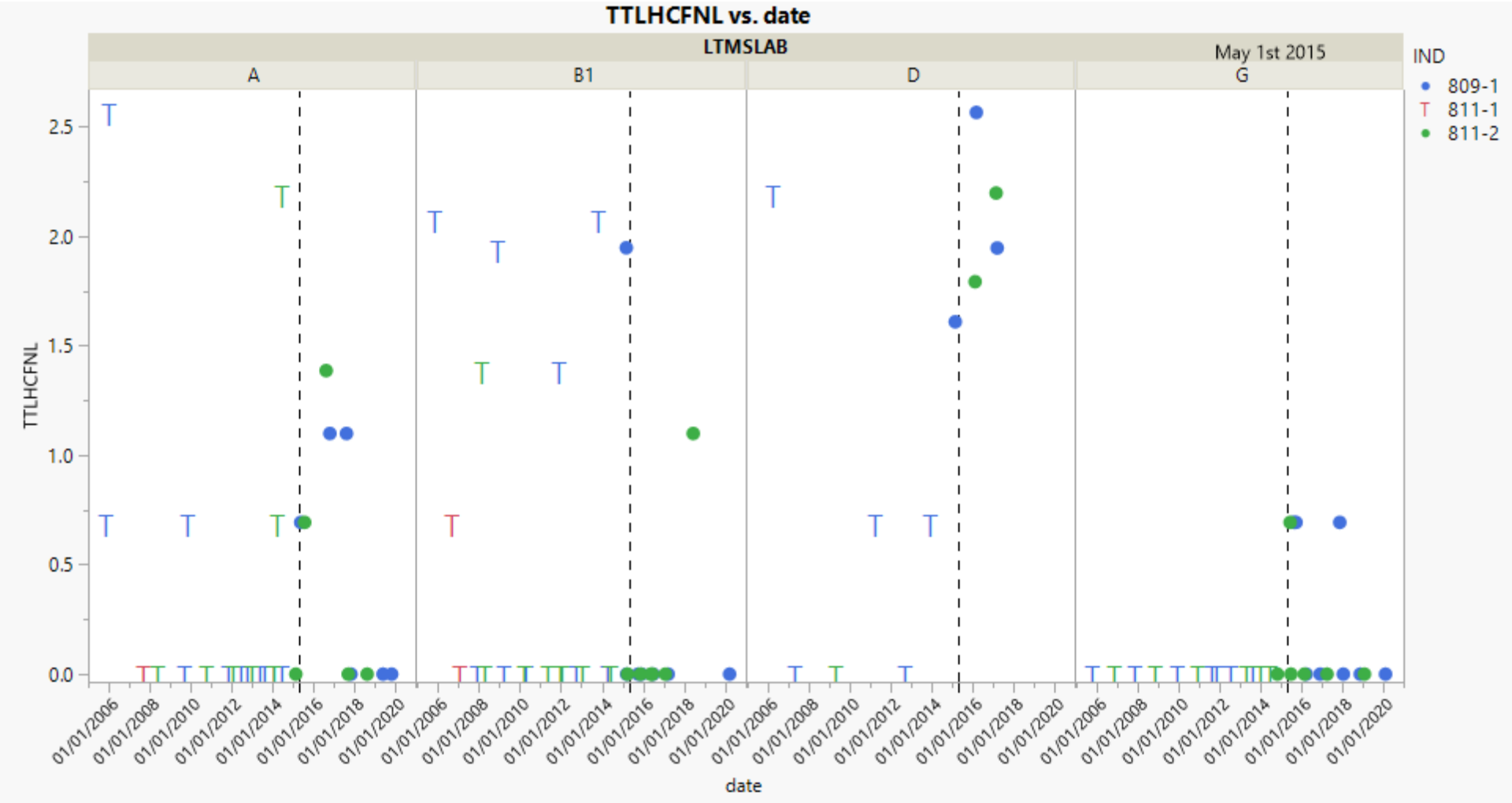
Weighted demerits (1Y3998 liner) over time by Lab and Oil



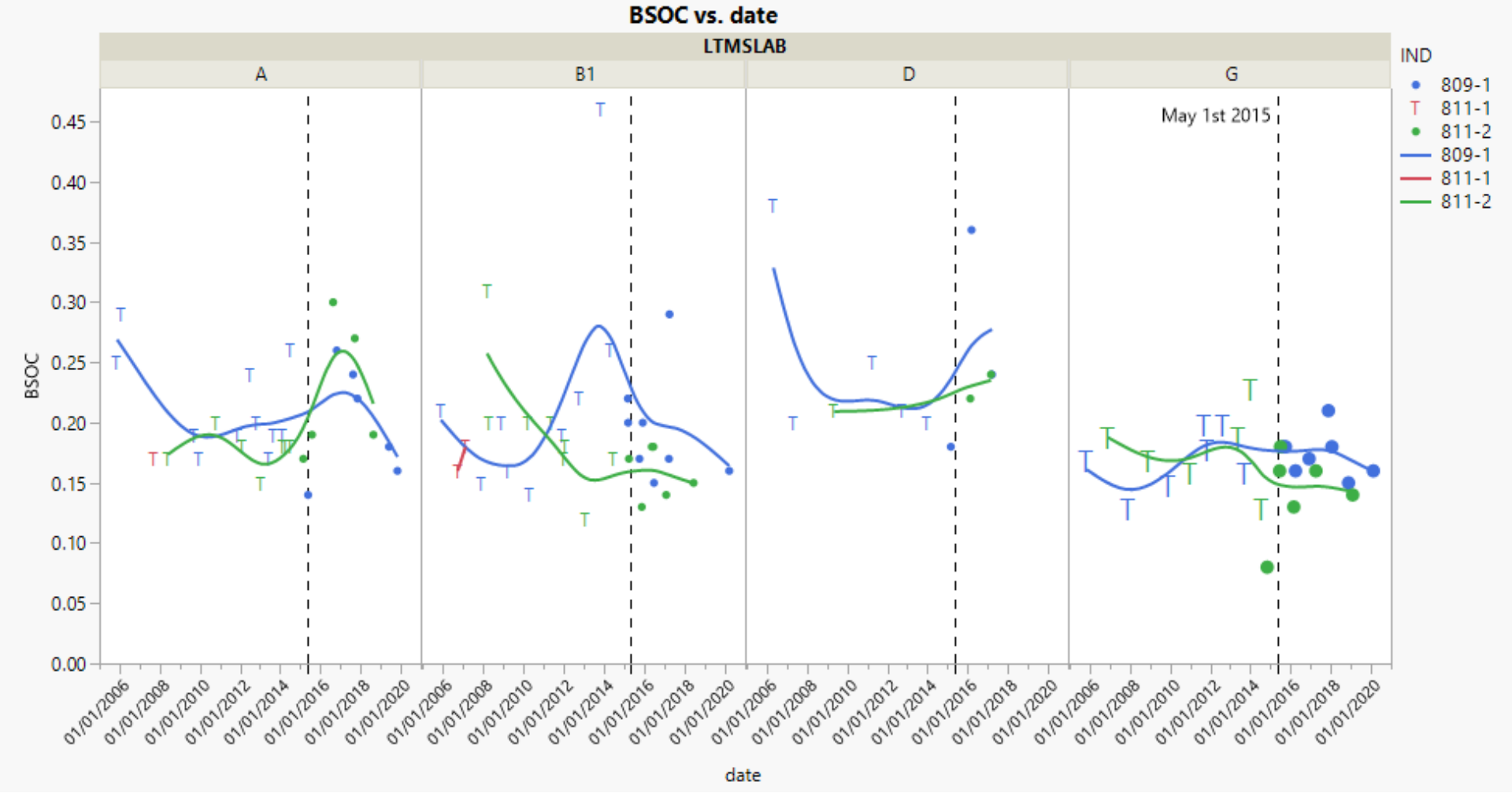
Top Land Heavy Carbon (1Y3998 liner) over time by Oil (transformed unit)



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 (Z_i) 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:	$SA = (-Z_i) \times (0.9)^1$

[1] s based on reference oil 1004-1
[2] s based on reference oil 811-1 and 811-2 on 1Y-3998 liners

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.

Appendices

1N Reference Oil Targets											
		Effective Dates		WDN		TGF[3]		TLHC[4]		BSOC	
Oil	n	From[1]	To[2]	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	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[9]	2-1-04	***	205.0	34.6	3.410591	0.563970	1.197	1.213	0.308	0.175
810-2	8[6]	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	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[9]	2-1-04	***	273.2	35.5	3.077855	0.362927	0.454	0.659	0.218	0.053
811-2[8]	20	11-26-06	1-31-04	281.5	37.4	24.7	21.6	0.366	0.6	0.223	0.052
	20[9]	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
1004-2[5]	--	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
9 Targets valid for 1Y3998 liners only

Permissions