Sequence X

ASTM D8729

Ford Chain Wear Test Surveillance Panel Meeting

June 16th, 2021

Prepared By: Alfonso Lopez, S.P. Chairman

Sequence X Surveillance Panel Meeting Agenda 06/16/21

- Roll call
- Approval of the meeting minutes 04/21/21
- TMC Update
- Mild shift Task Force update
- Statistician Report
- Oil 271 Suspension
- Report to Sub B

Motion List 06/16/21

- Motion 1: Approval of the SP Meeting minutes from 04/07/21
  - Motion: Christian Porter
  - Second: Mike Deegan
  - Passed: unanimous

- Extend suspension of reference oil 271 for additional 4 months.
  - No motion needed
  - Suspension period 04/07/21 – 10/07/21

Meeting Minutes

- Attendance roster attached below
- Meeting minutes from 04/21/21 were approved
- Lab Calibration status (after suspension of oil 271)
  - A – 2
  - B – 1
  - D – 1
  - G – 3
  - API letter for test unavailability has been put on hold considering the calibration status of the independent labs and progress of Task Force in finding root cause for mild shift

Meeting Minutes

- TMC update – slides attached
  - Oil 1011 depleted. 2 five gallon cans remain in inventory
  - Oil 1011-1 available but introduction on hold due to mild trend
  - Oil 270 remaining reference oil
- Valvoline presentation – slides attached
  - Research tests produced on target results for oils 270 and 1011
  - Test on oil 271 in progress to EOT June 21
  - Amol to upload all operational data to TMC for review and comparison
- Discussion on Crankcase gases
  - Orifice restriction on BB stack may increase residence time of BB gases and drainback of condensation. Increase of severity
  - PCV valve design change suspected. Labs to discuss at Task Force
  - BB measurement being performed with both J-Tech and BB cart – labs to discuss at Task Force

Meeting Minutes

- Statistician's Report – Travis Kostan
  - Slides attached below
  - An update of the reference oil standard deviations is the preferred mathematical correction if a mechanical solution can not be found

Panel Roster

Sequence X Surveillance Panel Meeting
June 16, 2021

	Attendance	Voting Member
Porter, Christian <Christian.Porter@AftonChemical.com>	x	Afton
Todd Dvorak <Todd.Dvorak@AftonChemical.com>	x	
Martin Chadwick Intertek <martin.chadwick@intertek.com>		
Dan Lanctot <DLanctot@tei-net.com>	x	TEI
Jason Bowden <jhbowden@OHTech.com>	x	OHT
'Rich Grundza' (reg@astmtmc.cmu.edu)	x	TMC
Jason Soto Intertek <jason.soto@intertek.com>	x	IAR
doyle.boese@infineum.com	x	
Martinez, Jo G. (jogm) <JoMartinez@chevron.com>	x	Chevron
J.Hsu@shell.com	x	Shell
Gleason, Joseph <Joseph.Gleason@lubrizol.com>		
Kostan, Travis G. <travis.kostan@swri.org>	x	
ptumati@jhaltermann.com	x	Haltermann
Khaled , Zreik Khaled.zreik@gm.com	x	GM
Chiappelli, Maria <Maria.Chiappelli@Infineum.com>		Infineum
Montufar, Ashley <ashley.montufar@exxonmobil.com>		ExxonMobil
Charlie Leverett <charlie.leverett@yahoo.com>		
Amol C Savant <ACSavant@valvoline.com>	x	Valvoline
Eickstead, Christine M. <christine.eickstead@swri.org>	x	SWRI
Brys, Jerome <Jerome.Brys@lubrizol.com>		Lubrizol
'Bob.Campbell@aftonchemical.com'		
Patrick M. Lang <patrick.lang@swri.org>	x	SWRI
Stockwell, Robert T (Robert.Stockwell@chevron.com)	x	Chevron
Bill Buscher Intertek <william.buscher@intertek.com>		
Ritchie, Andrew <Andrew.Ritchie@Infineum.com>		
Rais, Khaled <khaled.rais@swri.org>		
Stevens, Andrew <Andrew.Stevens@Lubrizol.com>		
Matthews, Tim <Tim.Matthews@uk.bp.com>		BP
Lopez, Alfonso <al.lopez@intertek.com>	x	Intertek
Deegan, Michael (M.D.) <mdeegan@ford.com>	x	Ford
Lochte, Michael D. <michael.lochte@swri.org>		
joshua cooley valvoline		
George Szappanos	x	LZ
Timothy Cushing <timothy.cushing@gm.com>		GM
Wingert, Dean (D.) <dwingert@ford.com>		
Michael Luhard		Afton
Ben Maddock		Afton
Angela Willis		
Haing Tang	x	Chrysler

Sequence X TMC Activity

April 2020 to October 2020

Sequence X Activity

Test Status	Validity Code	#
Acceptable Calibration Test	AC	5
Statistically Unacceptable Calibration Test	OC	3
Total Number of Tests		**8**

Sequence X - Failed Tests

Test Status	Number of Tests
CHST Ei Level 3 alarm	3
Total	**3**

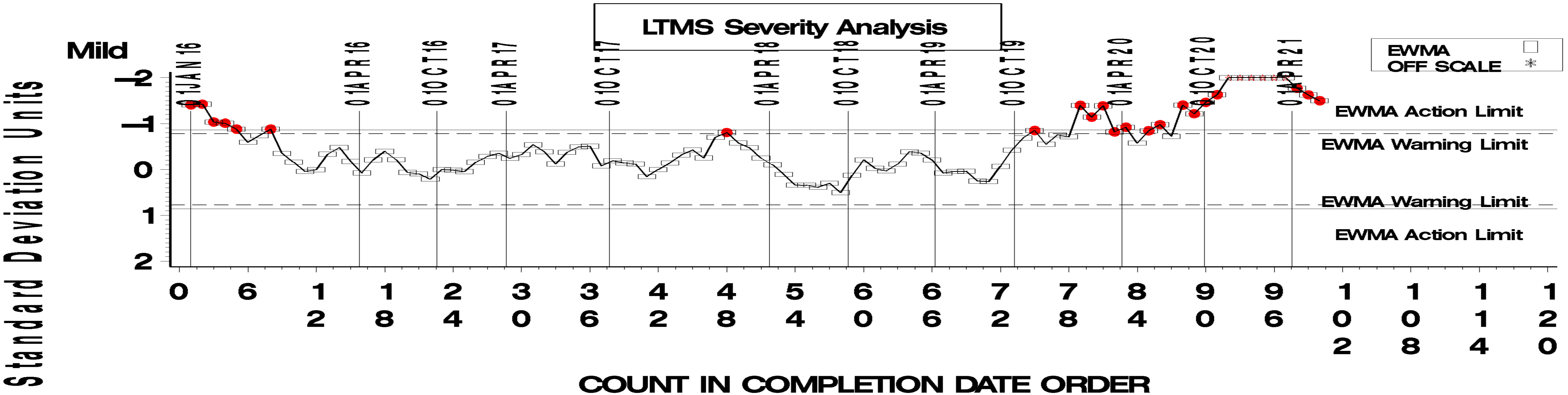
Sequence X - Lost Tests*

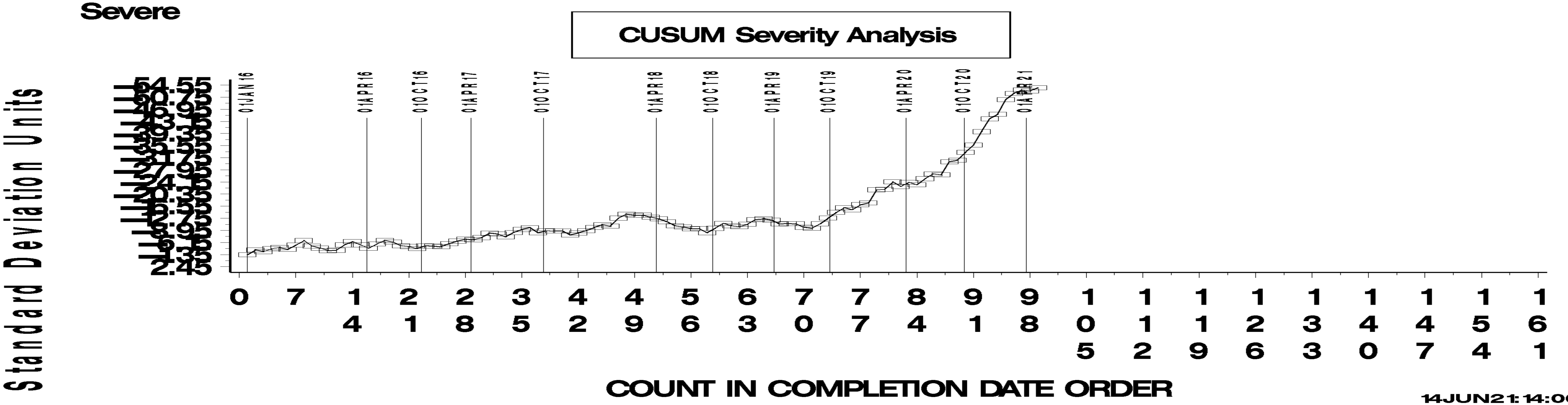
Test Status	Cause	#
Totals		0

*Invalid and aborted tests

SEQUENCE X INDUSTRY OPERATIONALLY VALID DATA

END OF TEST CHAIN WEAR FINAL RESULT





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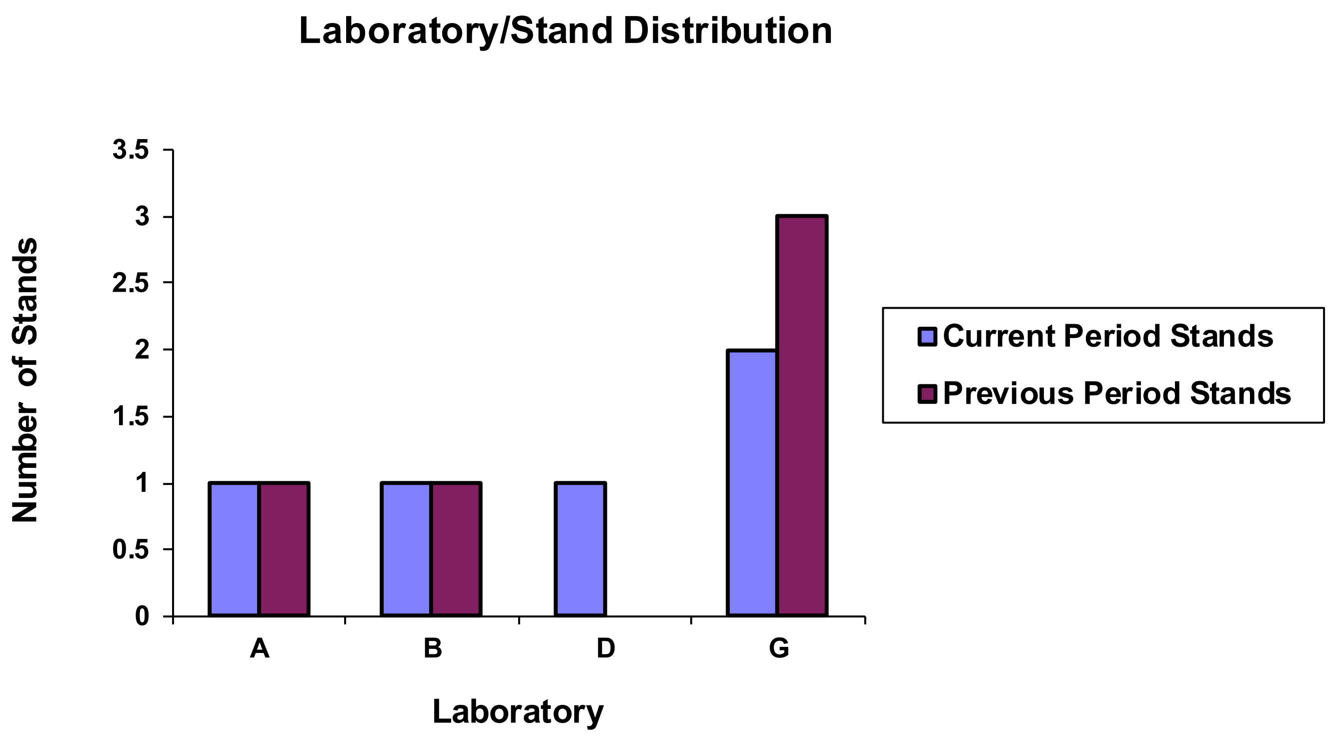
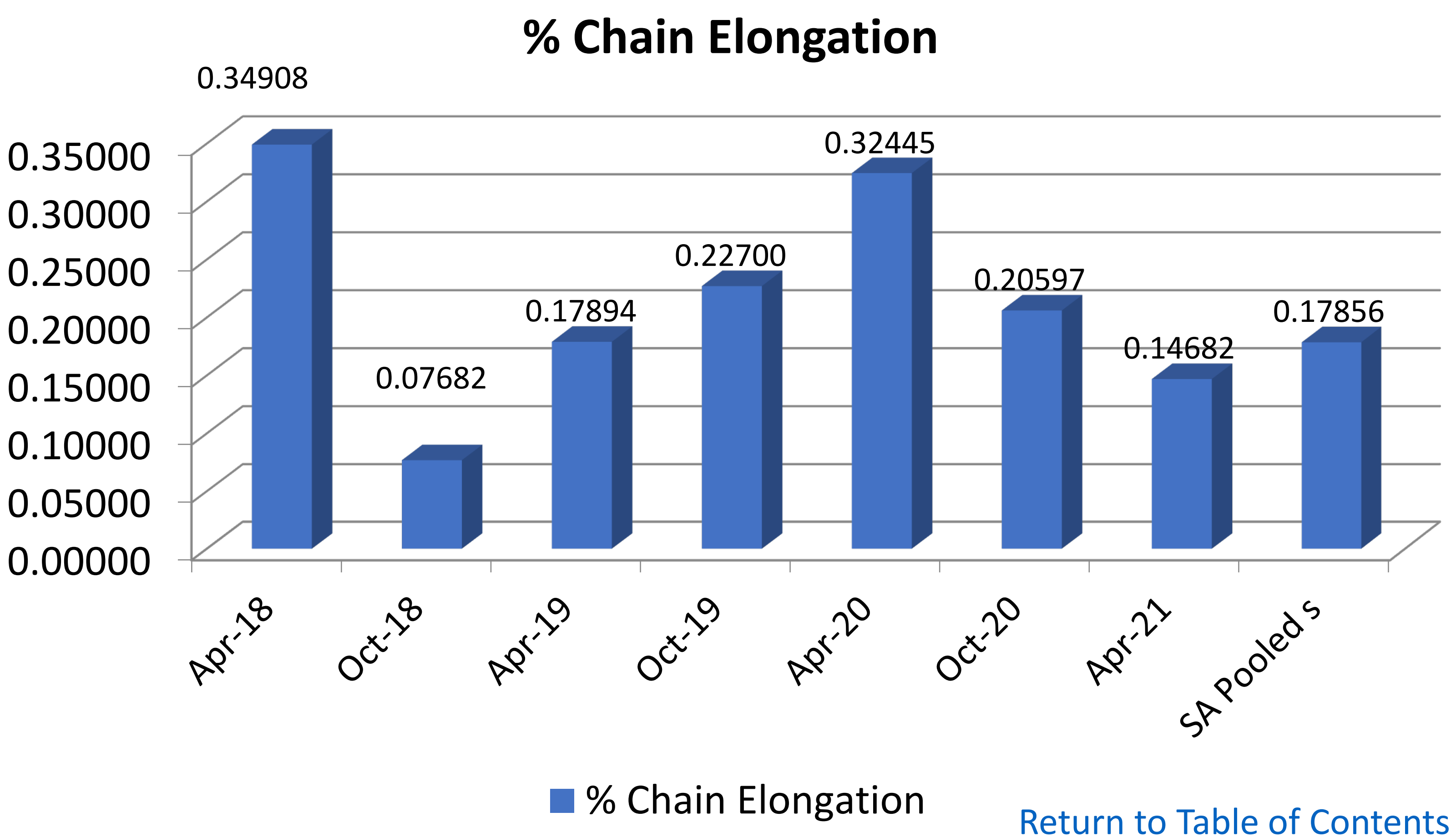
Sequence X S.P. Report
LTMS Laboratory/Stand Distribution

	Reporting Data	Calibrated as of 3/31/21
Number of Laboratories	4	5
Number of Stands	7	5



Sequence X Precision Estimates



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Sequence X S.P. Report
Reference Oils Status

- 271 SAE 5W-30 passing reference oil (5yr)
  Use suspended until mild trend is addressed

- 1011 SAE 0W-16 (<1yr) Limited to lab inventories Reblend (1011-1) available

- 270 SAE 5W-30 failing reference oil (5yr)

Mild Severity Shift Task Force Update

- 5 Meetings since last panel call
- List of action items – see attachment
  - Hardware
  - Fuel
  - Torsionals
  - Chemistry
- On going test experiments with blowby stack orifice plate
  - Higher CC pressure
  - More severity. Amol Data, see attached
- Task force needs more time to analyze Lab F data

Chainwear runs on Valvoline Stand and Troubleshooting Lack of Severity Issue

- Amol Savant
- *Valvoline Engine Test Lab*
- *06/16/21*

Background

Valvoline Test Lab participated in Chainwear Test Proveout runs back in mid 2015 – early 2016

With intention of participating in Precision Matrix

But was never hit the intended target window of CHST results despite running according to then current test procedure

So gave up and let the rest of the industry proceed to PM

However, maintained opinion that there was/is something in the stand/test config. that we (as industry) were not able capture or tighten down that may create situation of mildness/ lack of severity.

Proveout phase chainwear results at Valvoline stand

			CWT- Reference Oil Run History - Valvoline Stand							
								Ref. oil Targets		
	CW Test no.	Oil Code	EOT Date	no. of CW tests	IND	% CHST	Ln(CHST, %)	Mean	s	Shewhart Severity
Stand Status / Change description	(Internal no.)			on Ref. Oils	Industry oil Code	Normal units	Transformed units	target mean of precision matrix population for specific oil	target std. dev of precision matrix population for specific oil	Standardized Mean deviation
						Xi	Ti			Yi
Proveouts for attempt to get into Prec. matrix (Unsuccessful)	6	FRO	20150610	1	270 -preblend	0.0580	-2.84731	-2.15699	0.17435	-3.959
	7	LWO	20150727	2	271 -preblend	0.0400	-3.21888	-2.60987	0.17537	-3.473
	8	FRO	20151111	3	270 -preblend	0.0530	-2.93746	-2.15699	0.17435	-4.476
	9	LWO	20151205	4	271 -preblend	0.0390	-3.24419	-2.60987	0.17537	-3.617

Valvoline CW/ Ecoboost stand

- After several unsuccessful attempts of trying to hit the CHST targets by early 2016, Valvoline lab abandoned running chainwear test on our stand
- And moved on to running few diff. types of Research & Dev. Tests on the stand (did not have had anything to do with CW). Ran ~ 45 odd such test in the period of 2016-2019
- Mid-2020: decided to resume chainwear testing on the stand – attempt to dial in the stand with intention of eventually obtaining reference calibration

Resumption of Chainwear testing on Valvoline stand

- Mid-2020: Put the stand back in Seq X ‘CW’ configuration according to the procedure. Full instrument calibration was performed on the stand.
- Ran multiple experimental tests to dial-in the stand / hit the intended result window using reference oils

1st run after resumption on Seq.X procedure (without doing any tune-ups or changes)

Stand Status / Change description	CW Test no.	Oil Code	EOT Date	no. of CW tests	IND	% CHST	Ln(CHST, %)	Ref. oil Targets: Mean	Ref. oil Targets: s	Shewhart Severity
						Xi	Ti			Yi
Stand was reset to Seq. X, CW config., incl. instru. calib.	10	FRO	20200902	5	270 -preblend (from Proveout)	**0.0513**	-2.97006	-2.15699	0.17435	**-4.663**

Result showed the same stand performance as back in proveouts 5 yrs ago (consistent) i.e. Low severity level

Resumption of Chainwear testing on Valvoline stand

- Made some improvements to try to move the "needle" on the stand severity

Fine tuned speed and torque (dyno) tuning, Tuned temperatures and blowby temp ramps
Changed to new engine mounts, Ensured correct engine mounting angles
Changed to new chain batch

								Ref. oil Targets		
Stand Status / Change description	CW Test no.	Oil Code	EOT Date	no. of CW tests	IND	**% CHST**	Ln(CHST, %)	Mean	s	Shewhart Severity
						Xi	Ti			Yi
fine tuned spd, trq (dyno) tuned temp. ramps & t-BB Engine mounts replaced, engine angles adjusted	10A	TK157100	20201022	6	TMC-270	**0.0552**	-2.89625	-2.15699	0.17435	**-4.240**
changed to new Chain batch	11	LWO	20201207	7	271 -preblend (from Proveout)	**0.0379**	-3.27280	-2.60987	0.17537	**-3.780**

Still the same status; consistently low severity level

Industry TF on troubleshooting "Drop" in CW severity

- Around the Nov.20 – Jan.21 timeframe some labs (multiple stands) reported drop in CW severity and a taskforce was formed to help investigate
- Taskforce looked (still looking) at several different aspects incl. hardware changes, driveline stiffness changes, op. data, stat. analy to find corrln, blowby config, oil chem data, oil charge, fuel, transform issue etc.
- One of the items identified in TF from the Op. data/Ind. LTMS data that few stands showing relatively higher (or retained) severity (amongst other) recorded higher crankcase pressure
- That spawned the thought of running experiment/runs with increased crankcase pr. (CCP)
  - Several options to increasing CCP were thought – control valve, small gate valve, orifice etc.
  - Smooth-entry Orifice was picked to provide higher Cv / Cd (to have no/very little affect on flow) and to have a quick way to experiment
  - Jason (IAR) volunteered to find few different orifice sizes and choose one which provides intended CCP
  - This orifice piece made in the form of pipe-adapter was put in at the exit of blowby coming out of oil separator
  - Jason (IAR) sent VAL a piece and both ran experiments with higher CCP

“Orifice constrictor” and it’s placement in blowby ckt.

Valvoline Chainwear runs with higher Crankcase Pr. using "Orifice constriction" in blowby ckt.

								Ref. oil Targets		
CWT- Reference Oil Run History - Valvoline Stand										
Stand Status / Change description	CW Test no.	Oil Code	EOT Date	no. of CW tests	IND	% CHST	Ln(CHST, %)	Mean	s	Shewhart Severity
						Xi	Ti			Yi
		vv Experimental Reference Runs vv								
Orifice constriction added in the blowby ckt. past oil separator everything else same as before (no other change)	12	TK131725	20210413	8	TMC-1011	**0.1282**	-2.05416	-2.08191	0.18882	**+0.147**
	13	TK157101	20210524	9	TMC-270	**0.1165**	-2.14986	-2.15699	0.17435	**+0.041**
	14	TK157103	Running	10	TMC-271					

CHST results moved by ~ + 4 to 4.5 Yi (On target for RO1011 and RO270)

	Crankcase Pressure with Orifice Constriction in BB ckt.			
Test 12				
On Target	Stage	Starting	Ending	Avg.
Perf	**1**	2.7	1.4	**~ 1.9**
RO 1011	**2**	3.7	2.6	**~ 3.2**
	Crankcase Pressure without Orifice Constriction			
Before	Stage	Starting	Ending	Avg.
	1	1	0.3	**0.4 - 0.5**
	2	1.4	0.6	**0.7 - 0.9**

Unit of Crankcase Pr. 'kPa'

Valvoline Chainwear runs
Comparison (before and after)

			CWT- Reference Oil Run History - Valvoline Stand							
								Ref. oil Targets		
Stand Status / Change description	CW Test no.	Oil Code	EOT Date	no. of CW tests	IND	**% CHST**	**Ln(CHST, %)**	**Mean**	**s**	Shewhart Severity
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Proveouts for attempt to get into Prec. matrix (Unsuccessful)	6	FRO	20150610	1	270 -preblend	0.0580	-2.84731	-2.15699	0.17435	-3.959
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changed to new Chain batch	11	LWO	20201207	7	271 -preblend (from Proveout)	**0.0379**	-3.27280	-2.60987	0.17537	**-3.780**
		vv Experimental Reference Runs with Orifice Constriction in Blowby Ckt. vv								
Orifice constriction added in the blowby ckt. past oil separator everything else same as before (no other change)	12	TK131725	20210413	8	TMC-1011	**0.1282**	-2.05416	-2.08191	0.18882	**+0.147**
	13	TK157101	20210524	9	TMC-270	**0.1165**	-2.14986	-2.15699	0.17435	**+0.041**
	14	TK157103	**Currently Running**	10	TMC-271					

Inferences -

- Orifice Constriction in blowby ckt. provides increased crankcase pressure

- As per the results on Valvoline CW stand, the increased crankcase pressure seems to bring up the CHST severity level

Sequence X Severity
Mathematical Corrective Options

Statistics Group

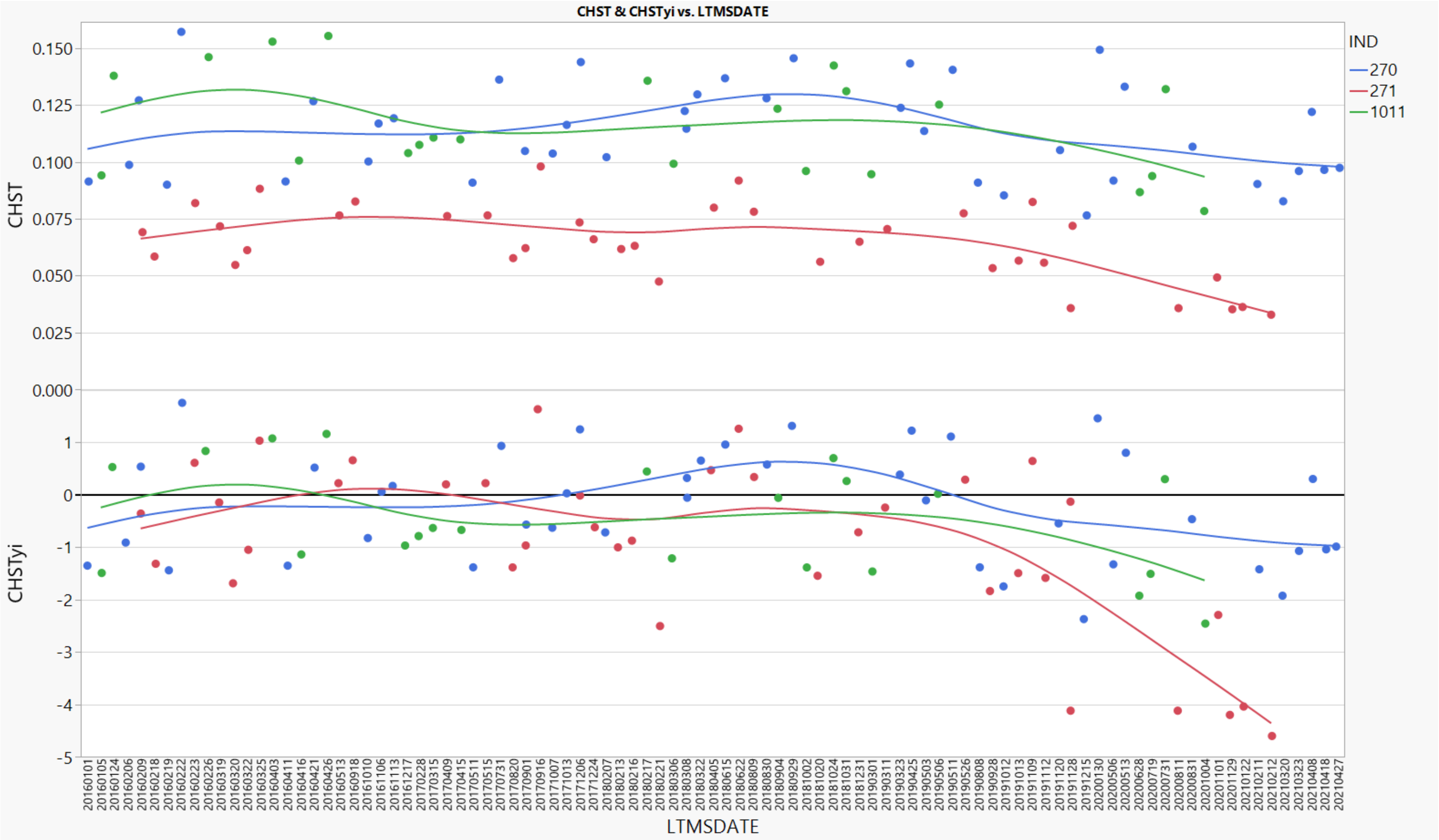
June 2021

Statistics Group

- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Martin Chadwick, Intertek
- Phil Scinto, Lubrizol
- Richard Grundza, TMC
- Todd Dvorak, Afton
- Travis Kostan, SwRI

Background

All 3 reference oils appear to have shifted by similar CHST amount. Therefore Ln(CHST) more greatly impacted Oil 271. Oil 271 has been temporarily suspended.



Executive Summary

The statistics group has ordered potential test severity remedies below in order from most to least preferred.

1. Return the test to traditional severity levels through an engineering solution.

2. Continue the suspension of reference oil 271.
   - The remaining 2 oils can still track test severity in both the mild and severe direction, and are not causing problems with lab calibration.
   - Some options exist for running 271 on a less frequent basis and not for calibration. This can be explored/discussed further if the panel desires.

3. If a mathematical solution is desired, the majority preference of the statistics group is to update the reference oil standard deviations as shown in the table below. To prevent an overly large influence of oil 271 on the severity adjustment standard deviation, the stats group recommends using the oil 270 standard deviation as the standard deviation for severity adjustments. This is appropriate if one believes candidate results near the performance of oil 271 have not seen as large a shift in transformed units.

Oil	Current S.D.	New S.D.
270	0.17435	0.24011
271	0.17537	0.56272
1011	0.18882	0.27434
Severity Adj. S.D.	0.17856	0.24011*

* - Standard deviation on Oil 270

Mathematical Corrective Options Considered

The following are a list of options for mathematical corrective options evaluated (in no particular order). Fixing a problem mathematically for the reference oils does not mean that the underlying problem will be fixed for candidate oils.

1. Re-evaluate the transformation based on the current data set. If different from Ln, calculate new means and standard deviations. Also consider removing the transformation from Oil 271 only. Would require new mean and standard deviation for this oil.
   - ***Result*** – A square root transformation was slightly preferred over the natural log but provided only small relief. This fix would likely be needed in addition to a standard deviation adjustment, and fewer changes are preferred to many.

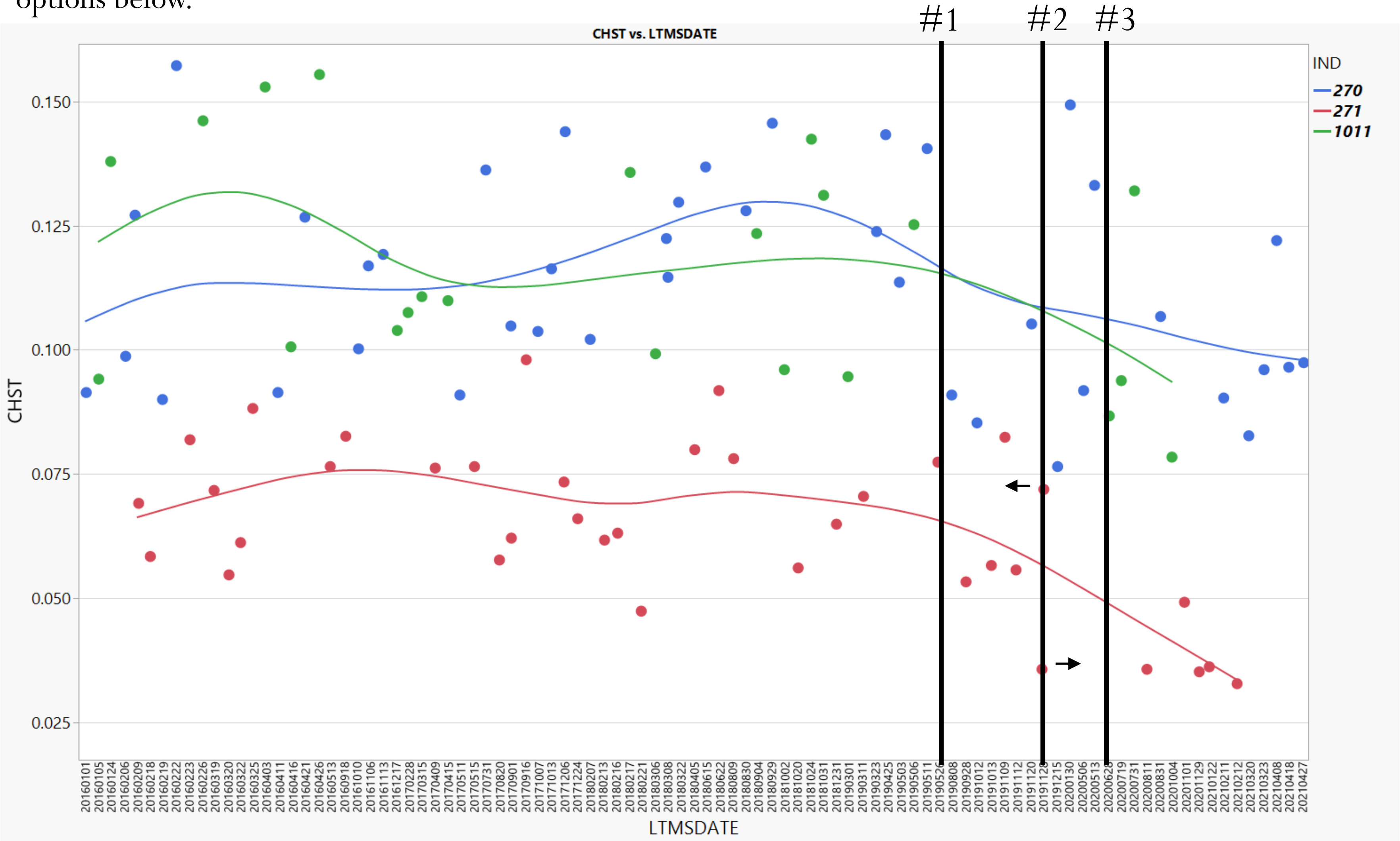
2. Correction factors. This would be applied equally to all oils, candidates and references. Evaluate constant and proportional correction factors to transformed and untransformed results.
   - ***Result*** – Constant correction factors in untransformed units were reasonable, but slightly over- and under-corrected some reference oils. Proportional correction factors bring all oils back to target, but results in large positive corrections for mild oils, requiring strong belief that candidates near oil 271 performance are behaving similarly. For any correction factor options, the lack of root cause also makes starting/stopping point of correction factor implementation unclear.

3. Calculate new standard deviations. This will make the standard deviation of 271 larger and thus bring the standardized result closer to target.
   - ***Result*** – This option was chosen, as it provides relief to the test while requiring the least amount of changes to the way the test has been run historically.

When Did the Shift Occur?

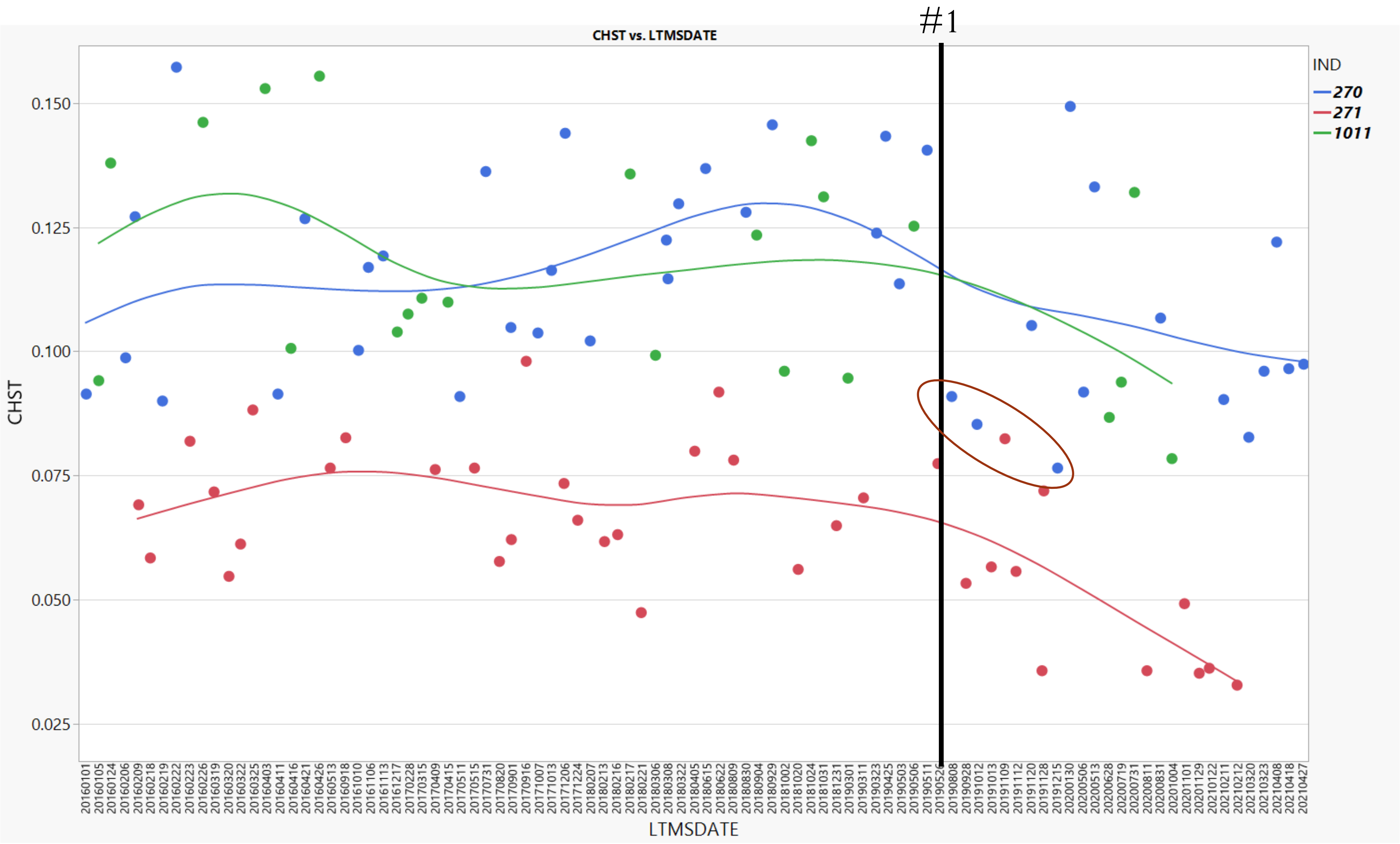
When did the shift occur?

Because we have been unable to tie the shift in severity to any particular change in the test, we do not have clear guidance as to how we draw the line in the sand. The following slides will discuss each of the 3 options below.



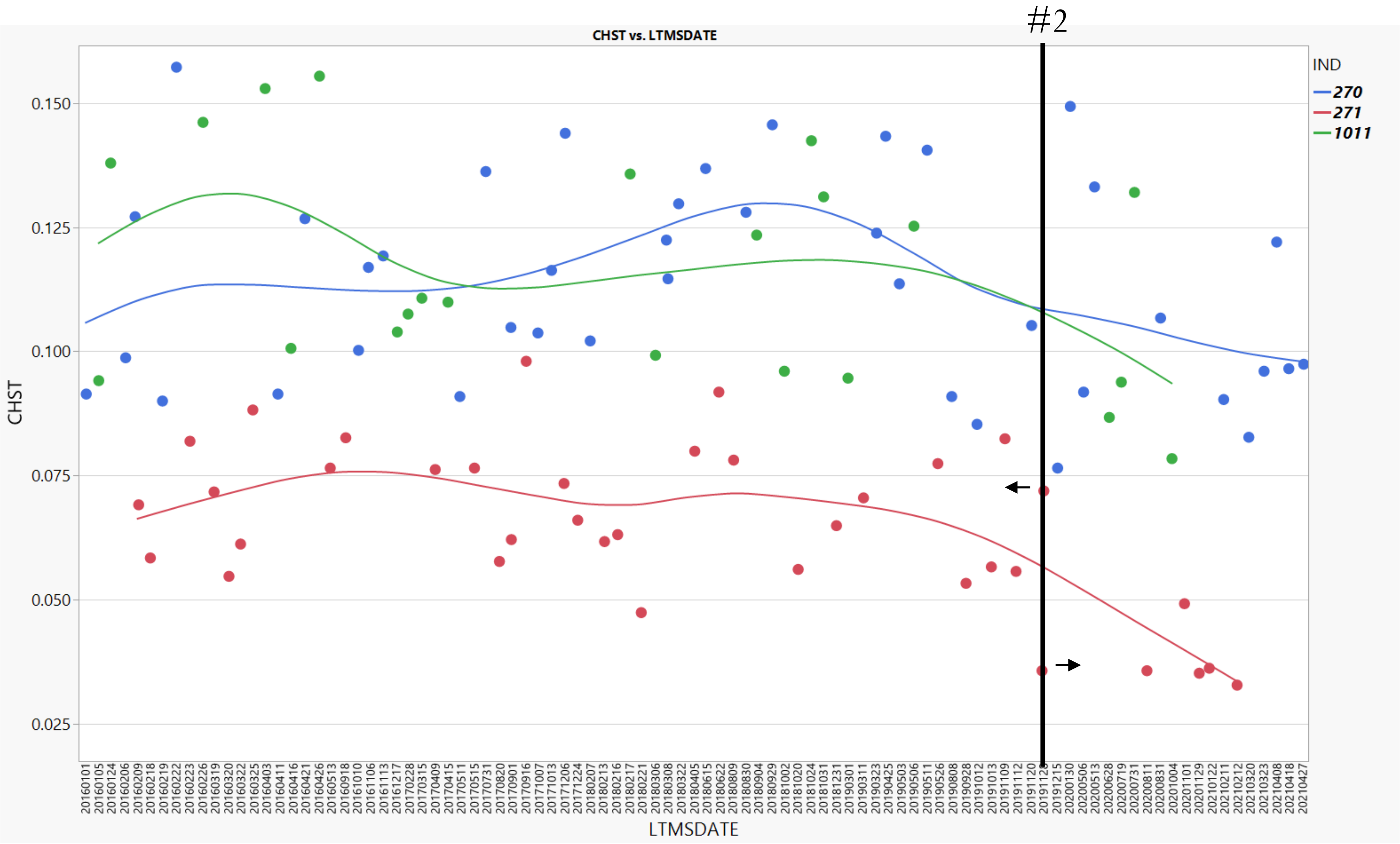
When did the shift occur?

Line #1 is suggested as the best split according to a partition analysis (08/08/19). After this date we began to see some of the lowest results even seen on oil 270.



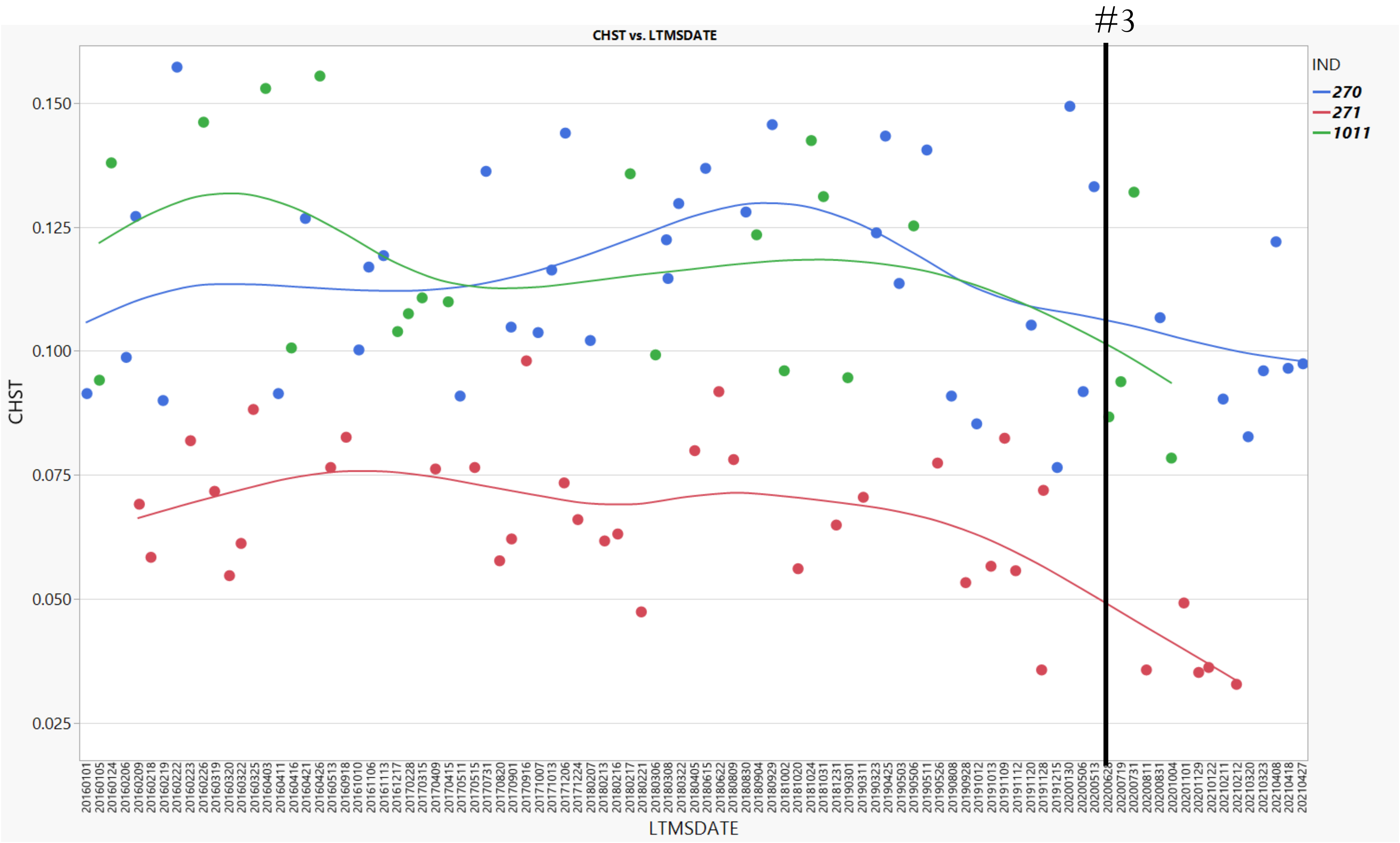
When did the shift occur?

Split #2 is based on the date of the first data of an extreme mild 271. The other 271 from the same day would go in the pre-shift group.



When did the shift occur?

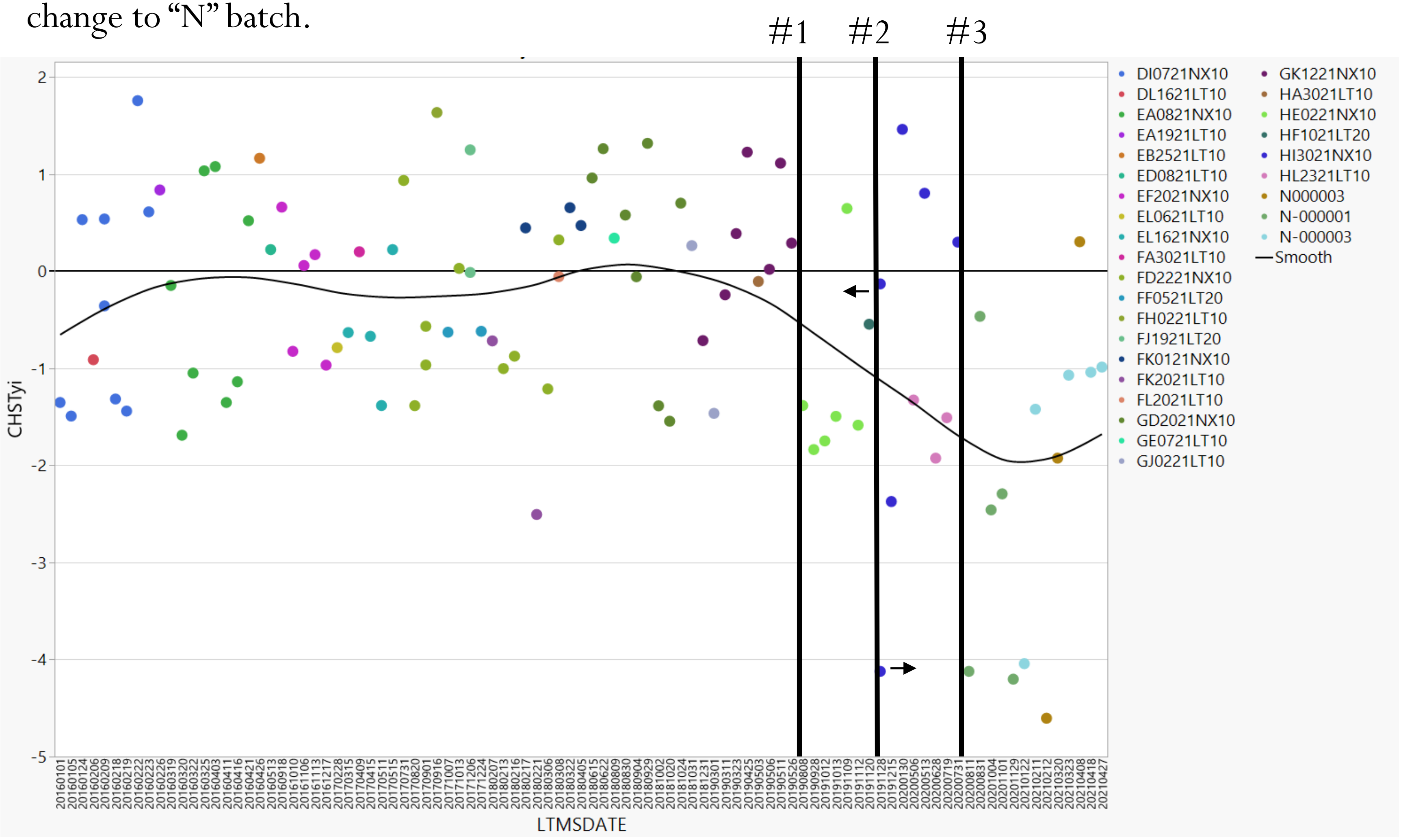
Split #3 appears to be the split which best captures the point in time when all 3 oils were producing almost exclusively mild results.



When did the shift occur?

-Fuel Batches

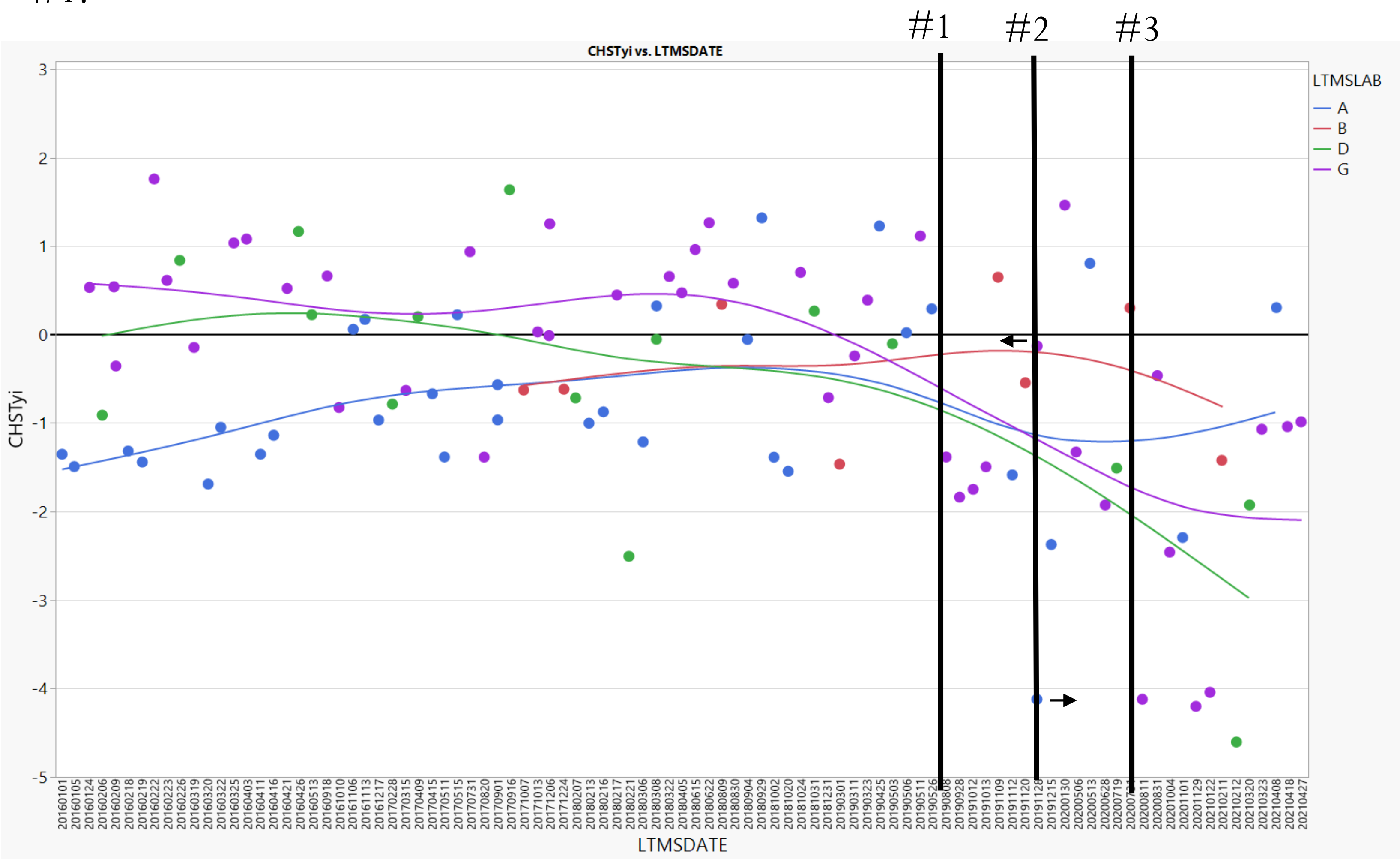
The data was colored by fuel batch ID to investigate how the timeline aligns with fuel batch changes. Split #1 lines up fairly well with change to "H" batch, while split #3 lines up with change to "N" batch.



When did the shift occur?

-Lab Differences

The plot below shows Lab G showed the first evidence of the shift among labs after split #1.



Standard Deviation Update

New Standard Deviations

Below are some comparisons of options for new standard deviations. The standard deviation update using "Post #1" was preferred.

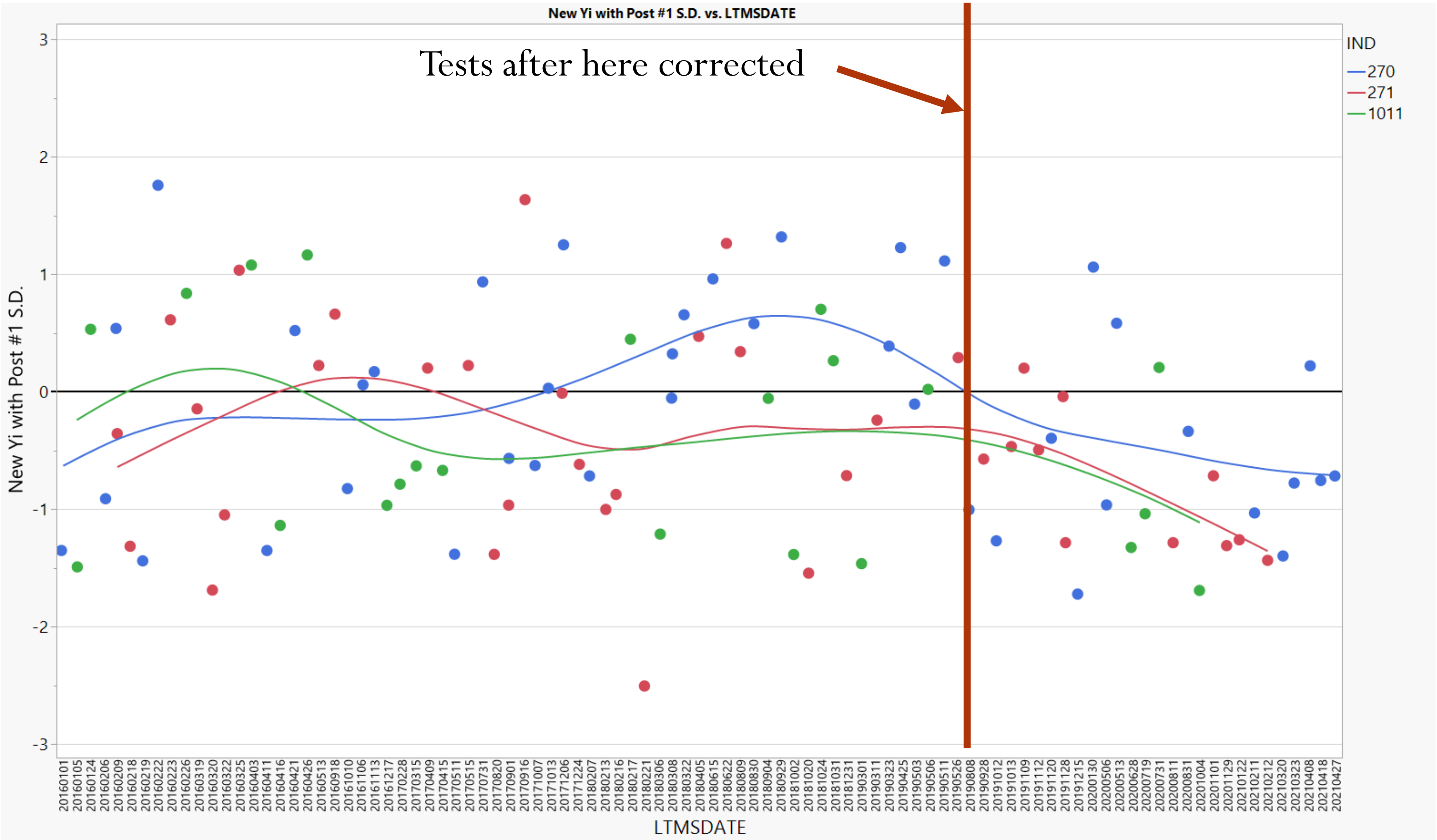
Oil	Current S.D.	S.D. Post #1	S.D. Post #3	S.D. All Data
270	0.17435	0.24011	0.21619	0.19023
271	0.17537	0.56272	0.77157	0.33291
1011	0.18882	0.27434*	0.24701*	0.21735
Pooled	0.17856	0.39913	0.46779	0.25746
Recommended		0.24011**		

* - Actual was 0.37932. However, with only 4 data points in Post #1 and Post #3, it seemed more appropriate to estimate using the ratio observed with the "All Data" standard deviation for 270/1011 (0.21735/0.19023).

** - Standard deviation of oil 270

Updating Yi Using Post #1 S.D.

Yi's after 08/08/2019 here shown with updated standard deviations for Post #1 period.



Impact of Updated Severity Adjustment S.D.

The table to the right indicates how candidate results will be adjusted on a stand with a Zi value of -1 with the updated pooled SA of 0.24011.

CHST	Ln(CHST)	Ln(CHST)+0.24011	CHST FNL
0.010	-4.6052	-4.3651	0.013
0.020	-3.9120	-3.6719	0.025
0.030	-3.5066	-3.2664	0.038
0.040	-3.2189	-2.9788	0.051
0.050	-2.9957	-2.7556	0.064
0.060	-2.8134	-2.5733	0.076
0.070	-2.6593	-2.4192	0.089
0.080	-2.5257	-2.2856	0.102
0.090	-2.4079	-2.1678	0.114
0.100	-2.3026	-2.0625	0.127
0.110	-2.2073	-1.9672	0.140
0.120	-2.1203	-1.8802	0.153
0.130	-2.0402	-1.8001	0.165
0.140	-1.9661	-1.7260	0.178
0.150	-1.8971	-1.6570	0.191

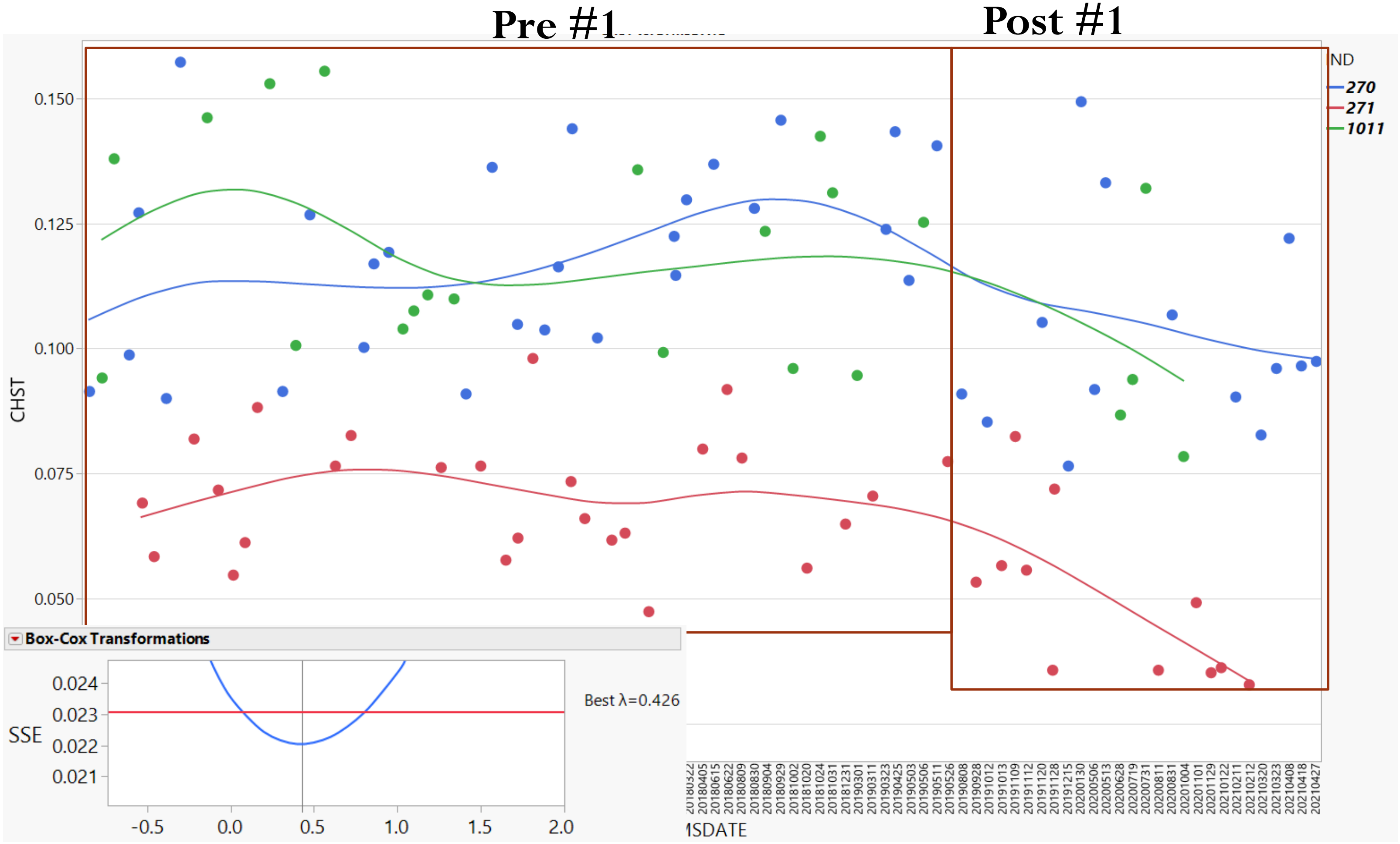
Appendix

Re-evaluation of the Transformation

Re-evaluating the transformation

-Using All Data with “Pre” or “Post” added to Model

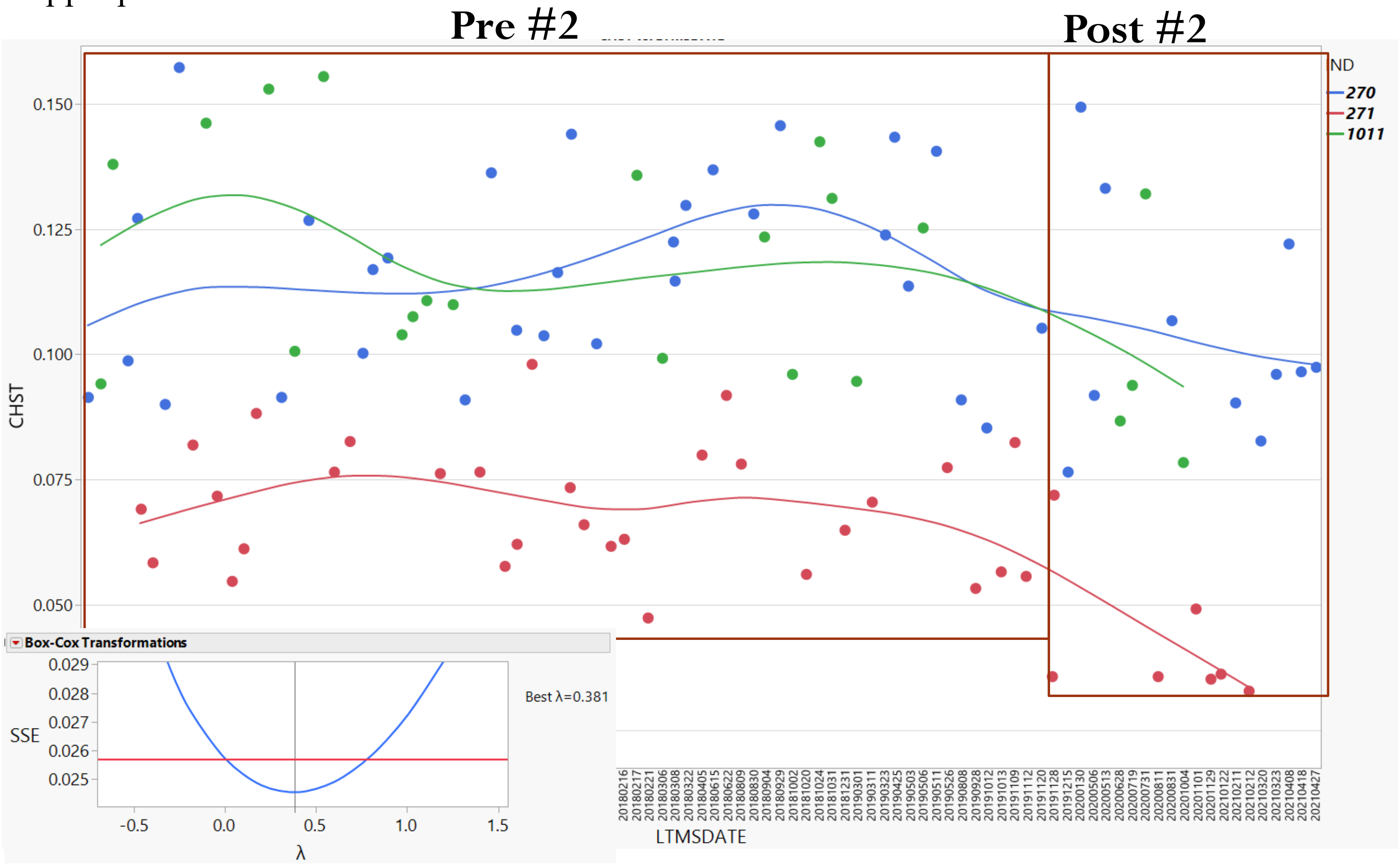
Partition analysis suggests best split at 08/08/19. All data in in right box labeled as “Post.” All other data labeled “Pre”. Then modeled CHST ~ Oil, Lab, Stand[Lab], Pre/Post. Square root transformation more appropriate here.



Re-evaluating the transformation

-Using All Data with “Pre” or “Post” added to Model

All data in in right box labeled as “Post” (except for first near target 271). All other data labeled “Pre”. Then modeled CHST ~ Oil, Lab, Stand[Lab], Pre/Post. Square root transformation more appropriate here.



Re-evaluating the transformation

-Using All Data with “Pre” or “Post” added to Model

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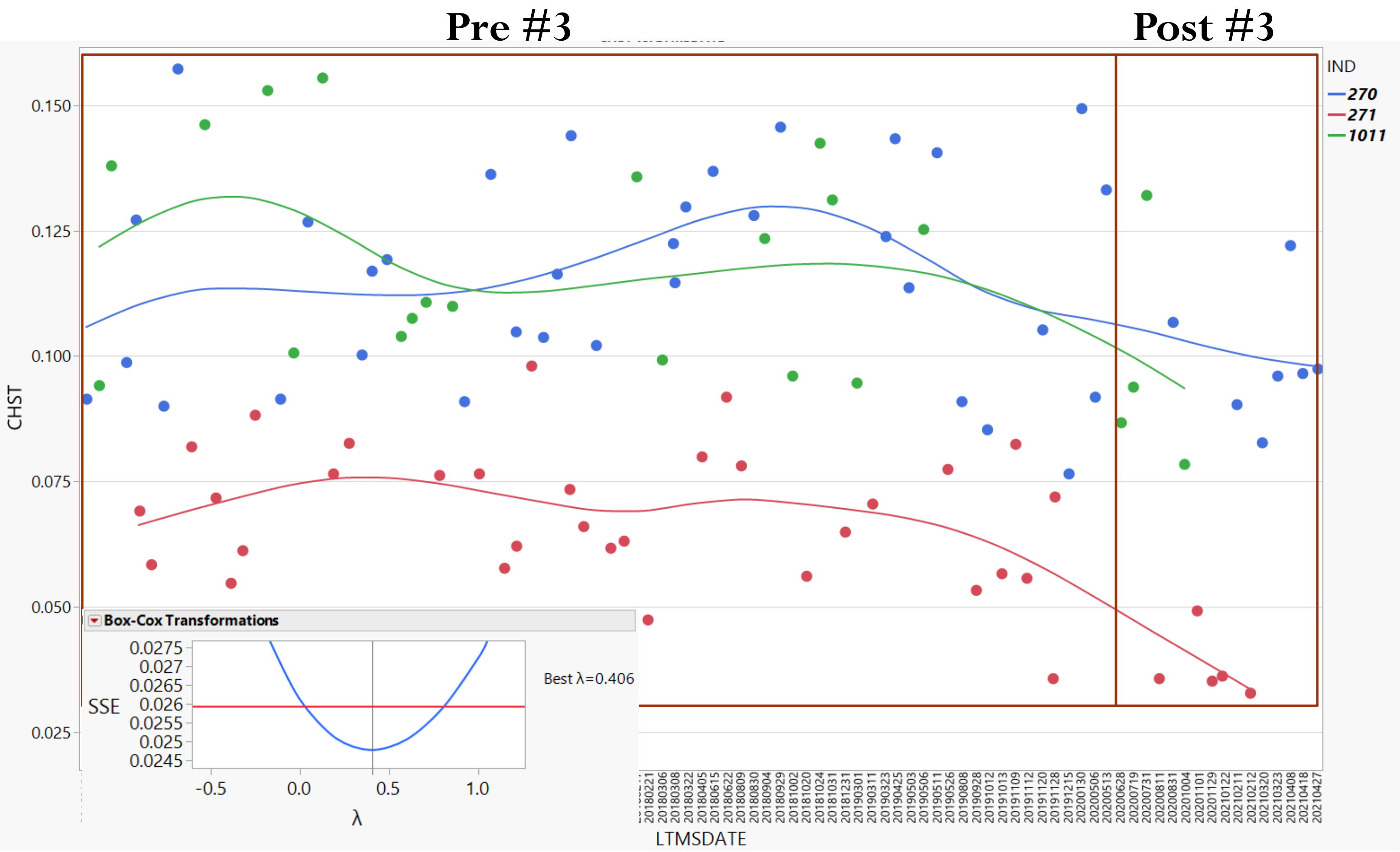


Sqrt. Transformed Targets -Averages

In order to keep the pivot point the same for positive and negative severity adjustments, the original targets were back-transformed into original units, and then the square root transformation is applied to obtain the target Sqrt(CHST) for each oil.

Reference Oil	Target Ln(CHST)	Target CHST	Target Sqrt(CHST)
270	-2.15699	0.1157	0.34011
271	-2.60987	0.0735	0.27119
1011	-2.08191	0.1247	0.35312

Sqrt. Transformed Targets -Standard Deviations

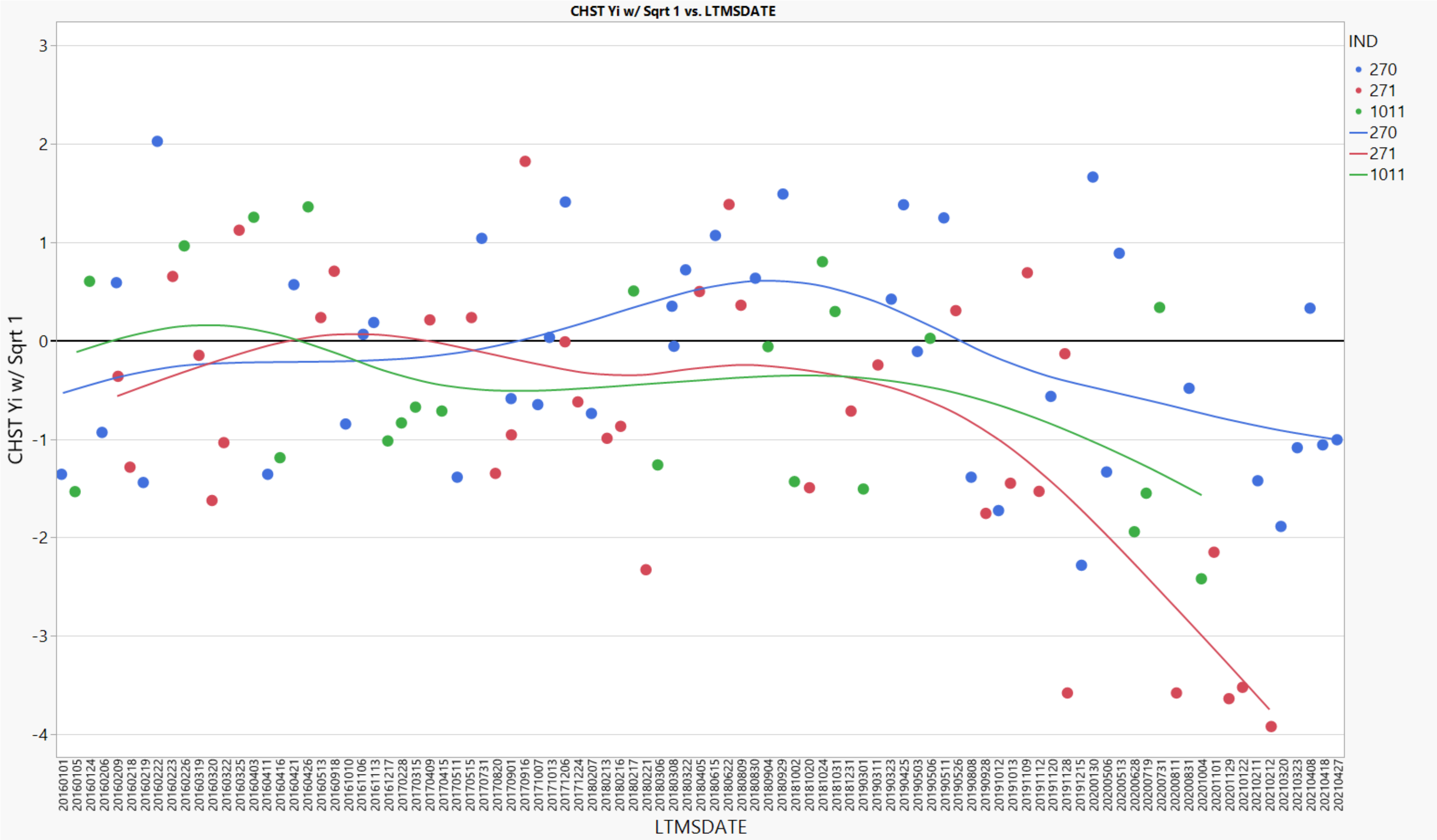
Standard Deviation #1 – For each Oil, Calculated Std. Dev. of (Result-Target). Used $n = 71$ data set prior to any evidence of the mild shift (labeled "Pre #1" in previous slide).

Standard Deviation #2 – For each Oil, Calculated Std. Dev. of (Result-Target). Used all data.

Reference Oil	Target Sqrt(CHST)	Std. Dev. 1	Std. Dev. 2
270	0.34011	0.02784	0.03116
271	0.27119	0.02298	0.03421
1011	0.35312	0.03023	0.03343
Pooled		0.02681	0.03281
Average		0.02702	0.03293

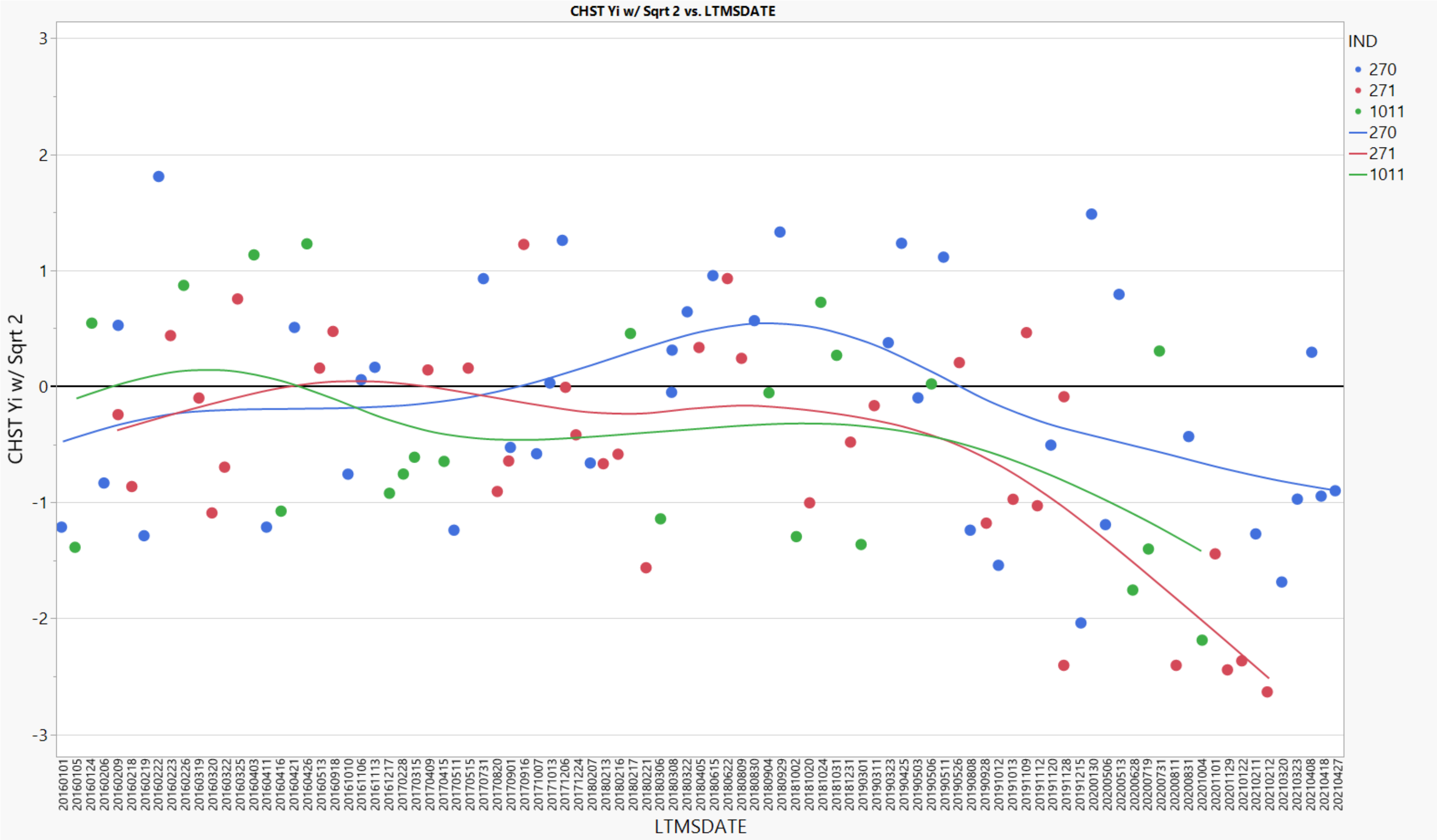
Plot of CHST Yi Using Sqrt. With SD#1

Below is a plot of the CHSTYi when calculated using the standard deviation of the data "PRE #1" data only with the square root transformation.



Plot of CHST Yi Using Sqrt. With SD#2

Below is a plot of the CHSTYi when calculated using the standard deviation calculated using all of the data and the square root transformation.



No Transformation for Oil 271

- For Oil 271, the mean of untransformed result is the back-transformed current mean for Ln(CSHT).
- Standard deviation of (result-mean) is calculated using the 271 untransformed data from data set "Pre 1" only.
- No changes to oil 270 or oil 1011.

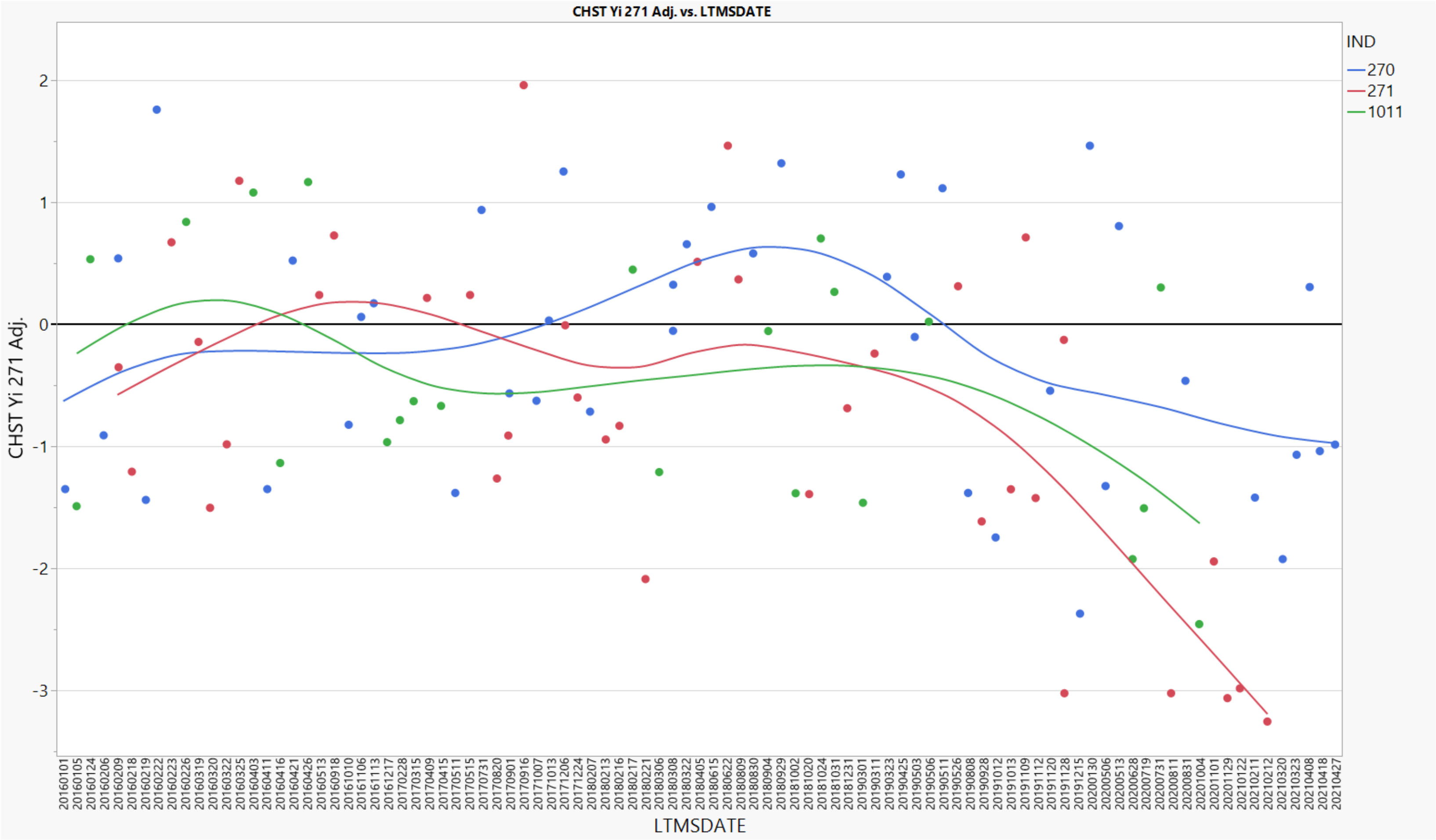
Oil	CHST Mean	Standard deviation
271	0.0735	0.0125

Same as current LTMS for these oils

Oil	Ln(CHST) Mean	Standard deviation
270	-2.15699	0.17435
1011	-2.08191	0.18882

271 New Yi's

The graph below shows how the 271 Yi values would change without the transformation.



Correction Factors

Pre- and Post-Transformation Options

Some Constant Correction Options

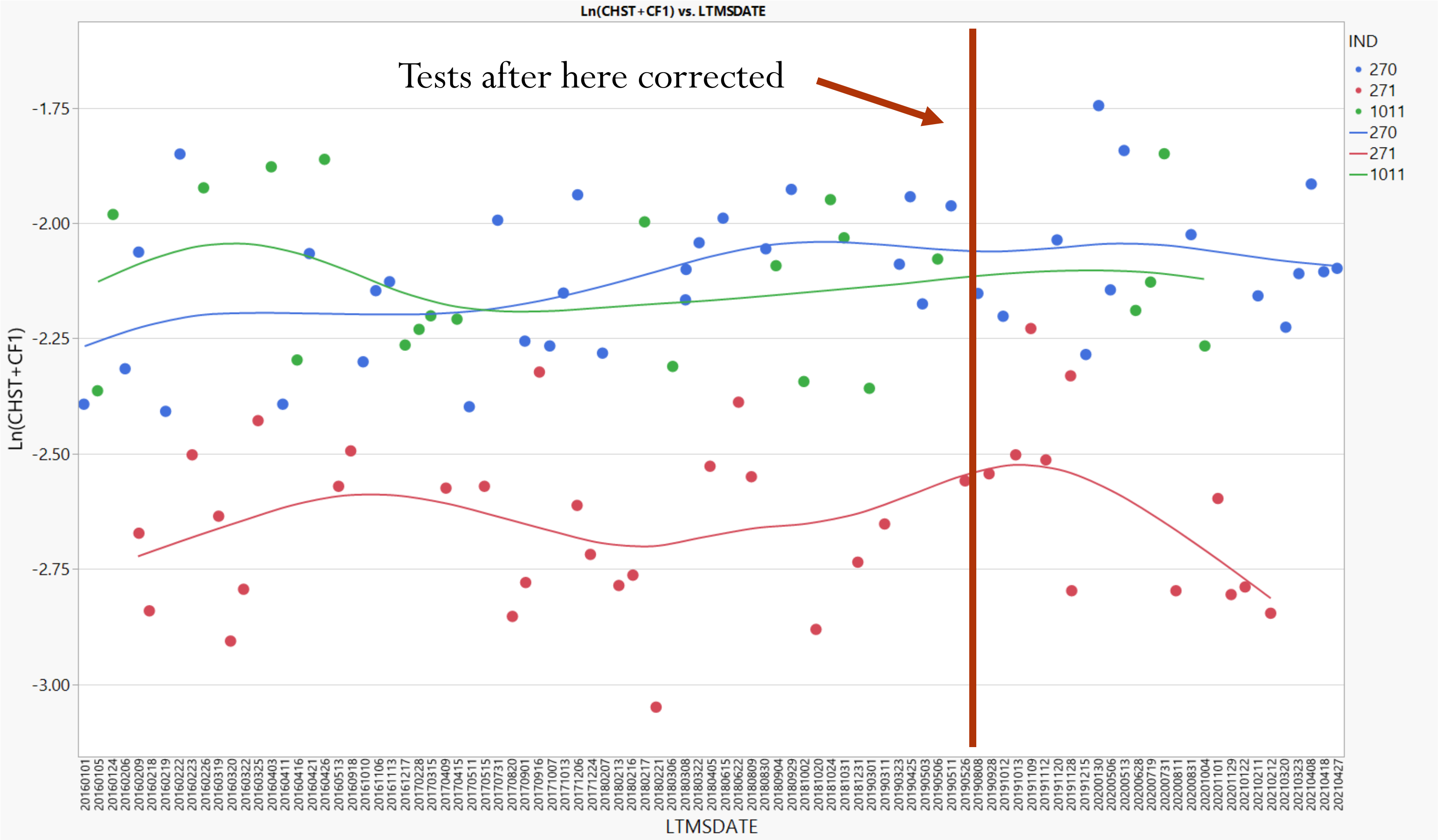
Below are some options for corrections to be applied to all tests depending on when you choose to identify the start of the shift and the type of correction factor you wish to apply (before of after transformation).

C.F. Number	Model	Pre LS Mean	Post LS Mean	Post Correction Factor (To "Pre")	Post Correction Factor (To Target)*
1.	CHST ~ Oil, Lab, Stand[Lab], Pre/Post #1	0.1047	0.0785	+0.0262	+0.0253
2.	CHST ~ Oil, Lab, Stand[Lab], Pre/Post #2	0.1021	0.0785	+0.0236	+0.0249
3.	CHST ~ Oil, Lab, Stand[Lab], Pre/Post #3	0.1024	0.0740	+0.0284	+0.0296
4.	Ln(CHST) ~ Oil, Lab, Stand[Lab], Pre/Post #1	-2.28375	-2.62183	+0.33808	+0.33073
5.	Ln(CHST)~ Oil, Lab, Stand[Lab], Pre/Post #2	-2.31325	-2.63989	+0.32664	+0.34451
6.	Ln(CHST) ~ Oil, Lab, Stand[Lab], Pre/Post #3	-2.31344	-2.68375	+0.37031	+0.39137

*Calculated by using the prediction equation to predict average performance across all lab-stands in the "post" period (did not use nested stand term here, but lab-stand).

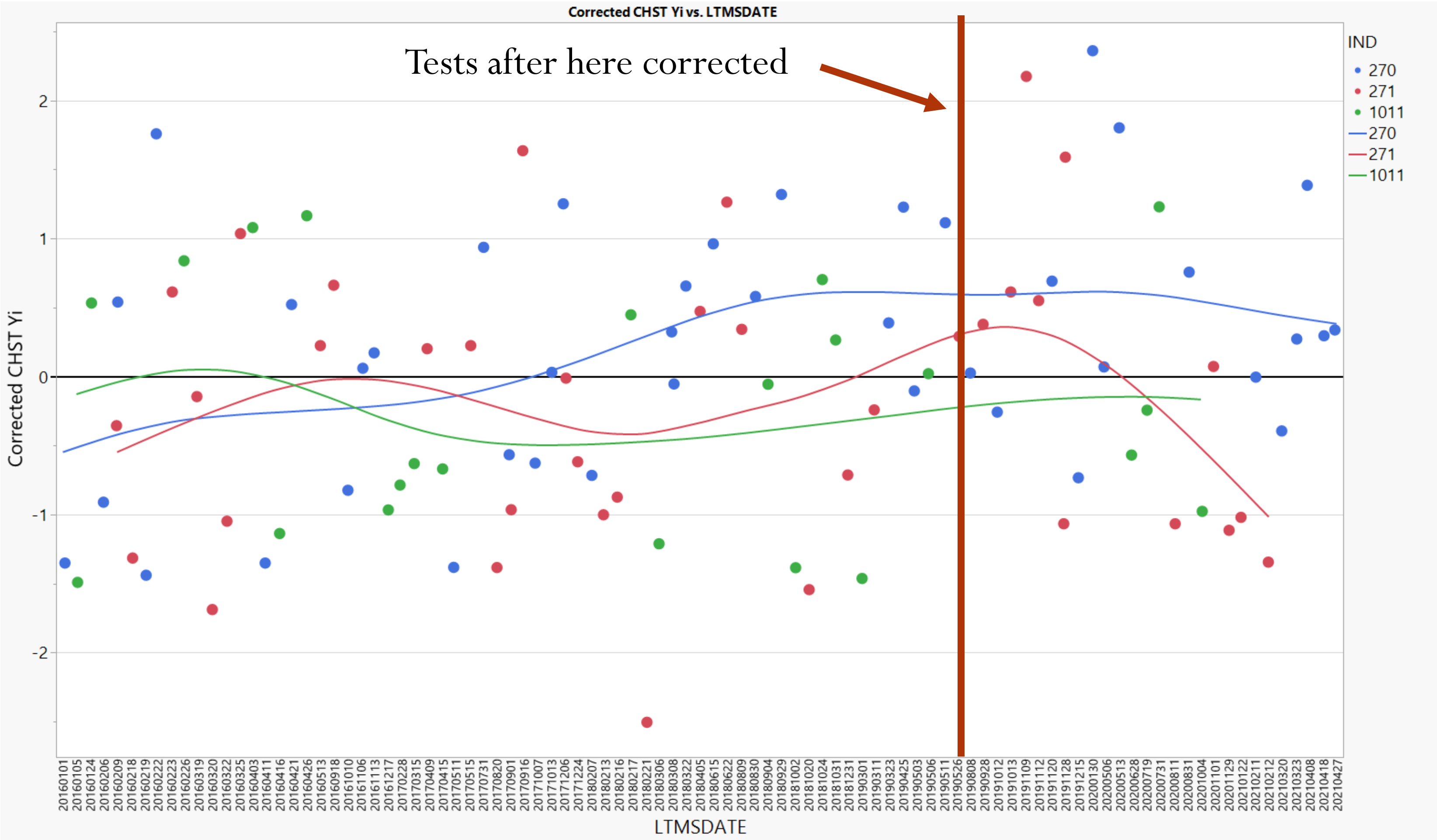
Ln(CHST+CF) with Measurement Correction Factor #1 -Corrected To Target

Reference tests shown below on of after 08/08/2019 have the measurement correction factor of +0.0253 applied.



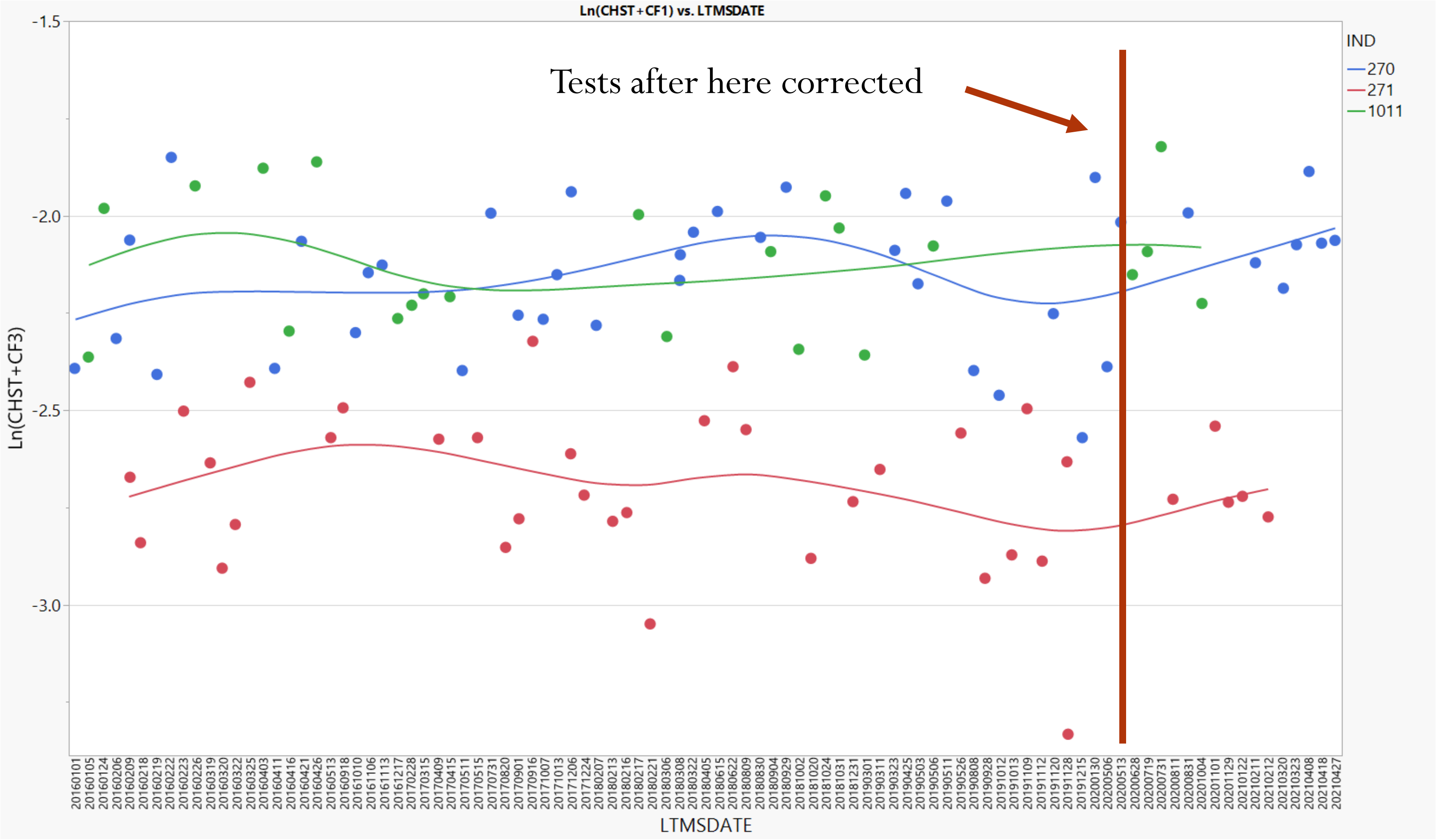
LN(CHST+CF) with Measurement C.F. #1

Reference tests shown below on of after 08/08/2019 have the measurement correction factor of +0.0253 applied.



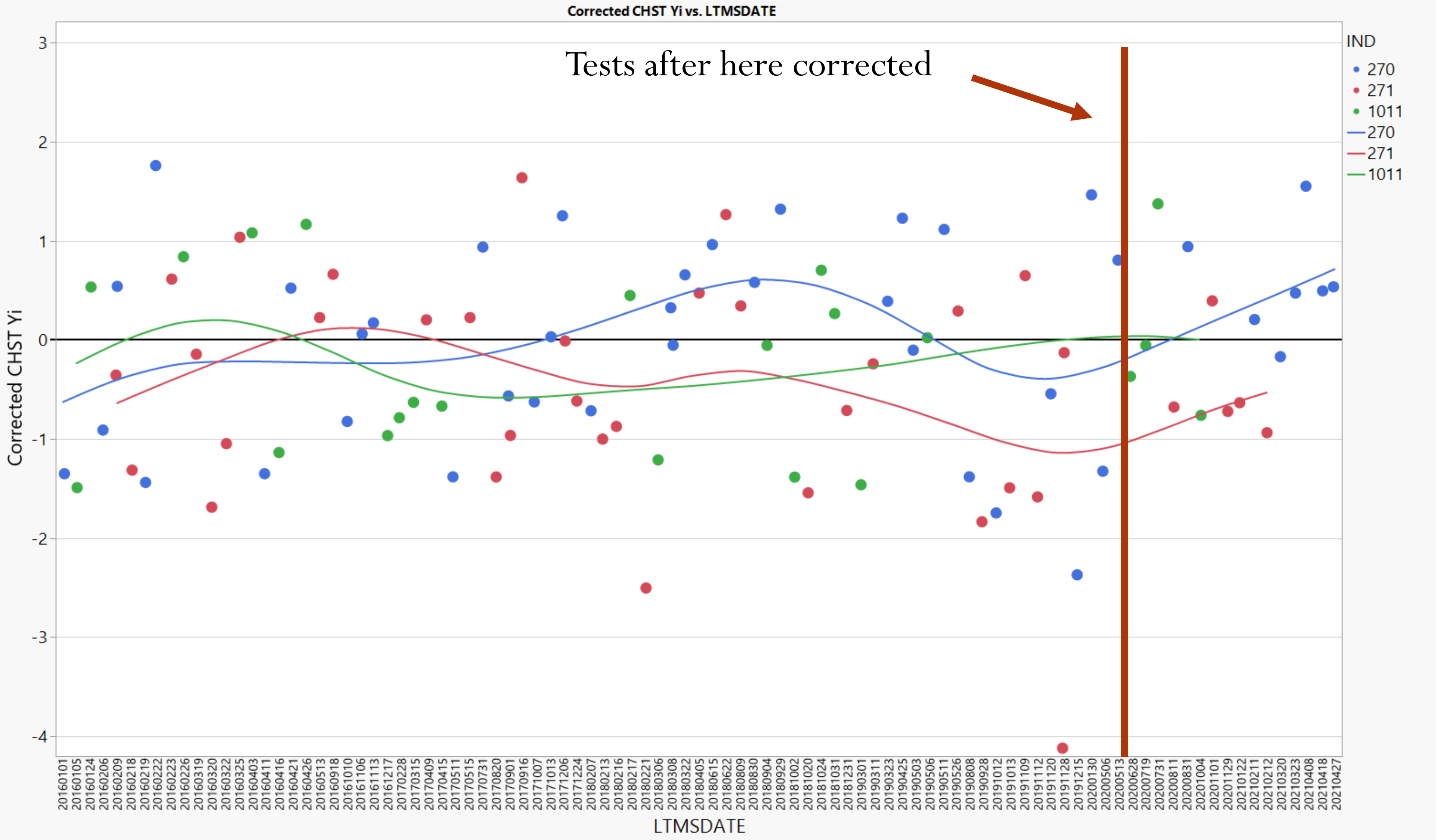
Ln(CHST+CF) with Measurement Correction Factor #3 -Corrected To Target

Reference tests shown below on of after 06/28/2020 have the measurement correction factor of +0.0296 applied.



LN(CHST+CF) with Measurement C.F. #3

Reference tests shown below on of after 06/28/2020 have the measurement correction factor of +0.0296 applied.

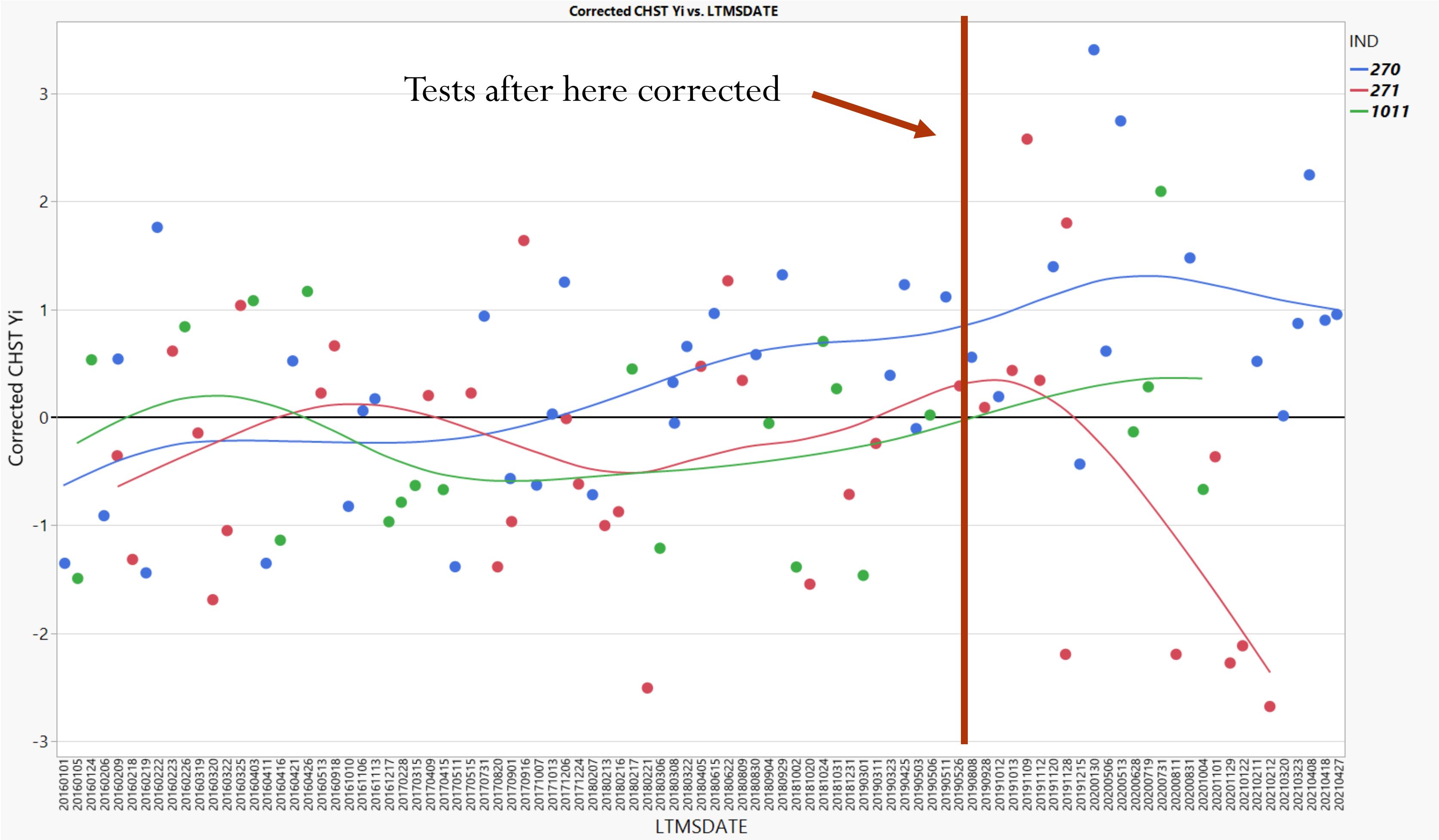


Ln(CHST)+CF with Correction Factor #4

Reference tests shown below on of after 08/08/2019 have the post-transformation (typical application) correction factor of +0.33073 applied.

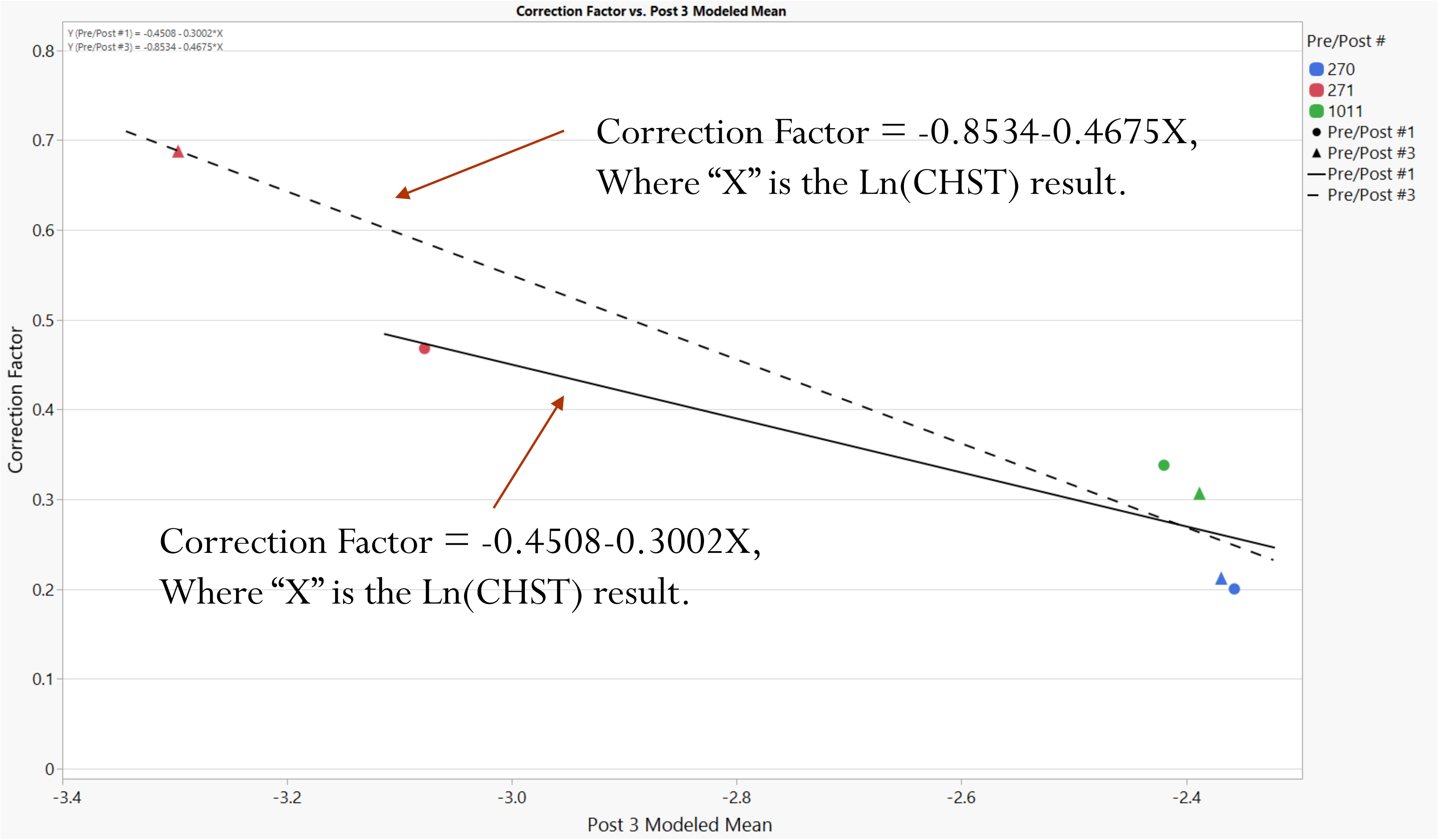
Ln(CHST)+CF with Correction Factor #4

Reference tests shown below on of after 08/08/2019 have the post-transformation (typical application) correction factor of +0.33073 applied.



What about a non-constant C.F.?
-Using Post #1 & #3 Modeled Means

The below shows how the correction factor would increase with improved oil performance. This assumes candidates are showing the same trend as the reference oils by level.



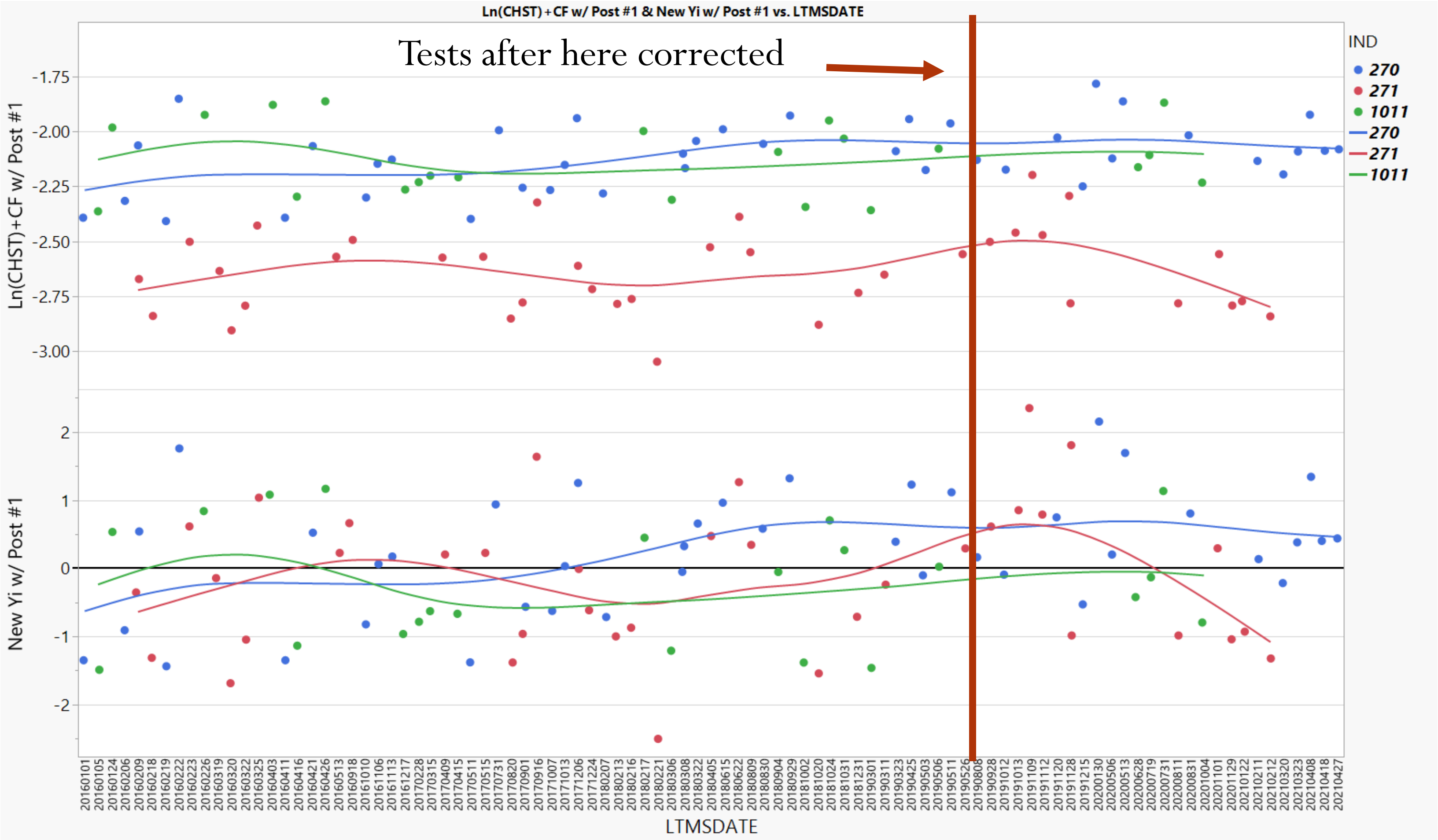
Correction factors by CHST Level

The table below shows how the CHST values would adjust when using a level dependent correction factor.

CHST	Ln(CHST)	C.F. w/ Post #1	Adj. CHST w/ Post #1	C.F. w/ Post #3	Adj CHST w/ Post #3
0.010	-4.6052	0.9317	0.025	1.2995	0.037
0.020	-3.9120	0.7236	0.041	0.9755	0.053
0.030	-3.5066	0.6019	0.055	0.7859	0.066
0.040	-3.2189	0.5155	0.067	0.6514	0.077
0.050	-2.9957	0.4485	0.078	0.5471	0.086
0.060	-2.8134	0.3938	0.089	0.4619	0.095
0.070	-2.6593	0.3475	0.099	0.3898	0.103
0.080	-2.5257	0.3074	0.109	0.3274	0.111
0.090	-2.4079	0.2721	0.118	0.2723	0.118
0.100	-2.3026	0.2404	0.127	0.2231	0.125
0.110	-2.2073	0.2118	0.136	0.1785	0.131
0.120	-2.1203	0.1857	0.144	0.1378	0.138
0.130	-2.0402	0.1617	0.153	0.1004	0.144
0.140	-1.9661	0.1394	0.161	0.0658	0.150
0.150	-1.8971	0.1187	0.169	0.0335	0.155

New Ln(CHST) and Yi w/ Post #1

The table below shows how data after 08/08/2019 would change with the level-dependent correction factor.



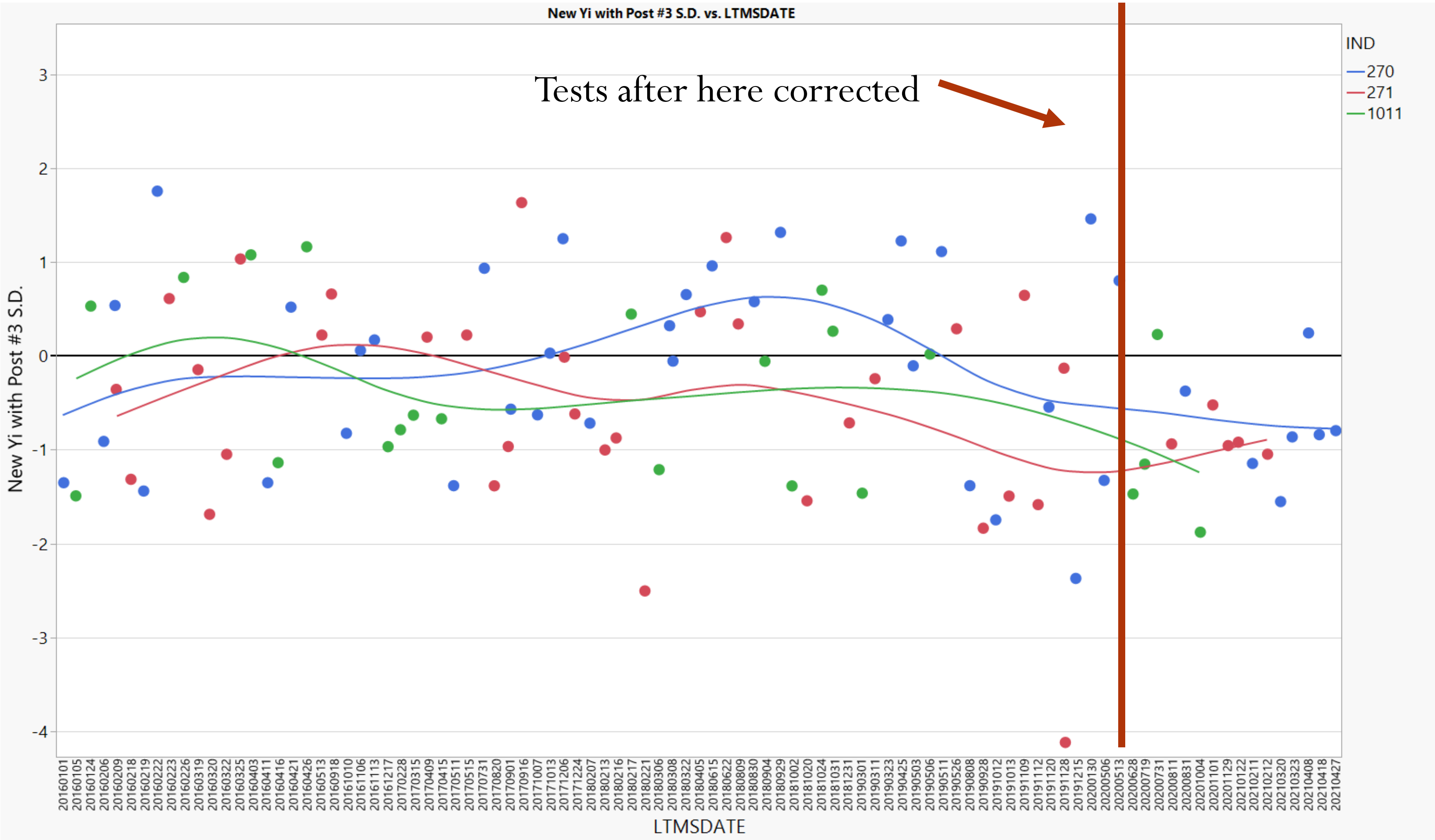
New Ln(CHST) and Yi w/ Post #3

The table below shows how data after 06/28/2020 would change with the level-dependent correction factor.

More Standard Deviation Options

Updating Yi Using Post #3 S.D.

Yi's after 06/28/2020 here shown with updated standard deviations for Post #3 period.



Updating Yi All Data Standard Deviations

All tests below have been corrected using the updated standard deviations calculated with all data.