

CATERPILLAR 1K TEST: PRELIMINARY ANALYSIS OF POTENTIAL SHIFT OVER TIME

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Performance you can rely on.



Outline



- Data
- Plots by parameter
- Data Analysis by parameter
- Main remarks

Data overview:

- Chart = Yes/ No

	CHART	N Rows
1	N	457
2	Y	647

Plots presented next: Target 809-1 and 811-1: 08 1993 (marked as “T”)

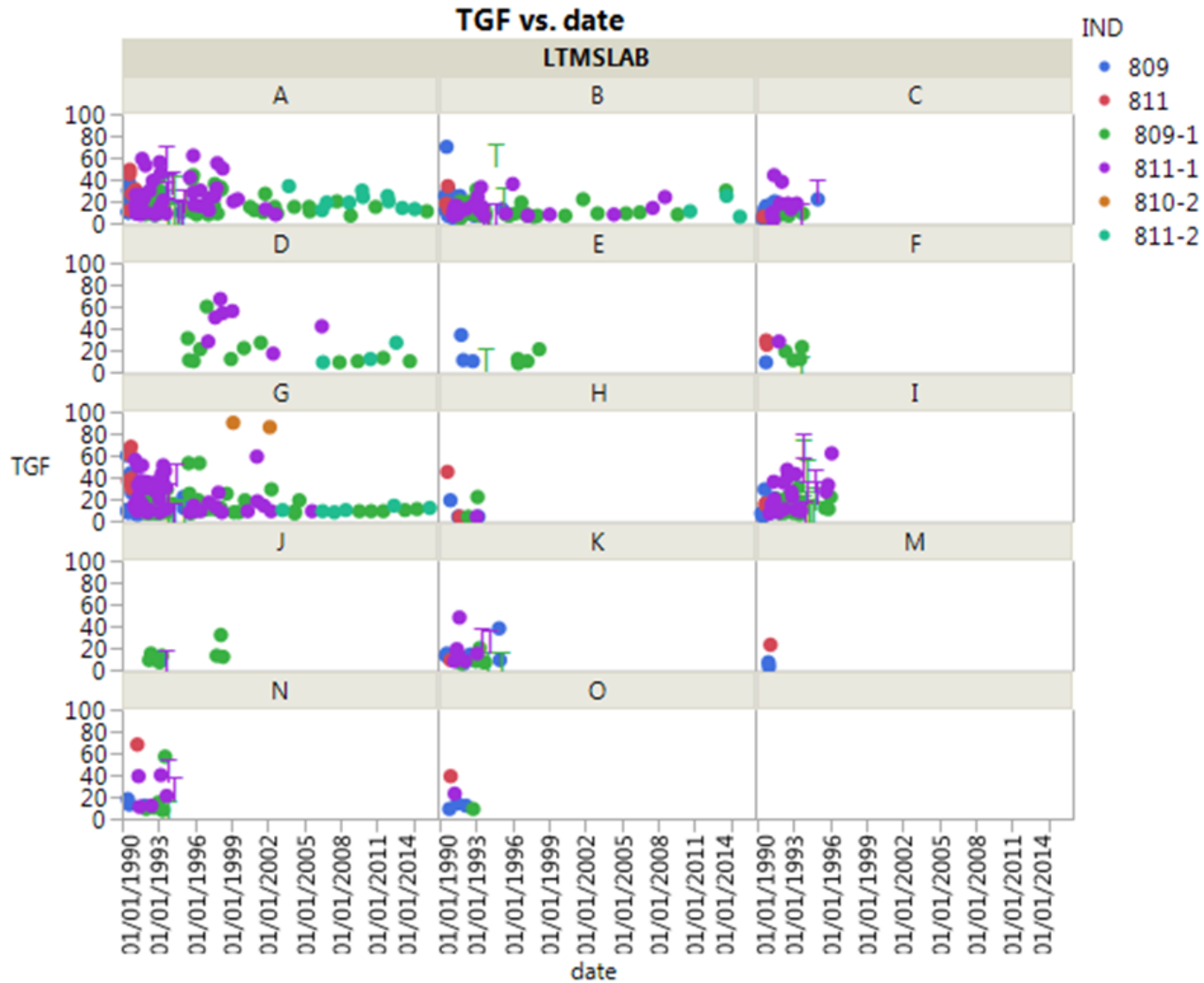
Labs running more recently: A, B, D, G

Labs without target tests: D, H, M, O

2	1Y3555	1
3	1Y3555G	1
4	1Y-35	1
5	1Y355	79
6	1Y3555	63
7	1Y35555	1
8	1Y3555G	27
9	1Y3555-G	1
10	1Y3556	1
11	1Y355G	2

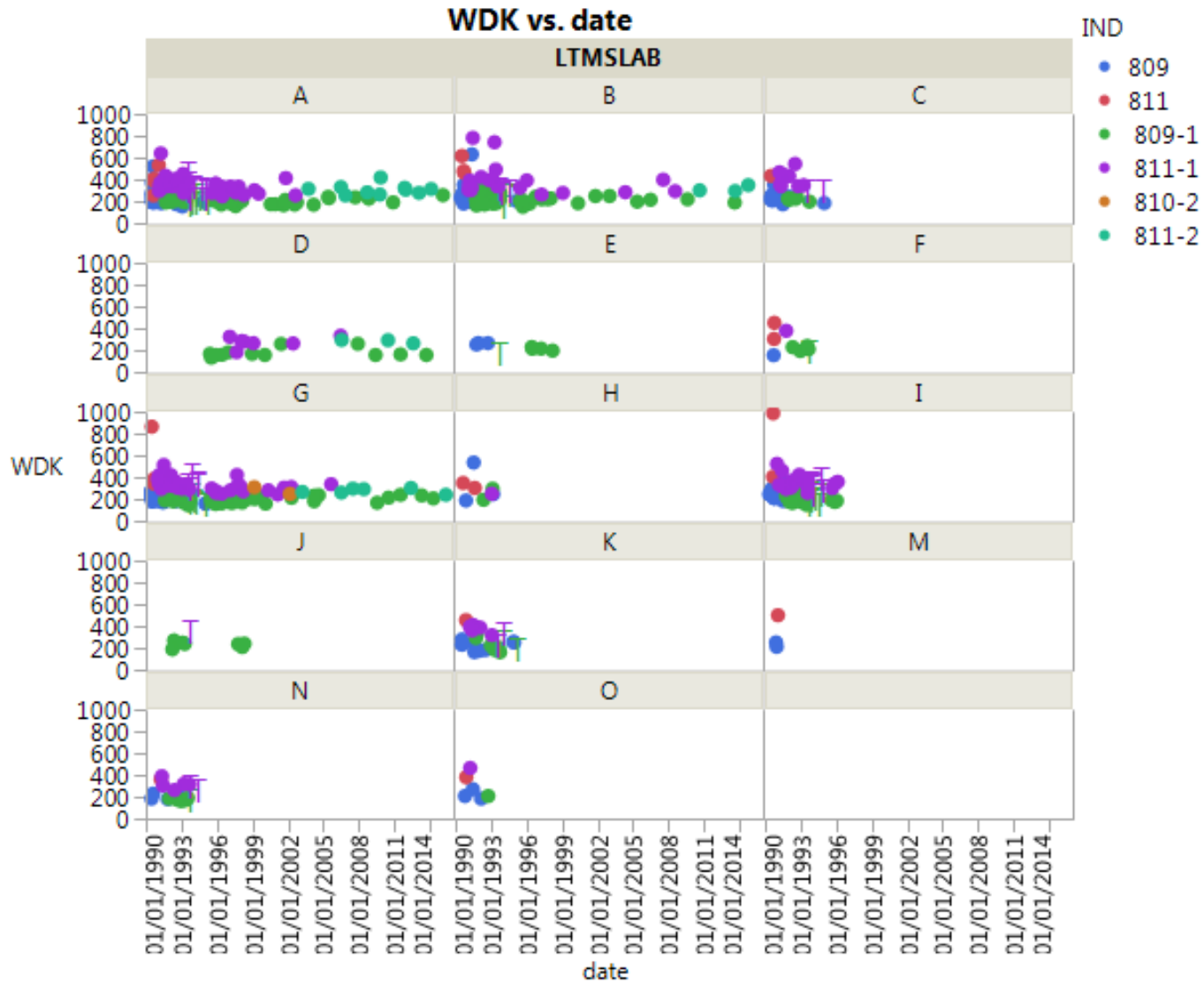
All liners coded by one of the names on the list were assumed to be 1Y3555

TGF: Chart = Yes; including 809/811 and re-blends



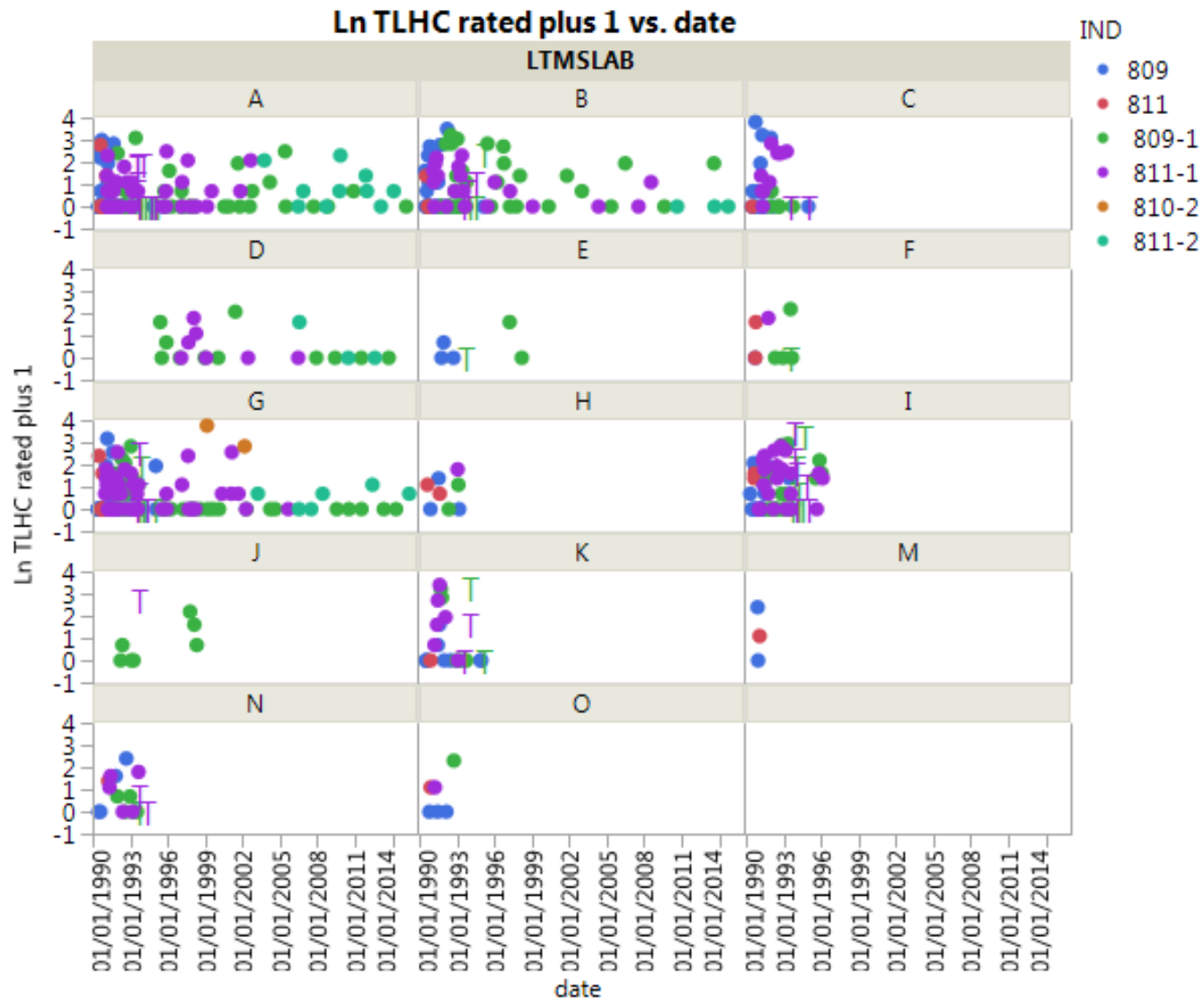
Data (cont.)

WDK: Chart = Yes; including 809/811 and re-blends



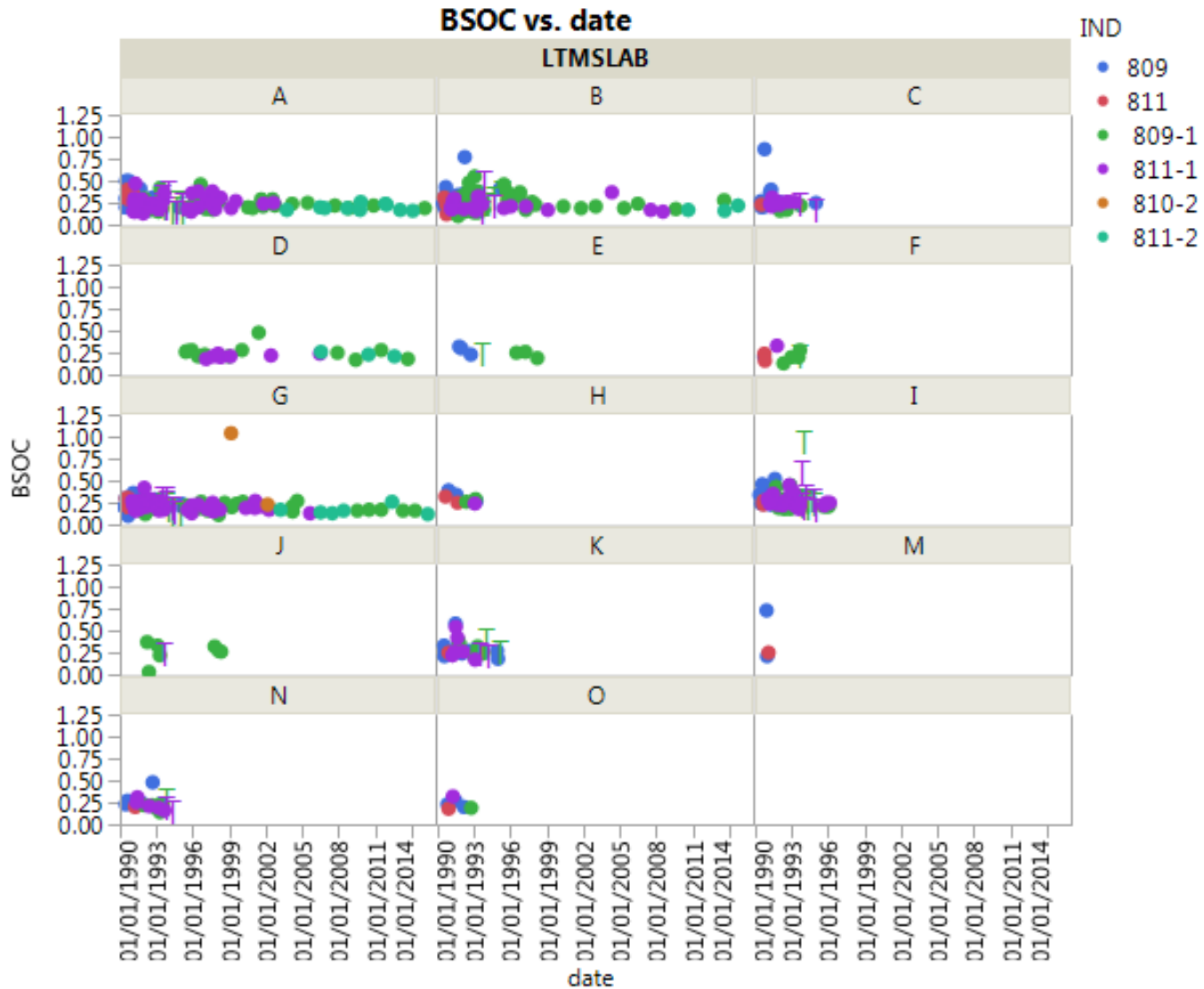
Data (cont.): Top Land Heavy Carbon transformed

Chart = Yes; including 809/811 and re-blends



Data (cont.)

Oil Consumption: Chart = Yes; including 809/811 and re-blends



Defining the working data set for modeling

- 1K started in 1990; initially lot of tests were being assigned chart = N
- Liners:
 - 1Y702 (at start of the test)
 - 7W355 (introduced in 1991)
 - 2W600 (introduced in 1992)
 - 1Y3555 (introduced in 1993)
 - 1Y3998 (introduced in 2005)
- 809-1 and 811-1 Targets, collected between 08/31/1993 to 05/20/1995, have been defined with multiple liners: 30 tests for each oil. One liner is missing.

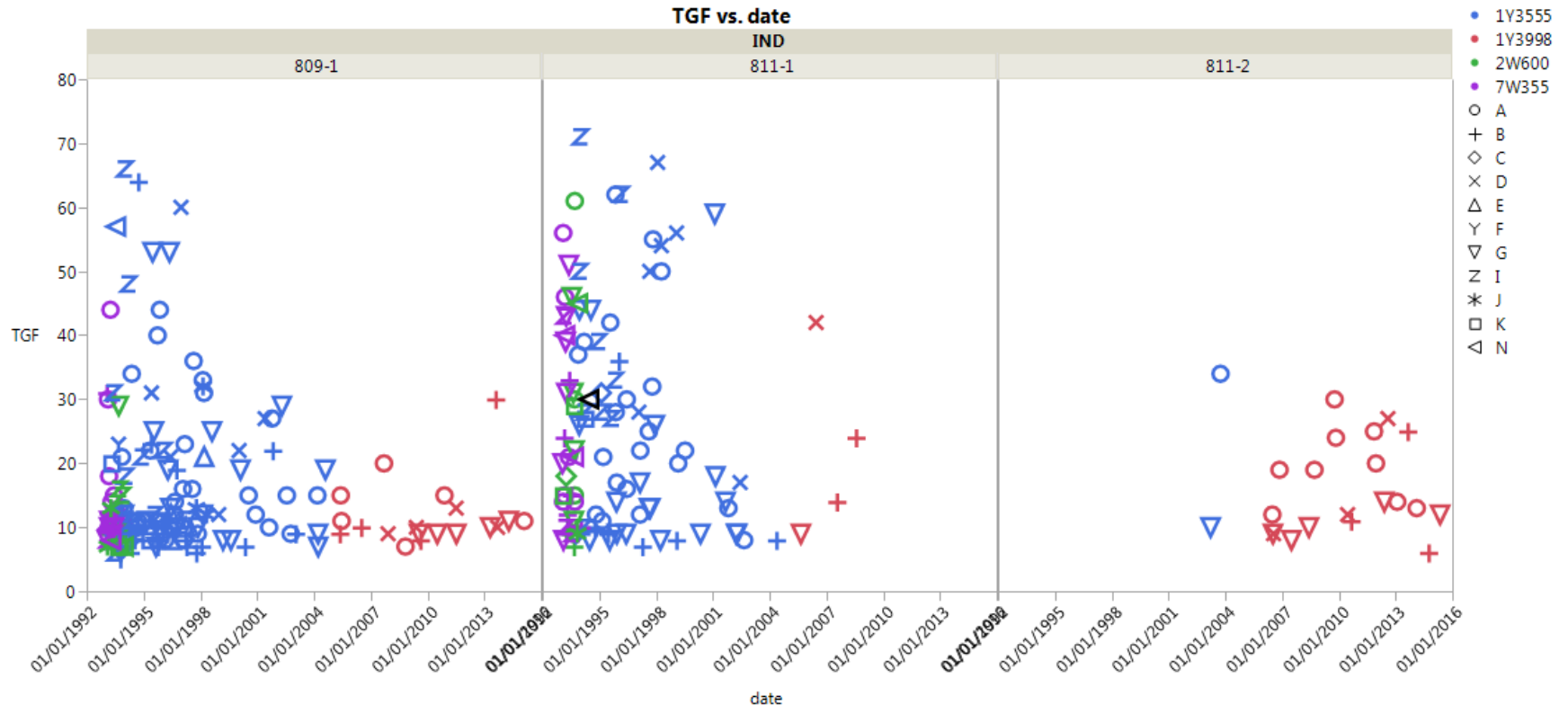
		LINER	Liner target	N Rows
T	1	7W355	Target	3
T	2	2W600	Target	10
T	3	1Y3555	Target	46
T	4		Target	1

- Working data:
 - Started with 301 tests from 1993 forward and chart = Yes. This subset included tests with liners 7W355 and 2W600 and I prefer to focus on the latest liners: 1Y3555 and 1Y3998. By the way, the conclusions are the same using 301 or 223 tests.
 - Went down to 223, after deciding to use Target tests with whatever liners they had plus all tests after last target test ran (which corresponds to all tests after 06/02/1995).
 - I created a new column called Liner/Target with levels: Target, 1Y3555 and 1Y3998

TGF vs. date by Oil and Lab



n=301*



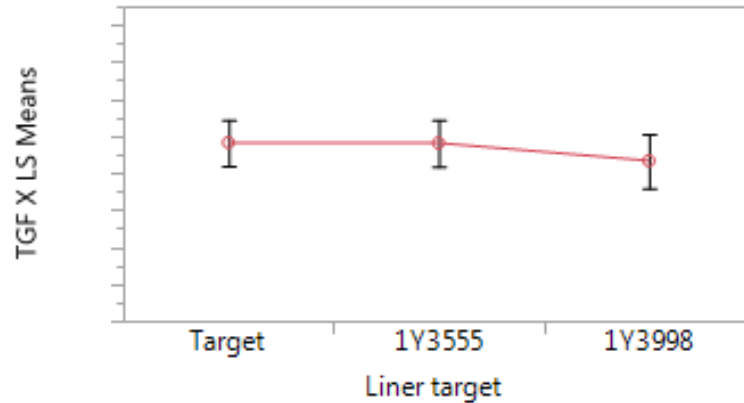
*includes liners 7W355, 2W600 and beginning of 1Y3555 before 809-1 and 811-1 targets were set

TGF transformed to achieve constant variance n=223



Model 1

LS Means Plot: liner target

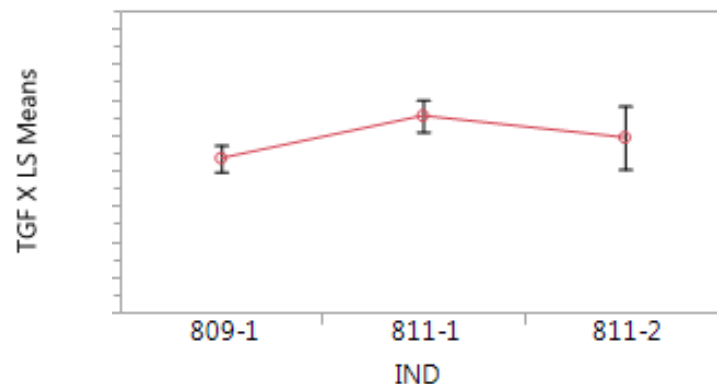


Model 1: Lab, Oil, Liner target*

No evidence that Target, 1Y3555 and 1Y3998 differ

Model 1: similar estimates for model 2

LS Means Plot: Oil



Model 2: Lab, Oil, Date (normalized)
n=223

The coefficient for Date is negative, (-0.880067), not statistically significant (t ratio=-1.27)

TGF: looking at variability

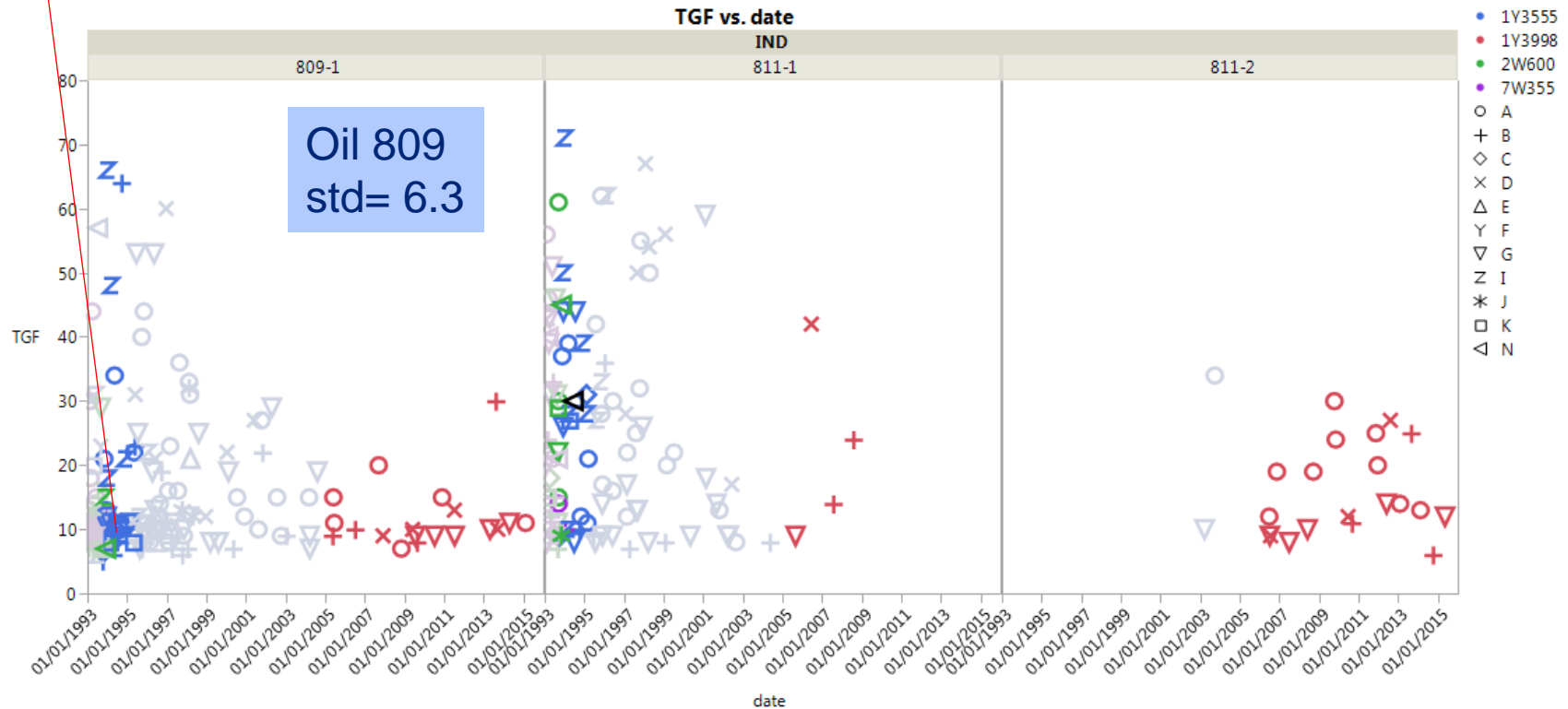
Pooled standard deviation for tests with most recent liner 1Y3998



At Target,
50% of the
data is
below 11

TGF							incl. 811-1
Oil	Liner	N	Mean	Std	pooled std	pooled std	
809-1	1Y3998	19	11.89474	5.332237	6.317585	7.268923	
809-1	Target	30	17.46667	15.6728			
811-1	1Y3998	4	22.25	14.5688			
811-1	Target	30	27.33333	16.57654			
811-2	1Y3998	20	15.95	7.126489			

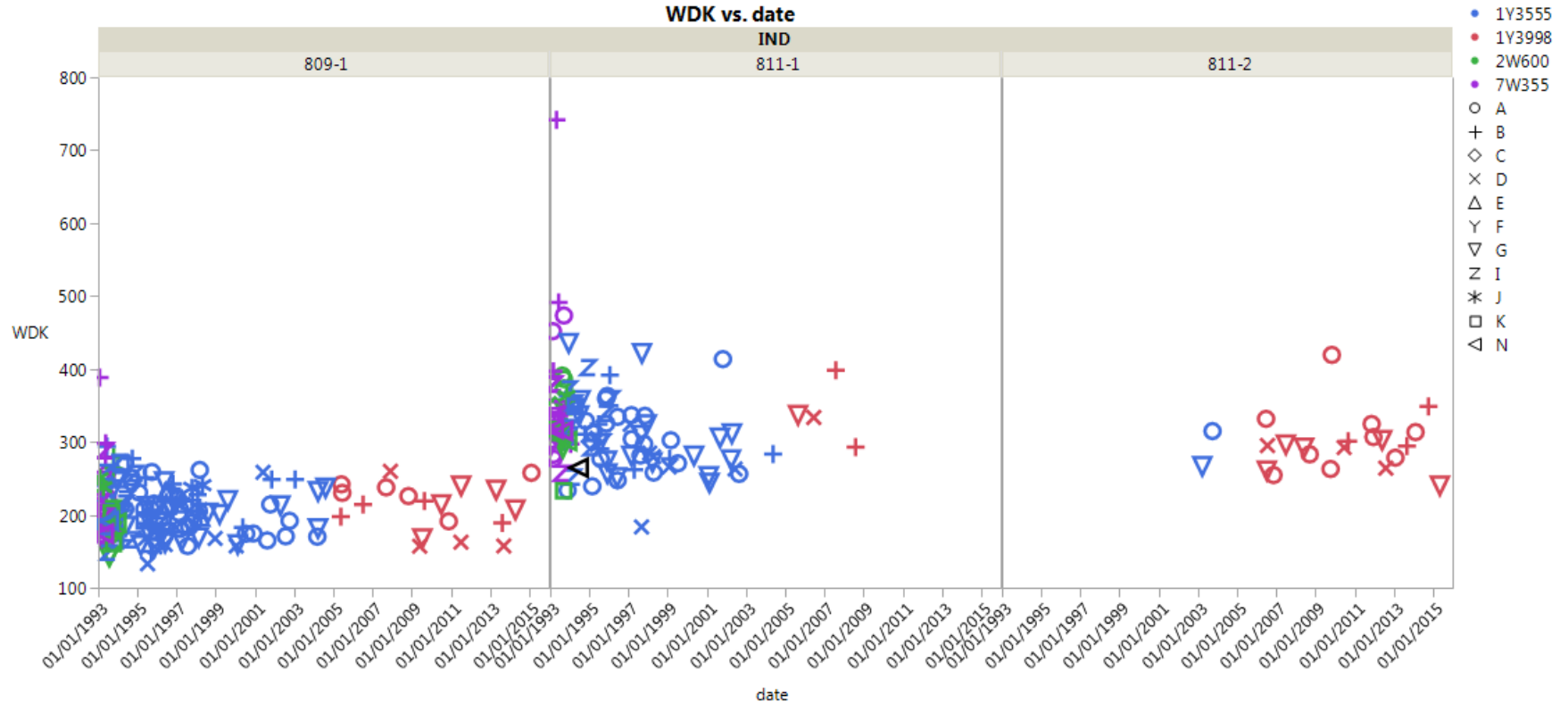
Std changed
over time



WDK vs. date by Oil and Lab



n=301*



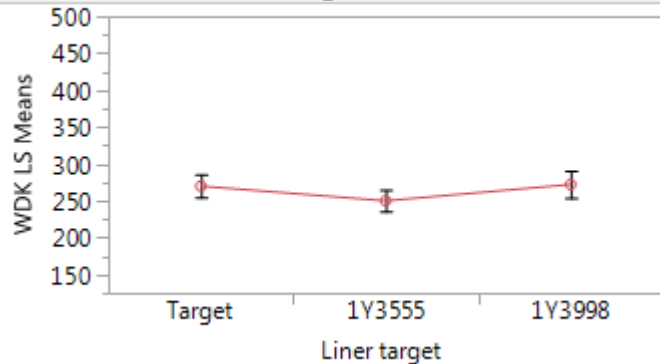
*includes liners 7W355, 2W600 and beginning of 1Y3555 before 809-1 and 811-1 targets were set

LN WDK: transformed to achieve constant variance n=223



Model 1

LS Means Plot: liner target



Liner Target	Least Sq Mean
1Y3998 A	272.2
Target A	270
1Y3555 B	250.1

Model 1: Lab, Oil, Liner target*
 Note that 17328, high test from Lab B - liner 7W355 is not part of the target and not included in this subset.

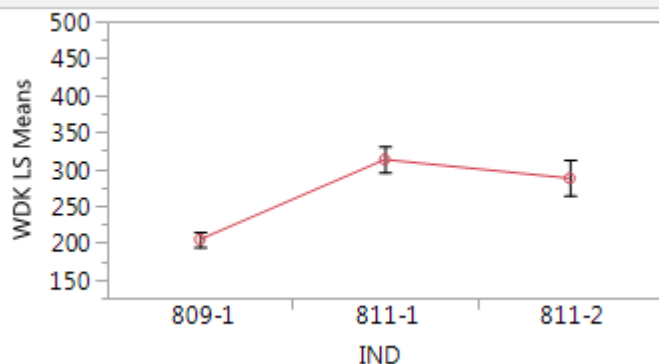
No evidence that Target and 1Y3998 differ

Model 2: Lab, Oil, Date (normalized)

The coefficient for Date is positive (+0.0097401), not statistically significant (t ratio=+0.73)

Model 1: similar estimates for model 2

LS Means Plot: Oil



Oil	Least Sq Mean
811-1 A	312.7
811-2 A	287.5
809-1 B	204.4

* Defined in slide 8

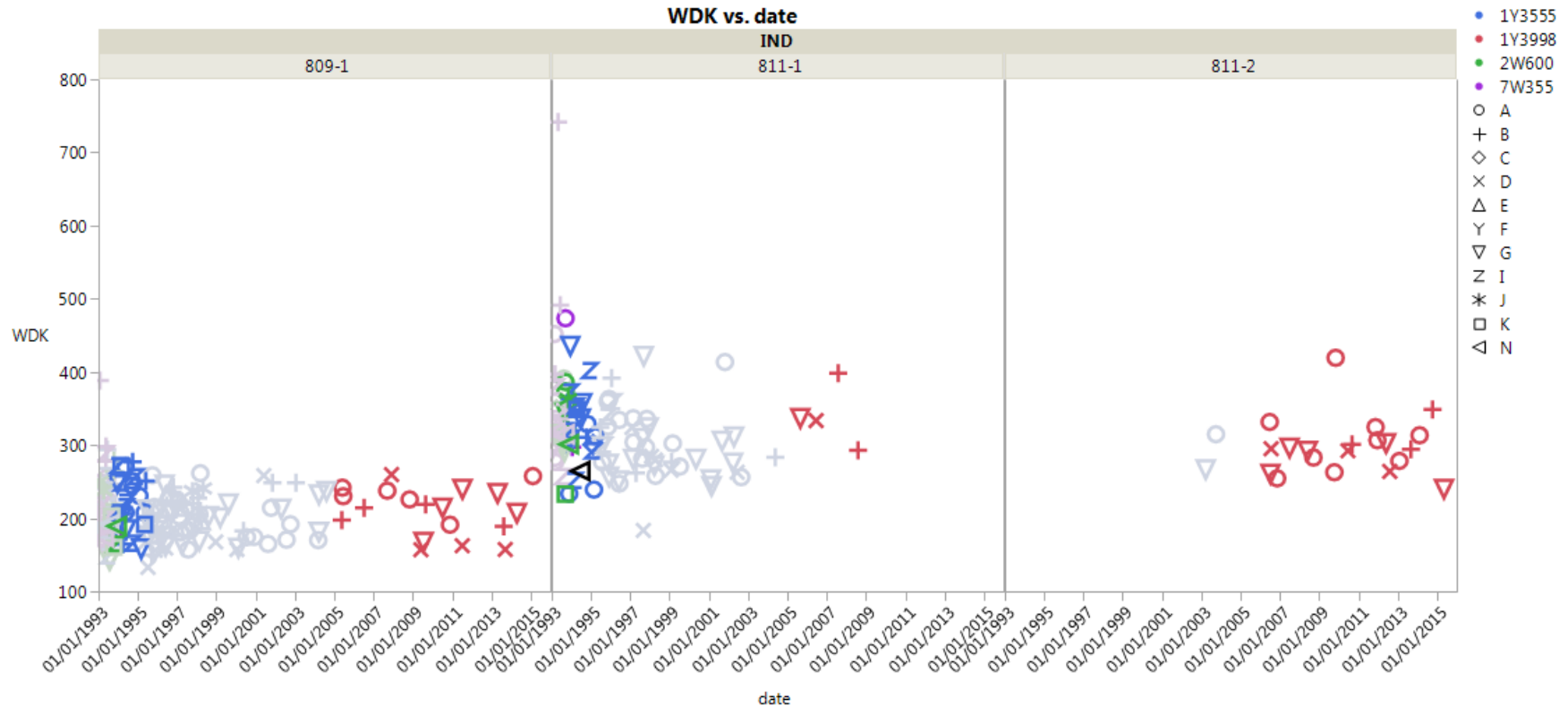
WDK: looking at variability

Pooled standard deviation for tests with most recent liner 1Y3998



WDK						incl. 811-1
IND	Liner target	N	Mean	Std	pooled std	pooled std
809-1	Target	30	216.4	35.64721	36.25158	36.84602
809-1	1Y3998	19	211.0421	32.78203		
811-1	Target	30	327.7433	55.91403		
811-1	1Y3998	4	340.825	43.51478		
811-2	1Y3998	20	298.36	39.25668		

Not suggesting change in std, but thought you would ask questions about pooled std

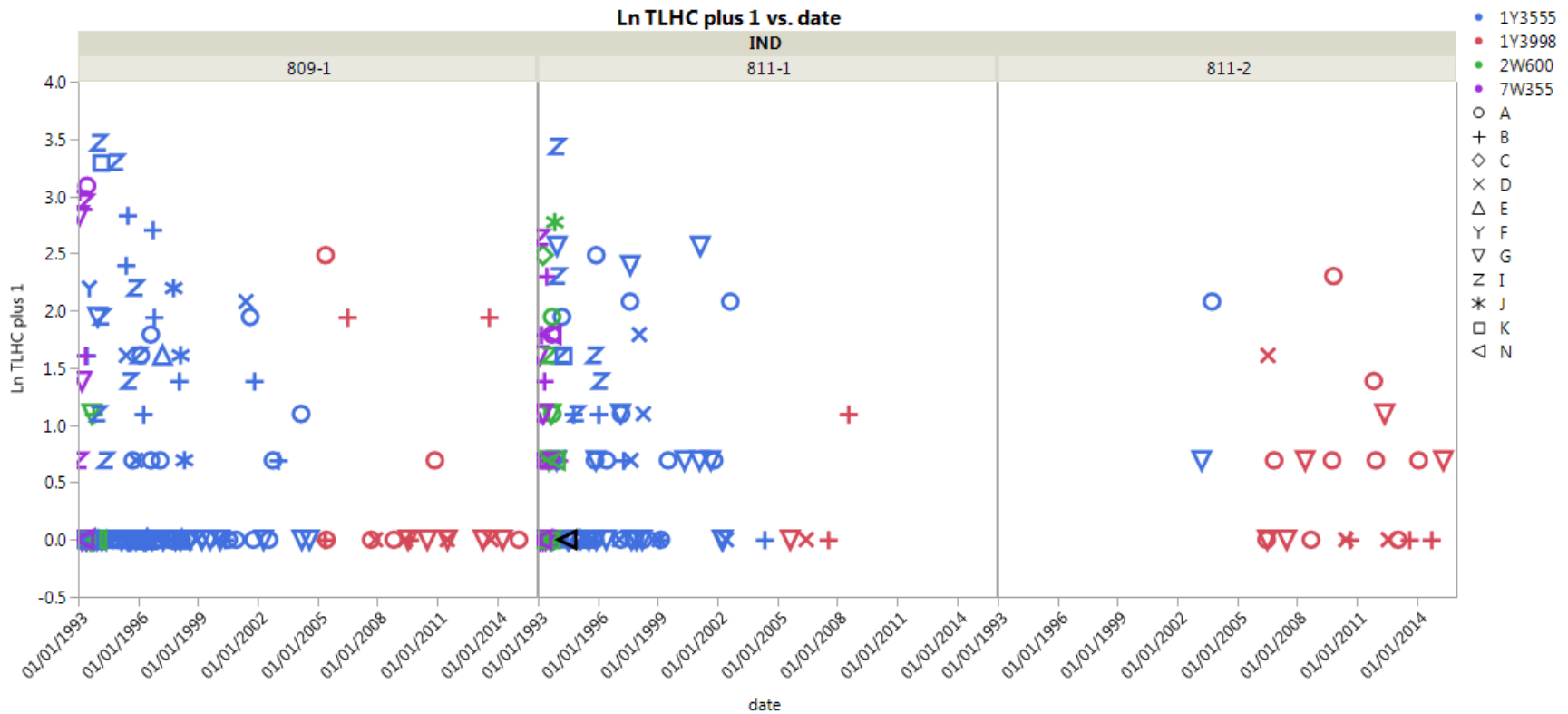


LN (TLHC +1) vs. date by Oil and Lab

Non critical



n=301*

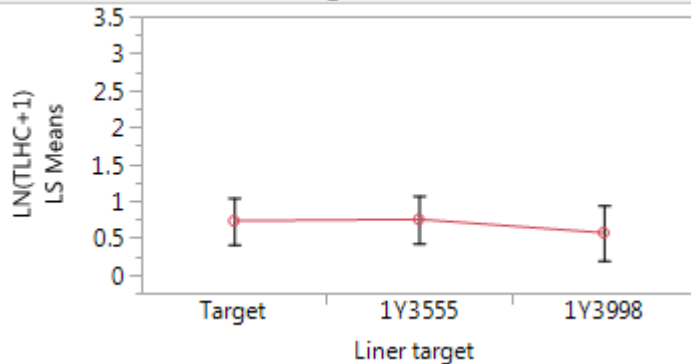


*includes liners 7W355, 2W600 and beginning of 1Y3555 before 809-1 and 811-1 targets were set

LN (TLHC+1): n=223

Model 1

LS Means Plot: Liner target



Level	Least Sq Mean
1Y3555 A	0.74969936
Target A	0.72933900
1Y3998 A	0.56808021

Model 1: Lab, Oil, Liner/Target*

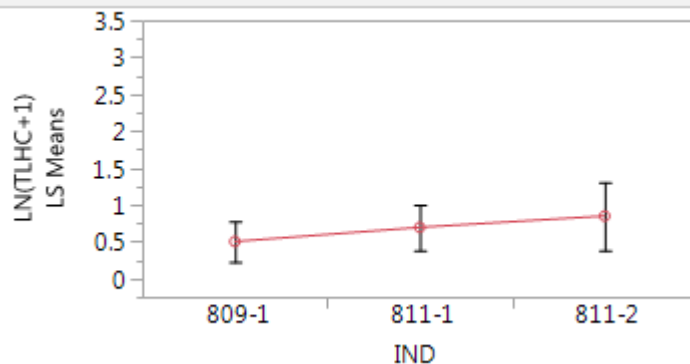
No evidence that Target, 1Y3555 and 1Y3998 differ

Model 2: Lab, Oil, Date (normalized)

The coefficient for Date is negative, (-0.059892), not statistically significant (t ratio = -0.85)

Model 1: similar estimates for model 2

LS Means Plot: Oil



Level	Least Sq Mean
811-2 A	0.84911024
811-1 A	0.69452440
809-1 A	0.50348394

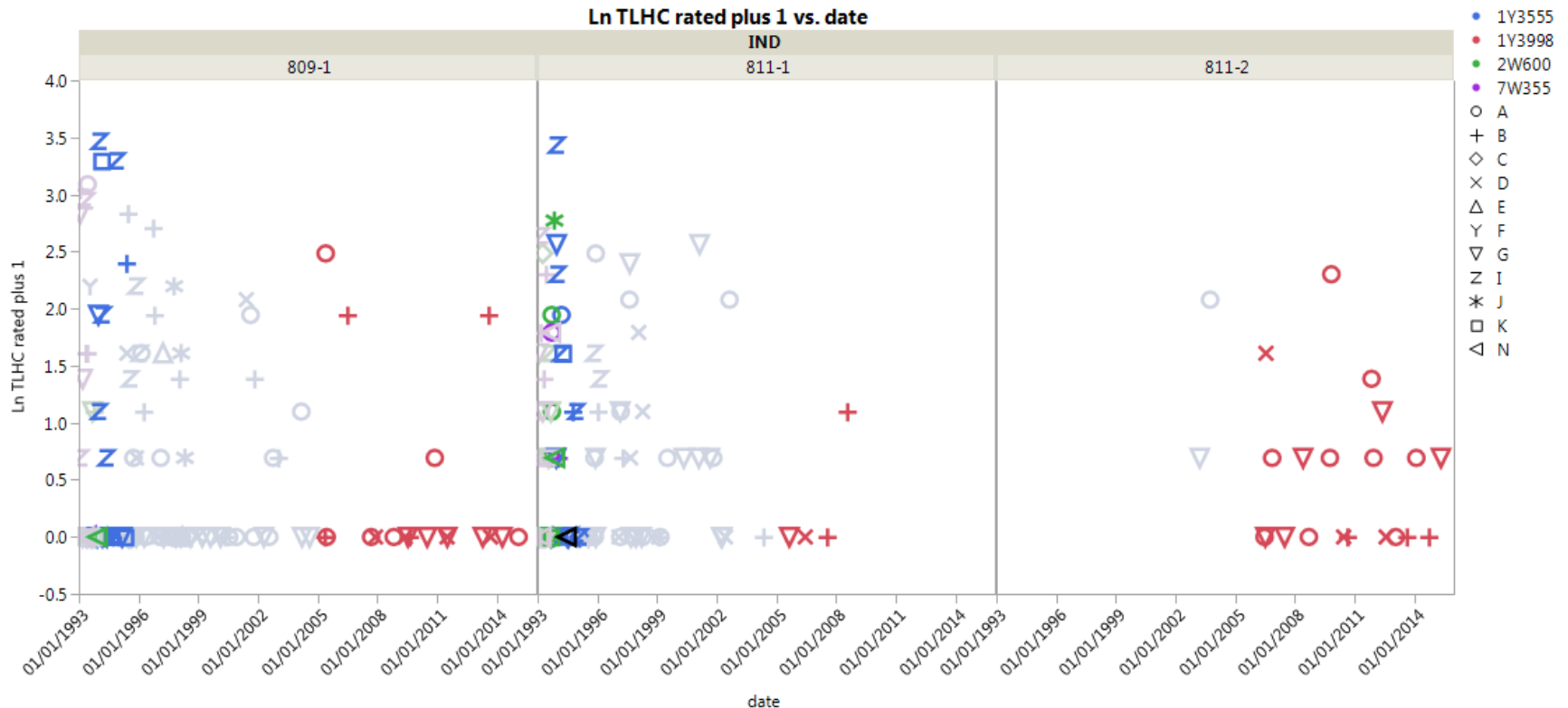
* Defined in slide 8

LN (TLHC+1): looking at variability

Pooled standard deviation for tests with most recent liner 1Y3998



Oil	Liner target	N	Mean	Std	pooled std	pooled std	incl. 811-1
809-1	Target	30	0.604629	1.141378	0.733928	0.721721	
809-1	1Y3998	19	0.372099	0.802692			
811-1	Target	30	0.868166	1.021422			
811-1	1Y3998	4	0.274653	0.549306			
811-2	1Y3998	20	0.527791	0.662229			

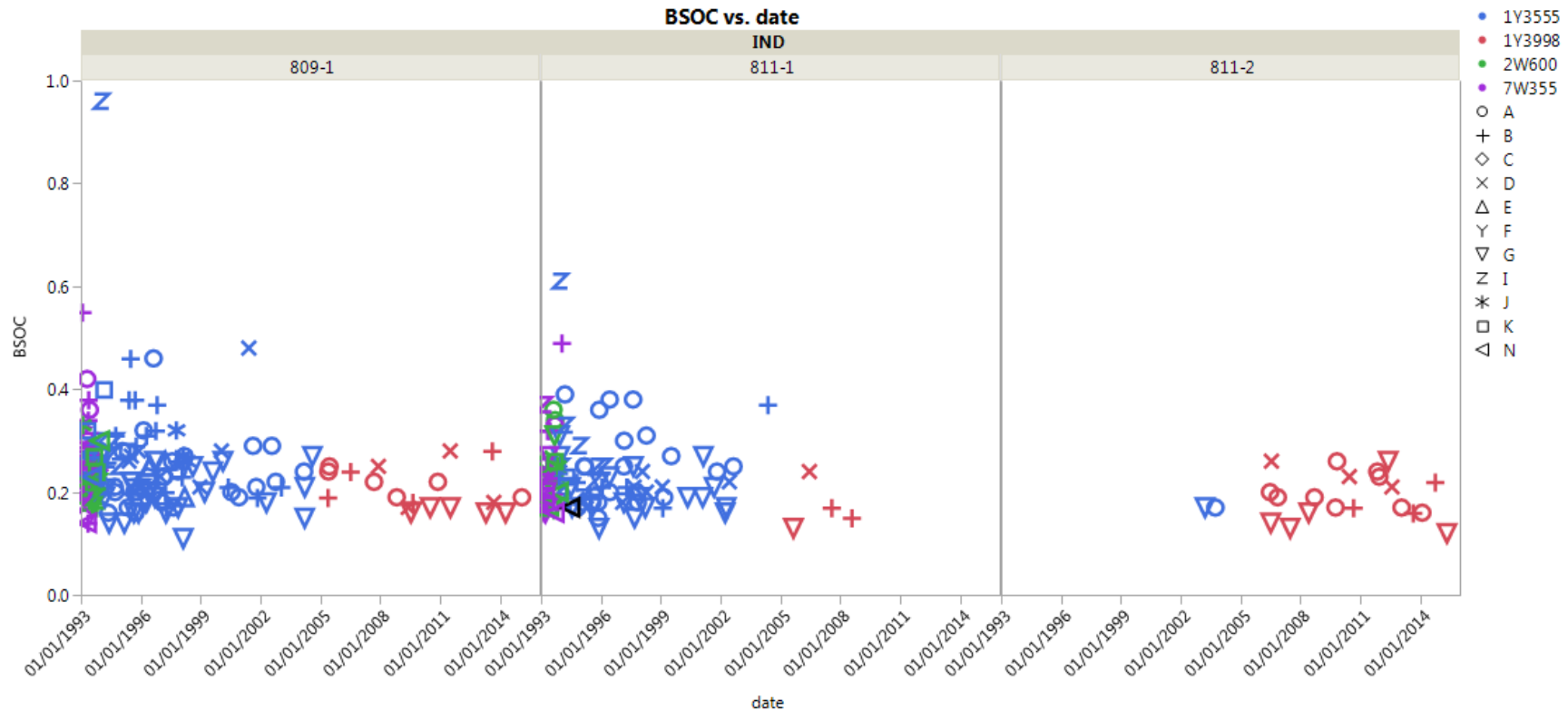


Oil Consumption: vs. date by Oil and Lab

Non critical

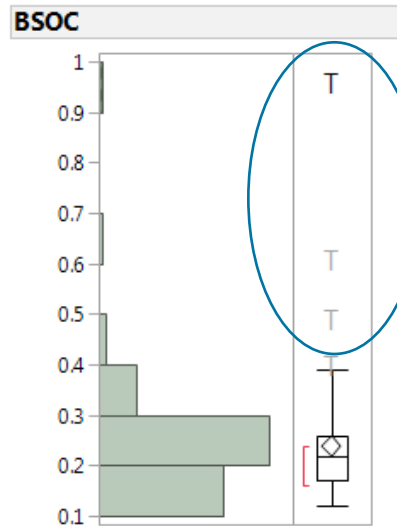


n=301



The analysis indicated that there may be a trend going down, likely associated with liner 1Y3998. Further analysis will be done and a correction will be proposed

Oil consumption: more details

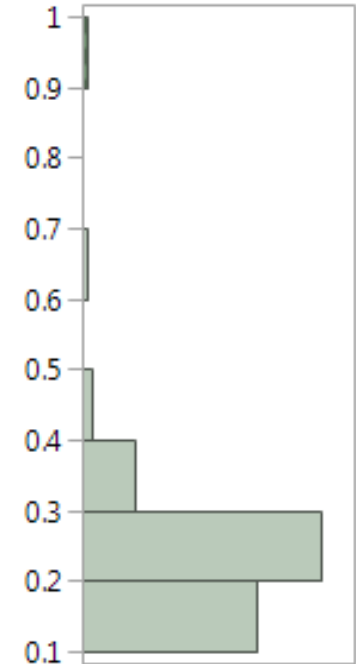


Part of the Target,
above the 0.5 g/kWh

Quantiles		
100.0%	maximum	0.96
99.5%		0.96
97.5%		0.538
90.0%		0.31
75.0%	quartile	0.26
50.0%	median	0.22
25.0%	quartile	0.17
10.0%		0.16
2.5%		0.13
0.5%		0.12
0.0%	minimum	0.12

Summary Statistics	
Mean	0.2383495
Std Dev	0.103138
Std Err Mean	0.0101625
Upper 95% Mean	0.2585068
Lower 95% Mean	0.2181923
N	103

Zoom of the plot



LTMS excerpt for 1K

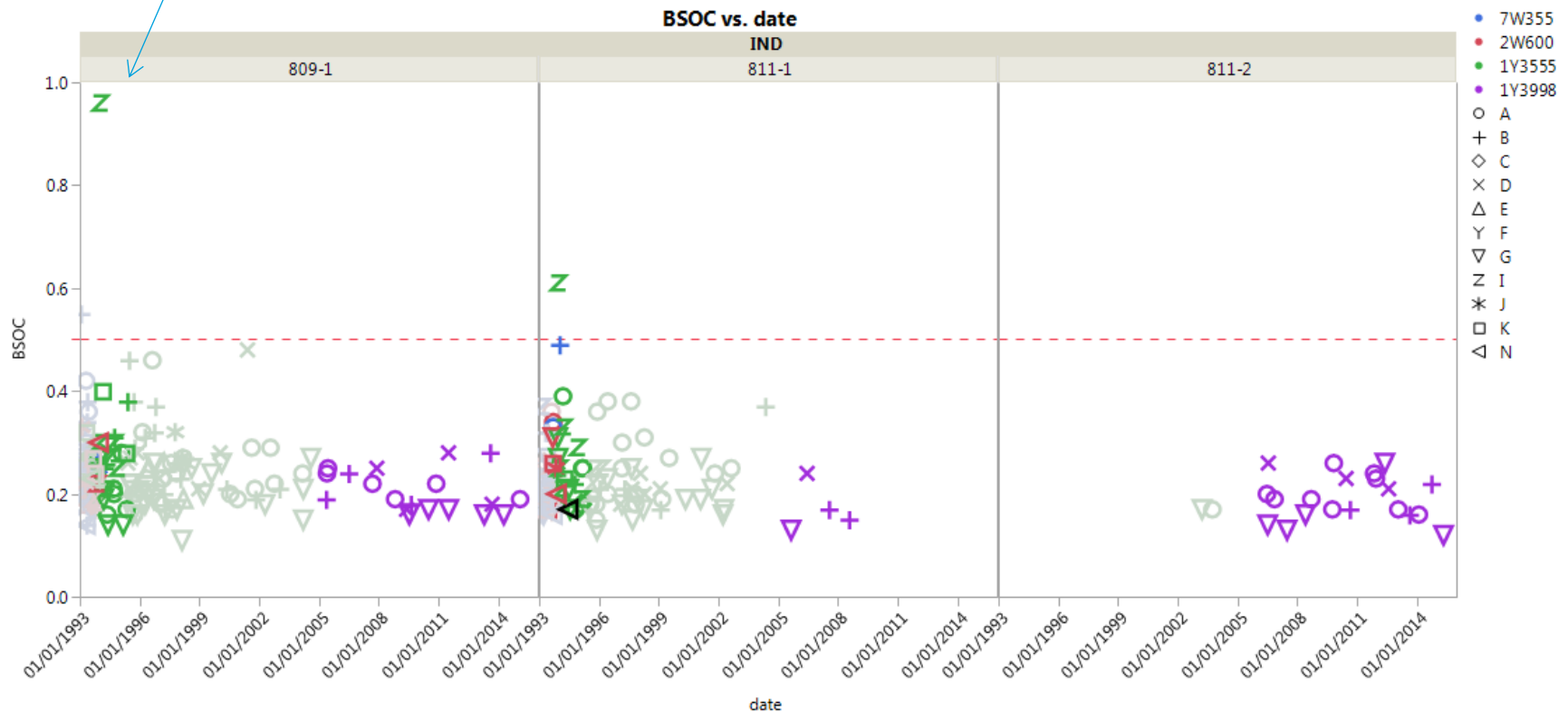
- Exceed Shewhart test stand chart limit for severity (all parameters except Average Oil Consumption)
 - Conduct an additional calibration test.
- Exceed 0.5 g/kWh Average Oil Consumption
 - Conduct an additional calibration test.

Oil Consumption: Mean and standard deviation by oil/liner combination



BSOC		excludes 18515 from lab I				incl. 811-1	
IND	Liner target	N= 222	Mean	Std	pooled std	pooled std	
809-1	Target	29	0.245862	0.063948	0.04234	0.04278	
809-1	1Y3998	19	0.205263	0.040739			
811-1	Target	30	0.266667	0.09693			
811-1	1Y3998	4	0.1725	0.047871			
811-2	1Y3998	20	0.1935	0.043803			

BSOC					
Oil	Liner target	N= 223	Mean	Std	pooled
809-1	Target	30	0.269667	0.144735	0.04234
809-1	1Y3998	19	0.205263	0.040739	
811-1	Target	30	0.266667	0.09693	
811-1	1Y3998	4	0.1725	0.047871	
811-2	1Y3998	20	0.1935	0.043803	



BSOC target clarification



- It seems that for Target test 15233, the BSOC value used for calculating the target is 0.22 when the Itms published value is 0.26

Lab	Testkey	VALID	OIL	REPORT	TGF	WDK	TLHC	BSOC	BSOC Itms	diff BSOC
E	15233	AC	809-1	931115	12	190.2	0	0.22	0.26	0.04

- The table below reflects this difference:
 - Target mean is 0.268 and std = 0.145
 - My calculations generate a mean = 0.270 and std = 0.145

BSOC						incl. 811-1
Oil	Liner target	N= 223	Mean	Std	pooled std	pooled std
809-1	Target	30	0.269667	0.144735	0.04234	0.04278
809-1	1Y3998	19	0.205263	0.040739		
811-1	Target	30	0.266667	0.09693		
811-1	1Y3998	4	0.1725	0.047871		
811-2	1Y3998	20	0.1935	0.043803		

- SP may want to review the standard deviation for TGF. Standard deviations seem to have gone back to levels seen before for 809. The standard deviations for WDK and Log (TLHC+1) did not change as much as TGF's.
- I will be happy to propose a correction factor for Oil consumption – non critical, if necessary
- Please, contact me if you have any questions or want to see more details about the analysis. I did not include all the details to keep the number of slides down.

APPENDIX

1K Reference Oil Targets

1K Reference Oil Targets											
Oil	n	Effective Dates		WDK		TGF		TLHC ³		BSOC	
		From ¹	To ²	\bar{X}	s	\bar{X}	s	\bar{X}	s	\bar{X}	s
809	30	5-6-90	***	219.2	41.9	12.3	6.3	0.398	0.9	0.272	0.117
809-1	30	8-16-91	***	216.4	35.6	17.5	15.7	0.605	1.1	0.268	0.145
810-2 ⁵	--	2-1-98	12-31-99	247.4	38.4	53.8	22.1	2.065	1.4	0.309	0.212
	8	1-1-00	***	261.3	38.8	55.3	20.2	1.935	1.7	0.375	0.331
811 ⁴	--	7-1-90	8-20-91	327.7	55.9	27.3	16.6	0.868	1.0	0.267	0.097
811-1	30	1-1-91	***	327.7	55.9	27.3	16.6	0.868	1.0	0.267	0.097

- 1 Effective for all tests completed on or after this date.
- 2 *** = currently in effect.
- 3 Transformation for TLHC is $\ln(\text{TLHC}+1)$
- 4 Targets based on 811-1.
- 5 Targets based on 810-1.

1K: No correction factors

APPENDIX B (continued) HISTORY OF INDUSTRY CORRECTION FACTORS

Test Area	Effective		Condition	Description
	From	To		
1M-PC	None		All Tests	None
1K	None		All Tests	None

WEIGHTED DEMERITS
Unit of Measure: Demerits
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809	219.2	41.9
809-1	216.4	35.6
811-1	327.7	55.9

TOP GROOVE FILL
Unit of Measure: Percent
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809	12.3	6.3
809-1	17.5	15.7
811-1	27.3	16.6

TOP LAND HEAVY CARBON
Unit of Measure: LN(TLHC+1)
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809	0.398	0.9
809-1	0.605	1.1
811-1	0.868	1.0

AVERAGE OIL CONSUMPTION
Unit of Measure: g/kWh
NONCRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
809	0.272	0.117
809-1	0.268	0.145
811-1	0.267	0.097

- 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: $SA = (-Z_i) \times (35.6)^*$

Top Groove Fill: $SA = (-Z_i) \times (15.7)^*$



Top Land Heavy Carbon: $SA = (-Z_i) \times (1.1)^*$

* s based on reference oil 809-1

Data n= 301: excluding 809/811 data

New targets have been established for 809-1 and 811-1

LINER	Target	N Rows
	Target	1
1Y3555		131
1Y3555	Target	46
1Y3998		43
1Y702		0
2W600		22
2W600	Target	10
7W355		45
7W355	Target	3
	Sum	301

	Liner target	N Rows	
1	Target	60	 N=223
2	1Y3555	120	
3	1Y3998	43	
4		78	 Other liners

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