Sequence X Severity Task Force

Meeting Minutes

06/14/22

Attendance 06/14/22

- Michael Deegan
- Rich Grundza
- Ben Maddock
- Christine Eickstead
- George Szappanos
- Jason Soto
- Alfonso Lopez
- Travis Kostan
- Amol Savant
- Joseph Hoehn
- Pat Lang
- Martin Chadwick

Agenda 06/14/22

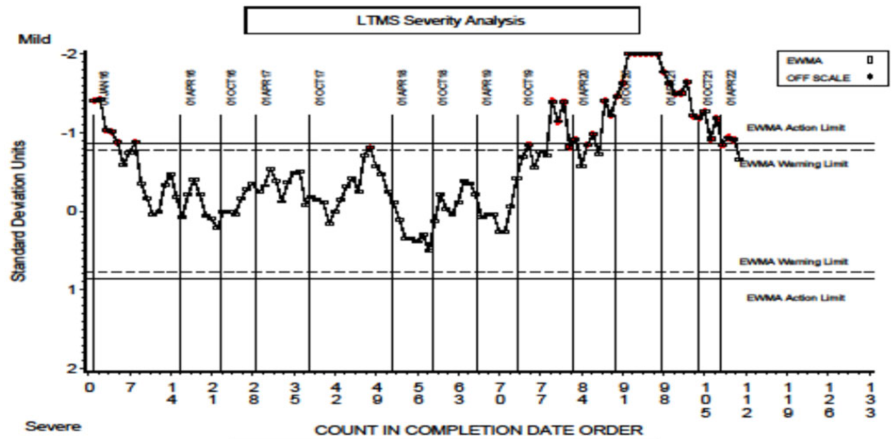
- Review current control charts
- Corrective Action for Severity Trend – Math Solutions
- Hardware Update – FCS purchases

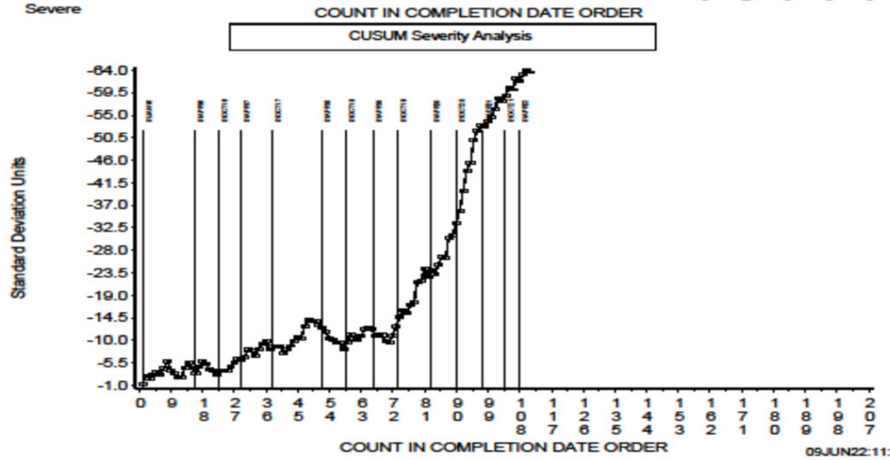
Current Control Charts

- The industry alarm has been cleared.
- Recent tests on oil 270 and 1011-1 have generated results closer to target

SEQUENCE X INDUSTRY OPERATIONALLY VALID DATA

END OF TEST CHAIN WEAR FINAL RESULT





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Statistician Report

- Travis and Martin presented the analysis of possible mathematical solutions to the severity shift and the over-effect on oil 271 due to the transform.
- Attached below is the Stats group presentation.
- Summary
  - Labs to donate runs on oil 271 prior to making any math changes
  - After donated tests are conducted, re-evaluate the standard deviation of oil 271 and apply new standard deviation to LTMS.
  - Increase referencing frequency to 6 months.
- All labs agreed to donate tests.
- The option to enlarge the standard deviation was accepted by the task force as the best solution.

Severity Discussion

- Martin explained how the solution of expanding the standard deviation for oil 271 would work as long as the test remains mild to on target. If the severity trend shifts towards the severe end of targets, the standard deviation solution would need further review. This triggered the increased reference in frequency request that we all agreed to.
- Oil 271 tests would be donated on stands that are currently closest to target.
- George recommended a review of transition data. Compare stands.
- Jason asked on what to do with the other mild stands. The group as a whole agreed that if one stands is on target, it is the labs responsibility to make other stands perform the same.

Hardware

- Labs were surveyed on the FCS quote and how they are doing with parts purchases.
- Christine requested a timeline for life of the Seq X with the current engine platform. Mike Deegan stated that we should plan to run this test through 2028. GF7 will require an engine change for the chain wear test.
- Labs to buy what they need directly from FCS. To date there has been no need to combine orders for any particular line item.

Sequence X Severity
Mathematical Corrective Options

Statistics Group

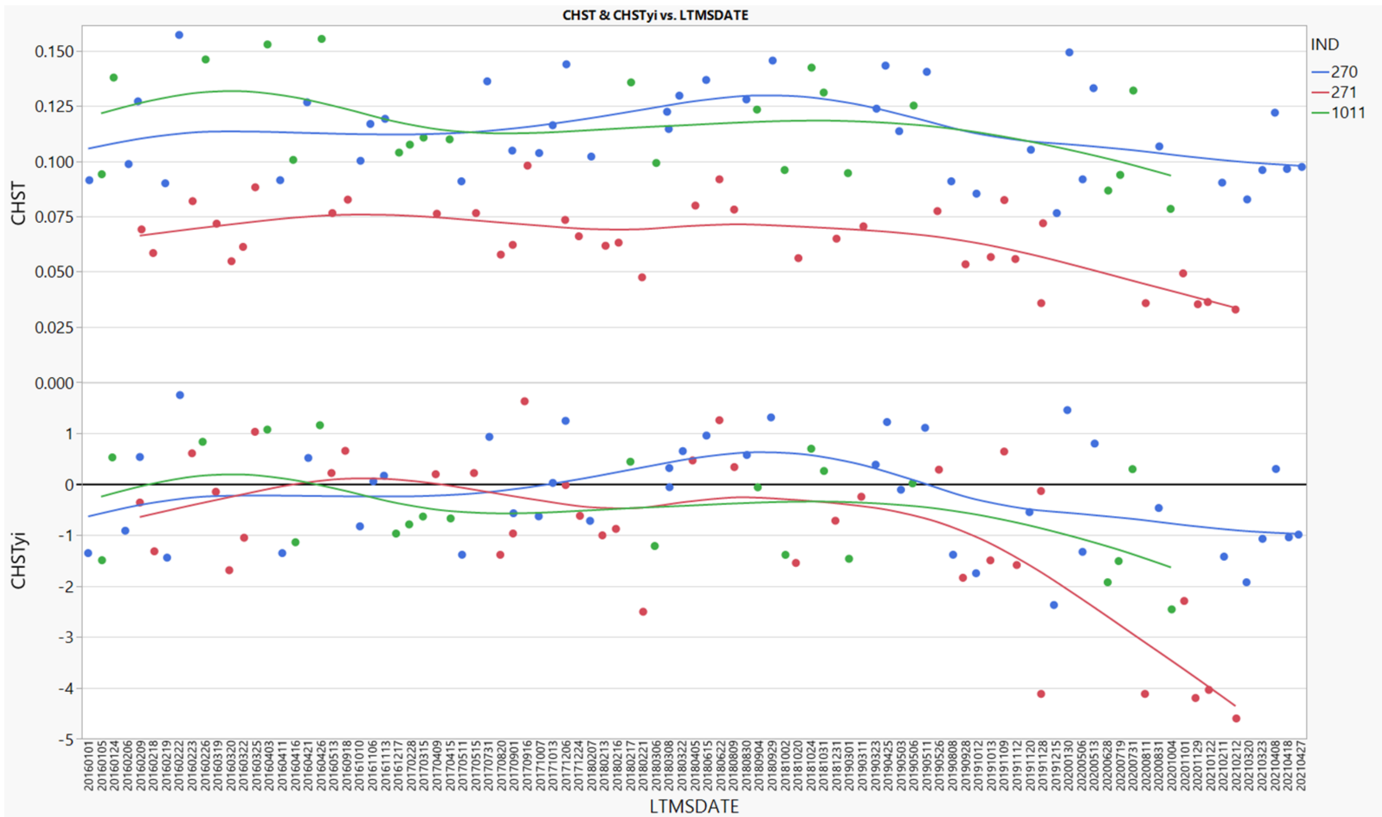
June 2021

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

Recommendations if Increased s Adopted

- Conduct additional tests on RO271 prior to implementing any changes. At least one test per lab is recommended.
  - The last 271 runs with the current procedure were in Feb-2021 and at least one lab may have shifted performance on 270 since then.
- Increase reference frequency as long as standard deviations that incorporate bias are used and perform regular reviews of the data.
  - The LTMS will not work as intended if standard deviations that incorporate bias are used for ei and Zi calculations. Any future shift in severity will be less likely to be detected while this correction is in use. It is critical that we collect more data than when the process is performing as expected to increase the chance of developing a correction that is more effective long term and to reduce the risk that a new shift in severity occurs that is not appropriately addressed by the severity adjustments resulting from the new calculations.

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.

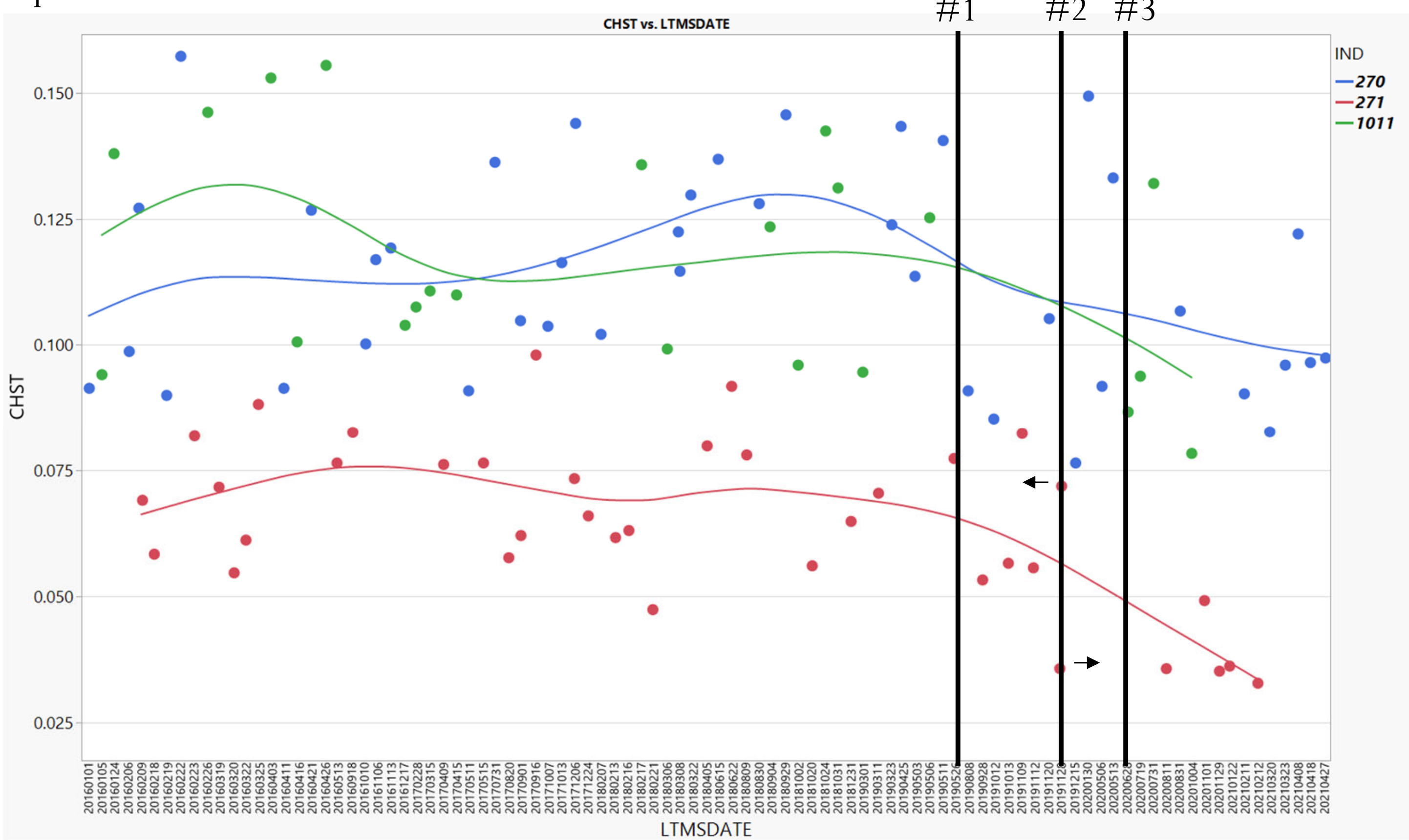
2. Correction factors. This would be applied equally to all oils, candidates and references. Evaluate constant and proportional correction factors to transformed and untransformed results.
   - ***Result*** – Constant correction factors in untransformed units were reasonable, but slightly over- and under-corrected 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?

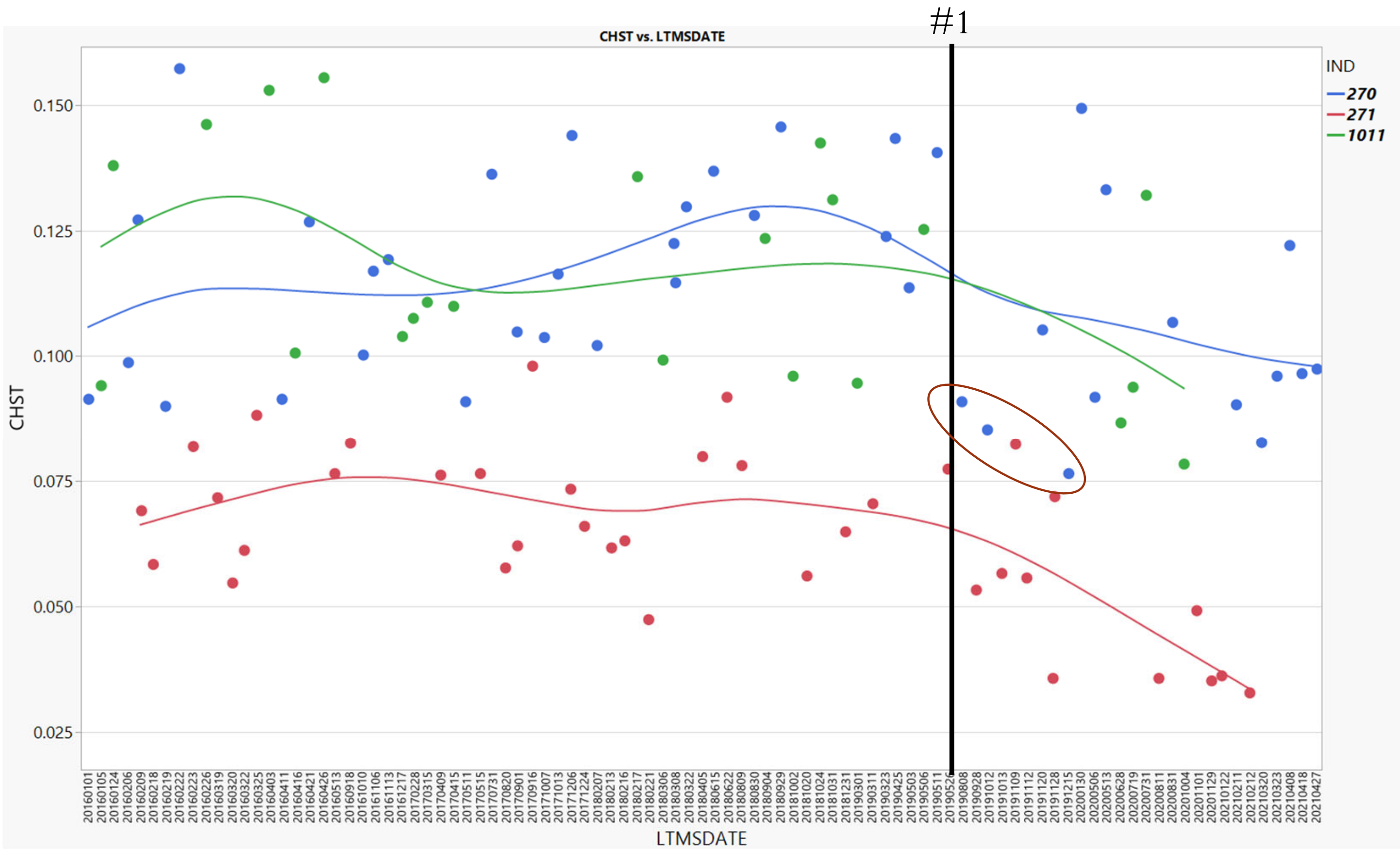
When did the shift occur?

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.



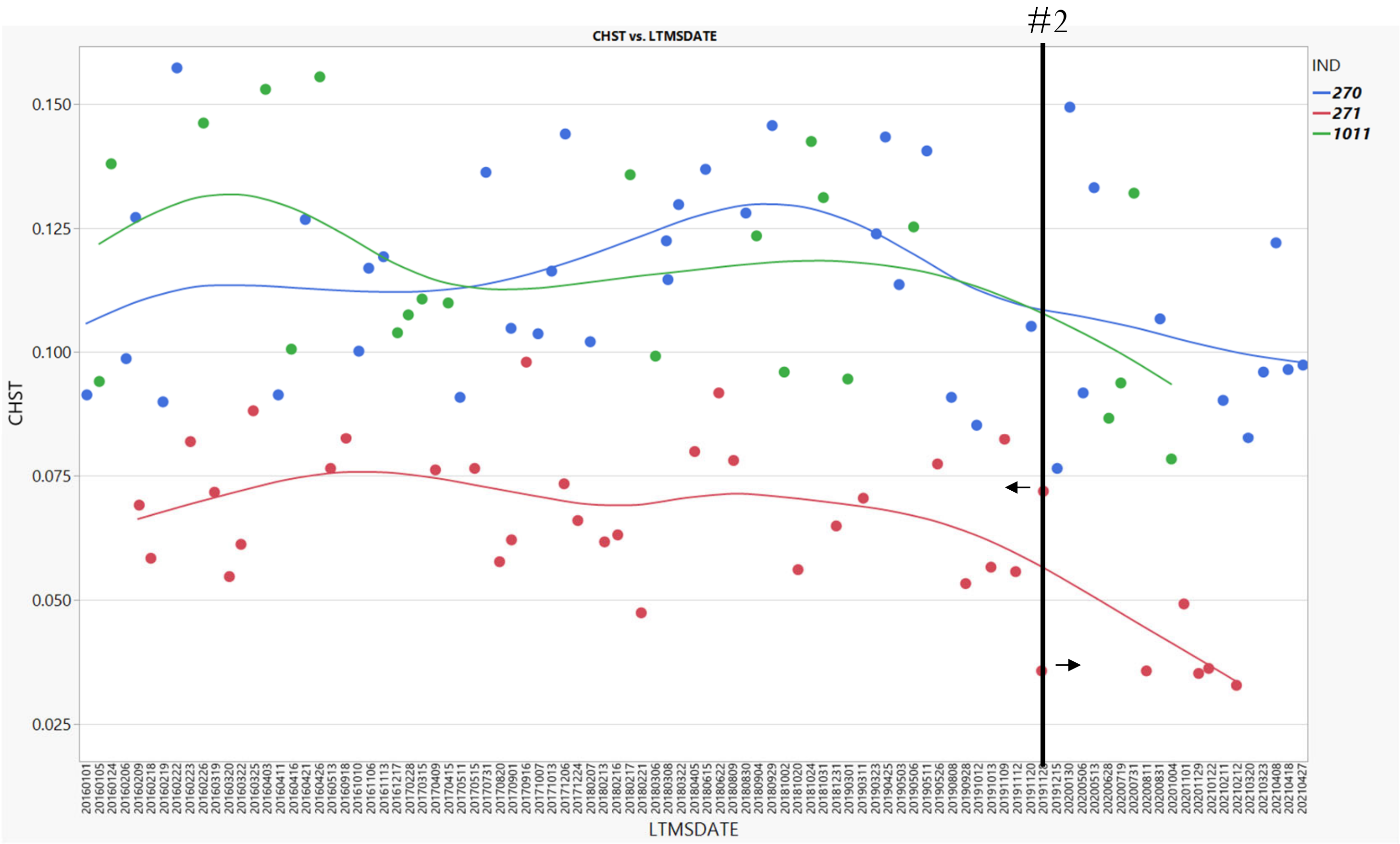
When did the shift occur?

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.



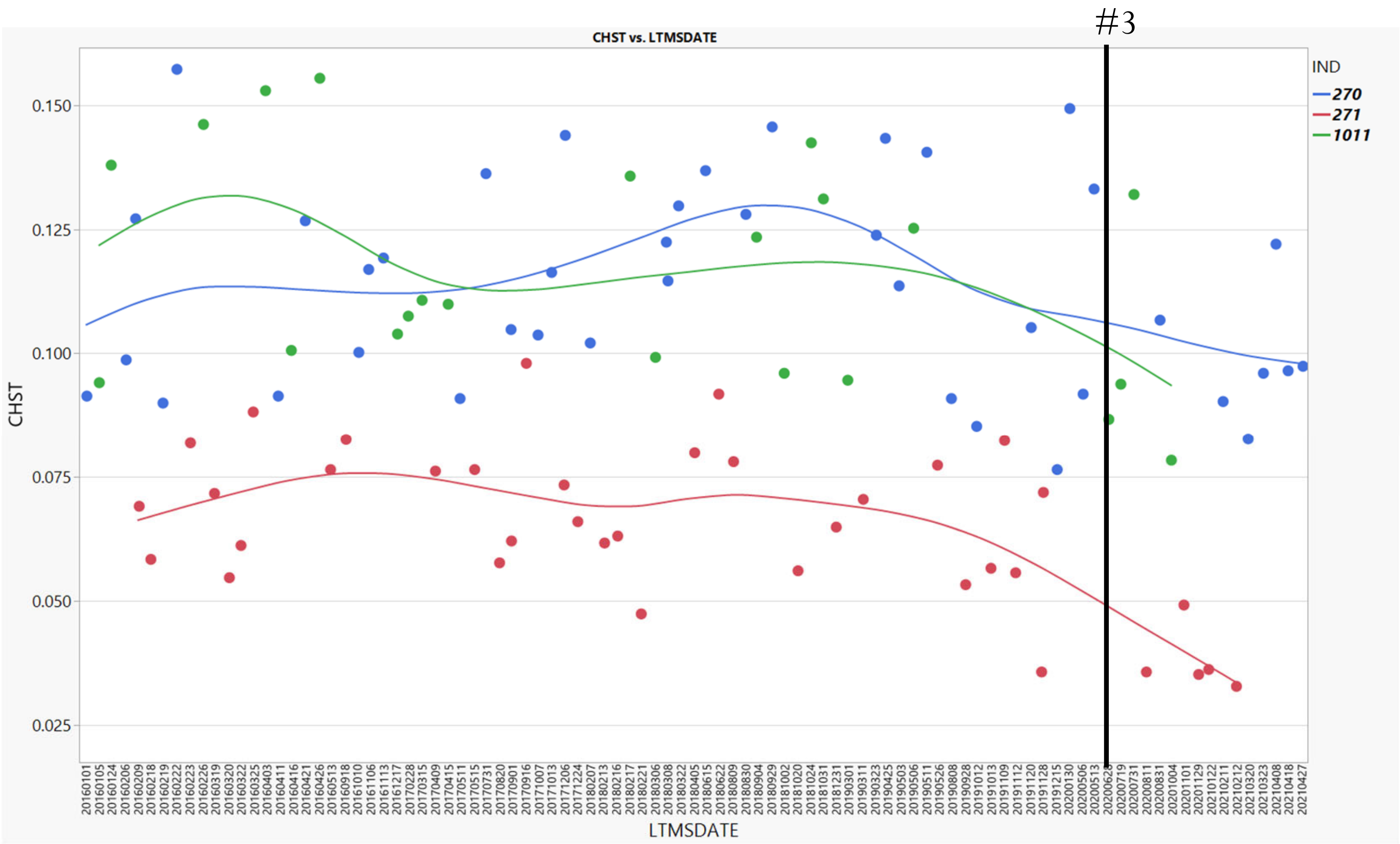
When did the shift occur?

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?

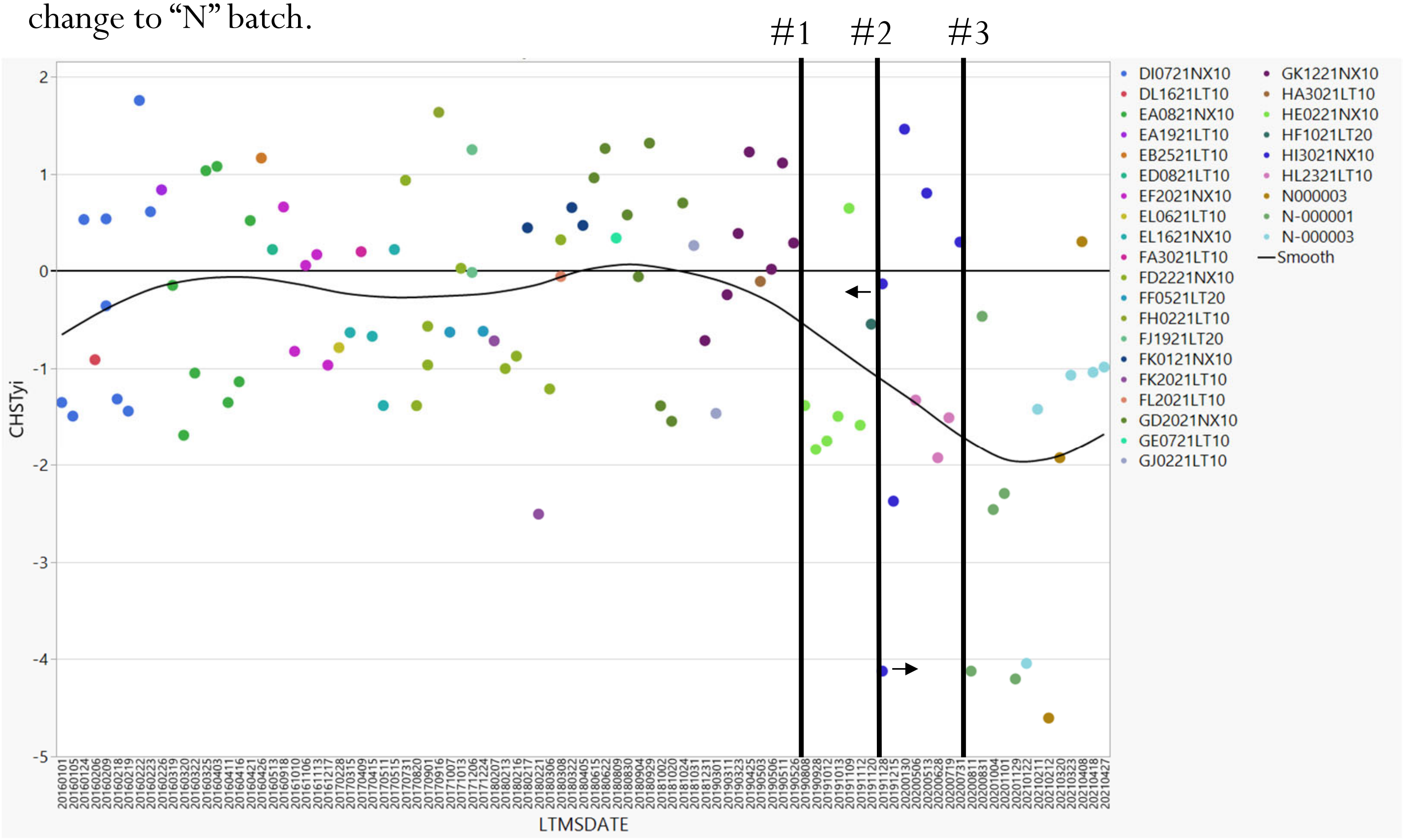
Split #3 appears to be the split which best captures the point in time when all 3 oils were producing almost exclusively mild results.



When did the shift occur?

-Fuel Batches

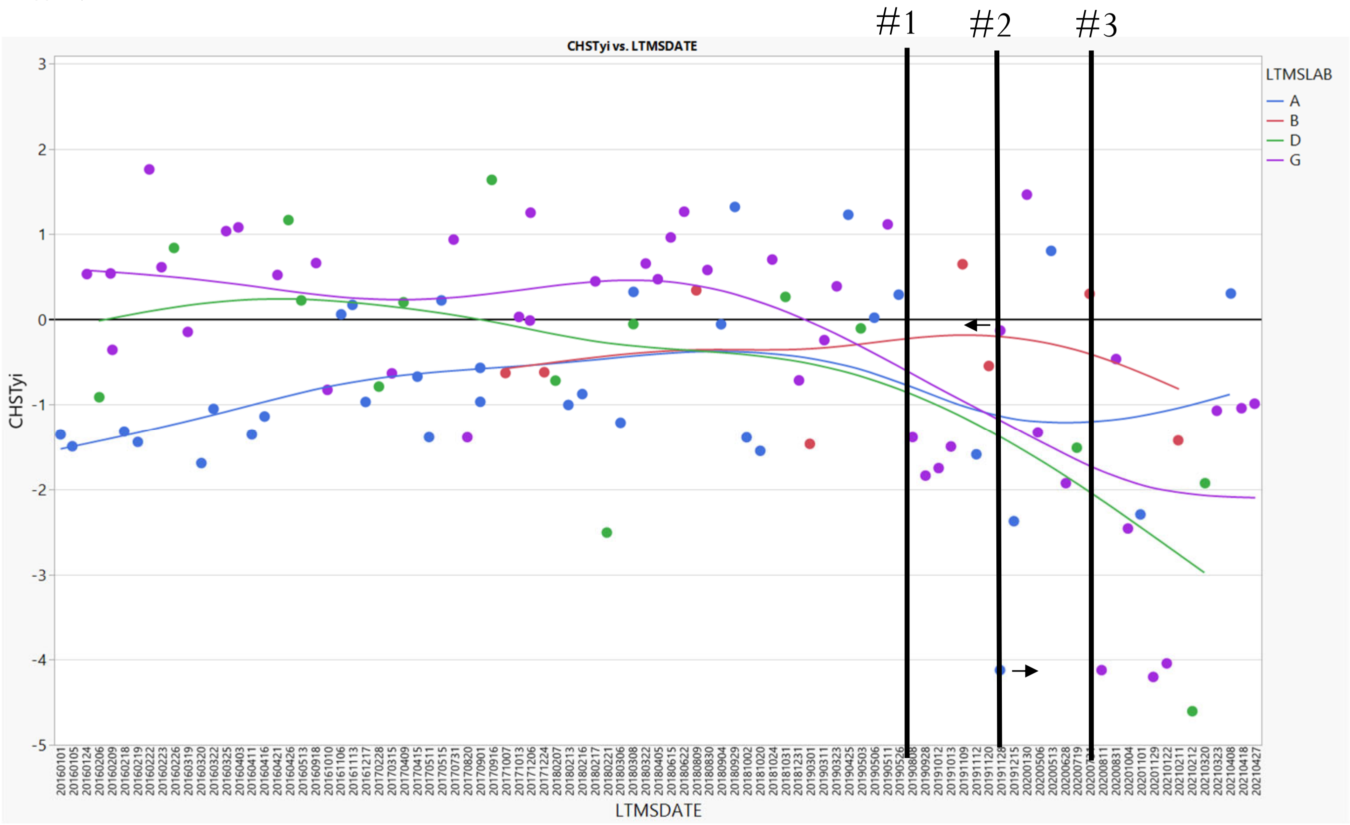
The data was colored by fuel batch ID to investigate how the timeline aligns with fuel batch changes. Split #1 lines up fairly well with change to "H" batch, while split #3 lines up with change to "N" batch.



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.

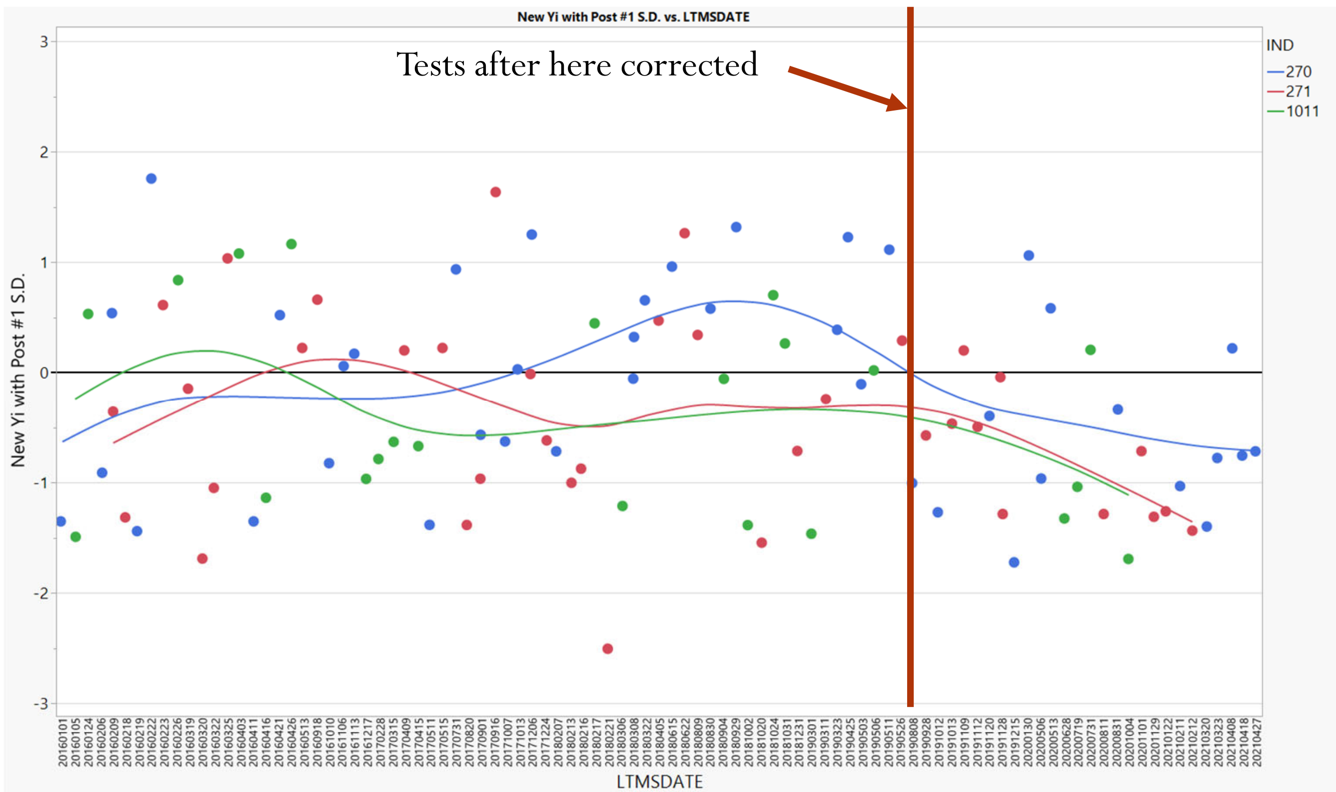
Oil	Current S.D.	S.D. Post #1	S.D. Post #3	S.D. All Data
270	0.17435	0.24011	0.21619	0.19023
271	0.17537	0.56272	0.77157	0.33291
1011	0.18882	0.27434*	0.24701*	0.21735
Pooled	0.17856	0.39913	0.46779	0.25746
Recommended		0.24011**		

* - 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

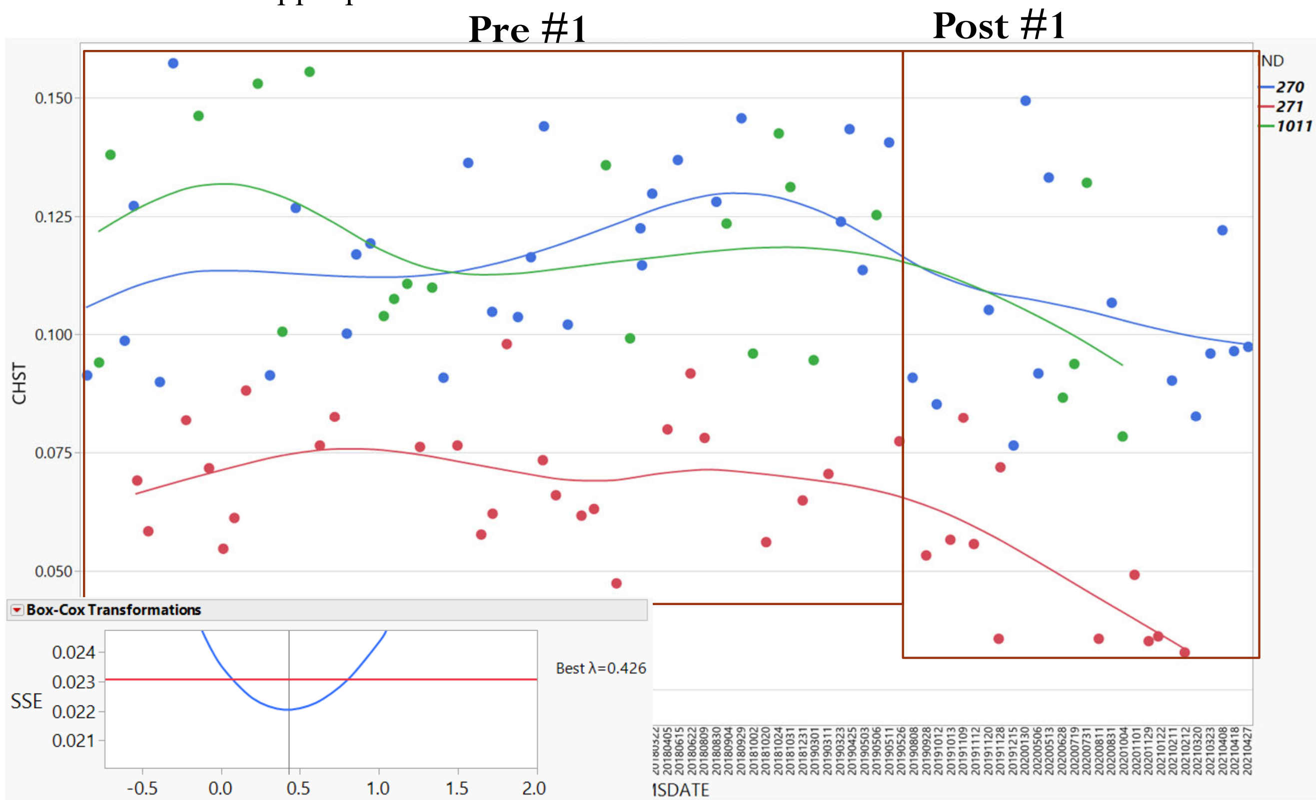
Appendix

Re-evaluation of the Transformation

Re-evaluating the transformation

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

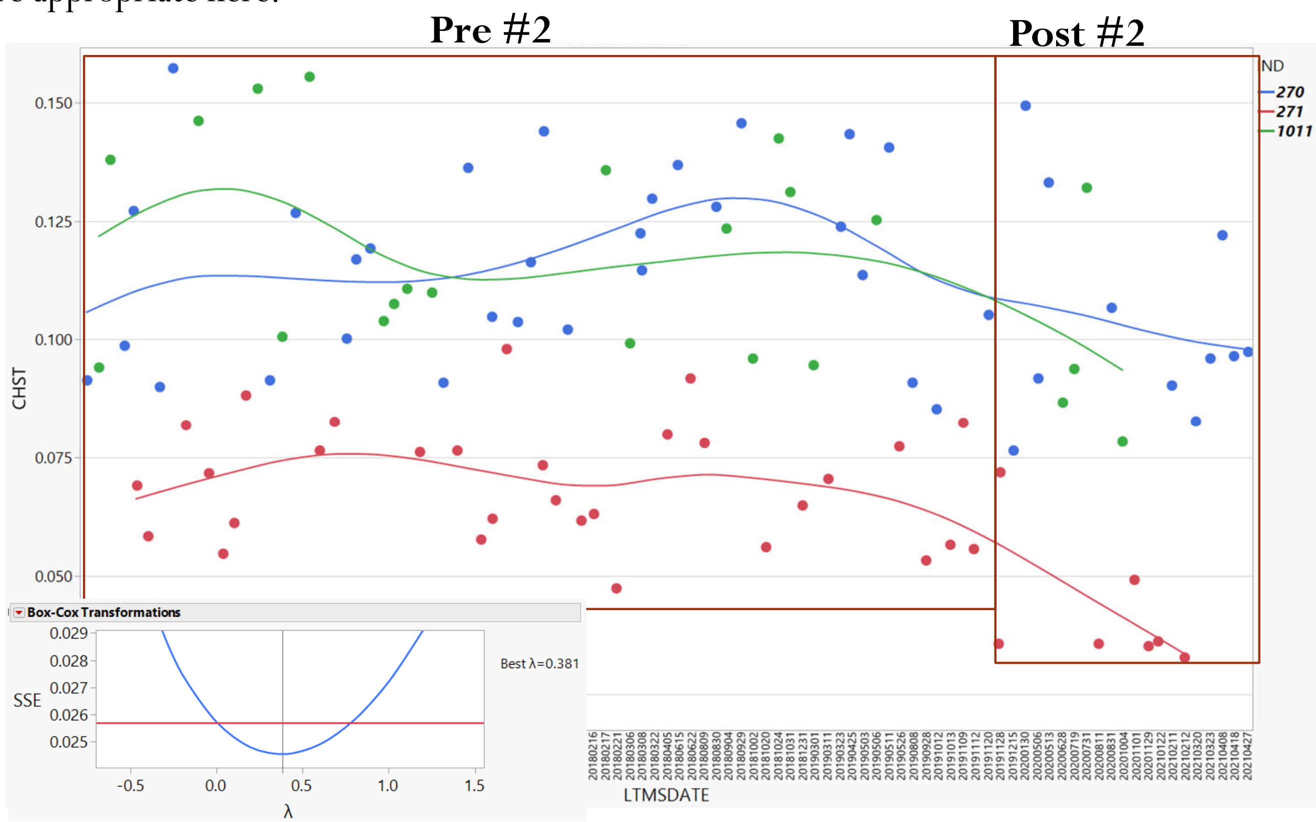
Partition analysis suggests best split at 08/08/19. All data in in right box labeled as “Post.” All other data labeled “Pre”. Then modeled CHST ~ Oil, Lab, Stand[Lab], Pre/Post. Square root transformation more appropriate here.



Re-evaluating the transformation

-Using All Data with "Pre" or "Post" added to Model

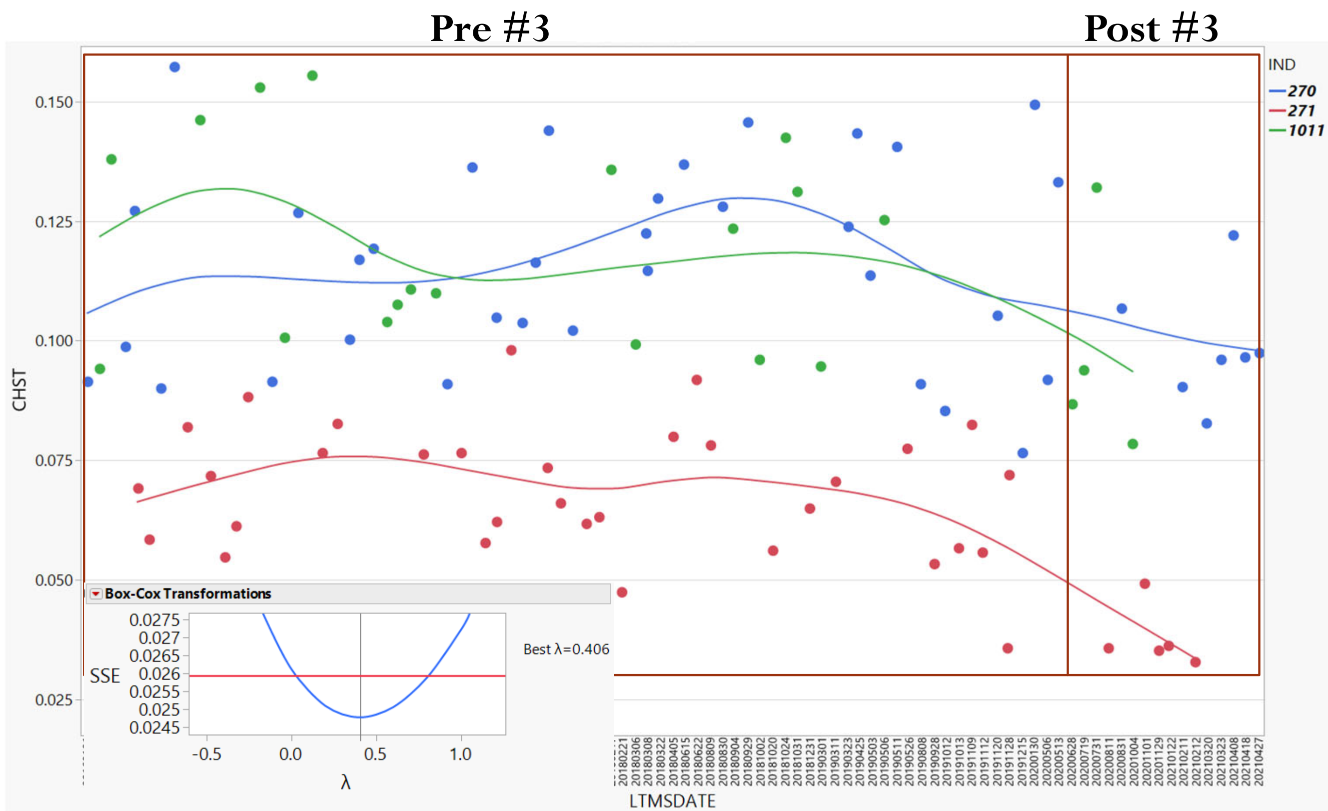
All data in in right box labeled as "Post" (except for first near target 271). All other data labeled "Pre". Then modeled CHST ~ Oil, Lab, Stand[Lab], Pre/Post. Square root transformation more appropriate here.



Re-evaluating the transformation

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

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.



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

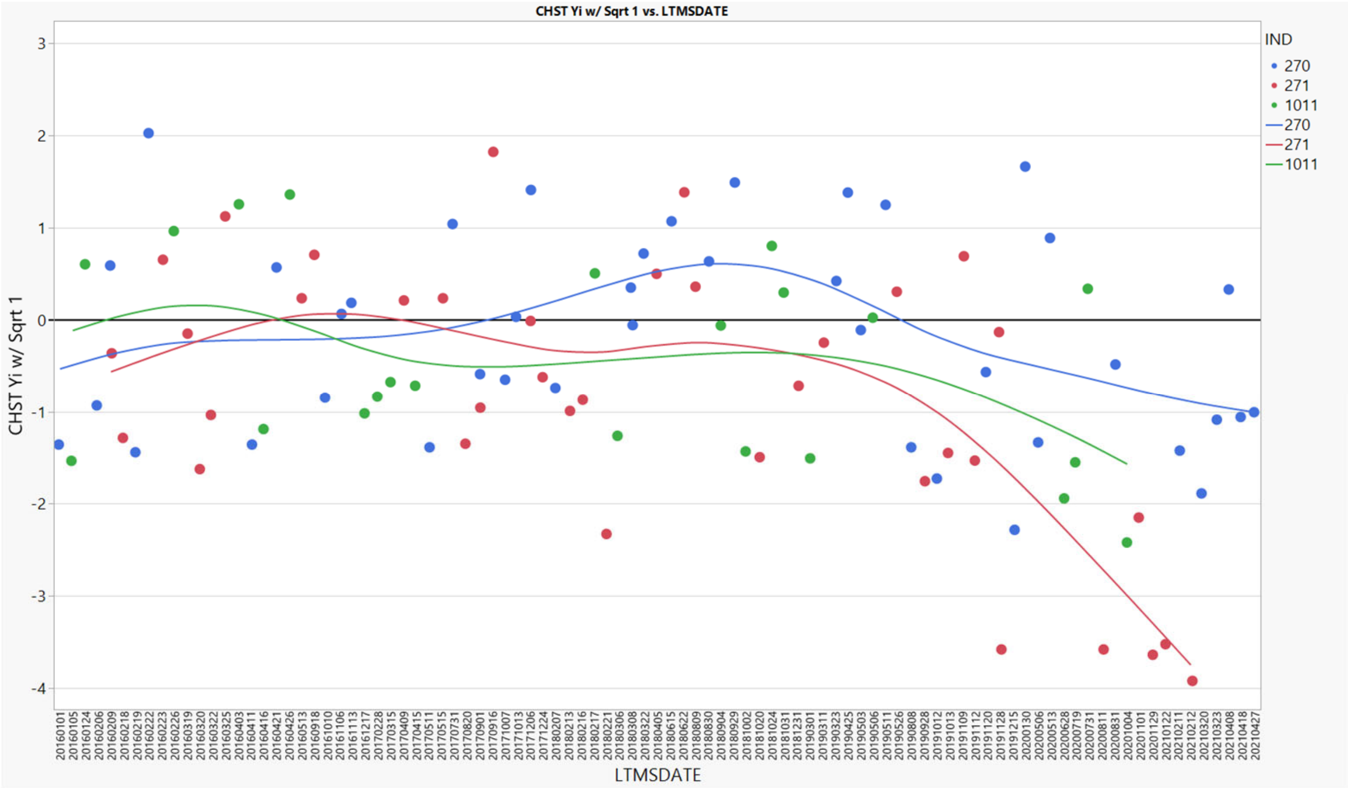
Standard Deviation #1 – For each Oil, Calculated Std. Dev. of (Result-Target). Used $n = 71$ data set prior to any evidence of the mild shift (labeled "Pre #1" in previous slide).

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

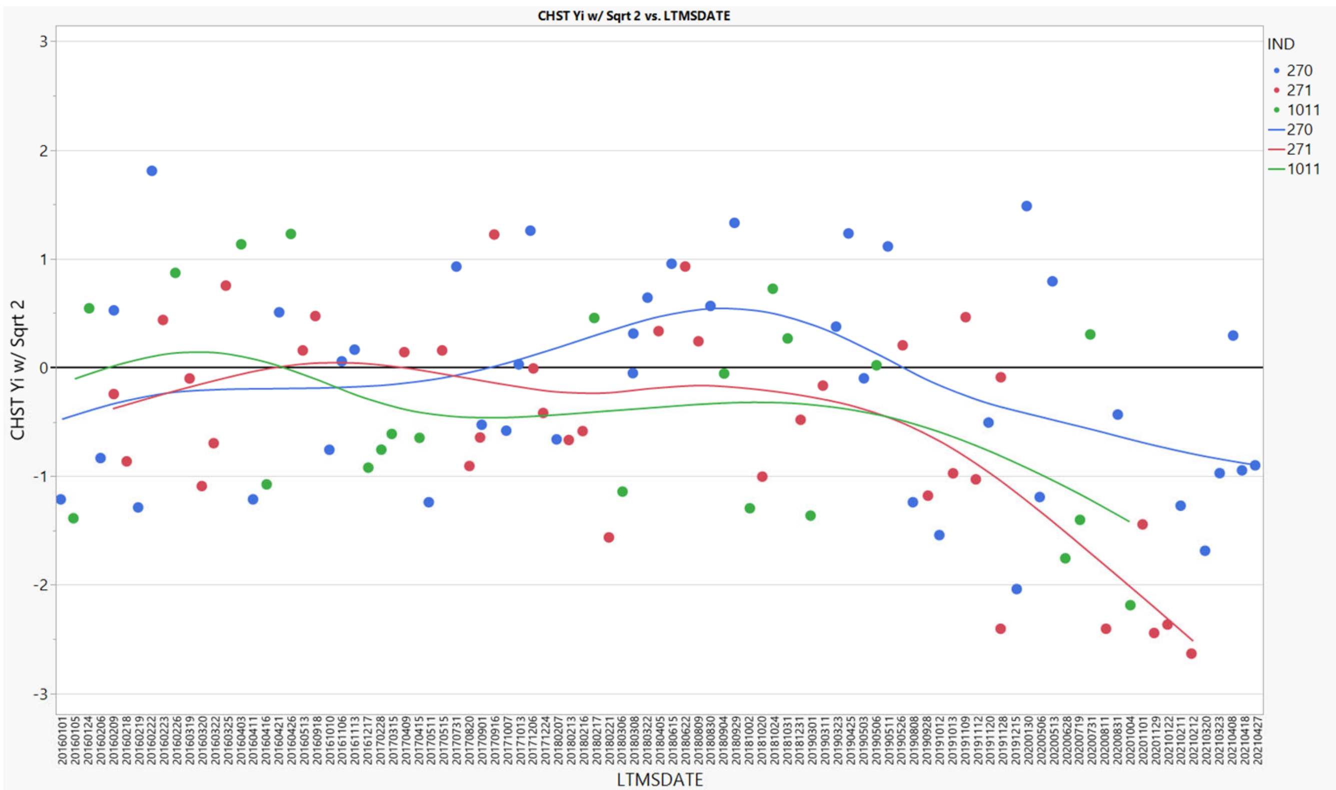
Plot of CHST Yi Using Sqrt. With SD#1

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.

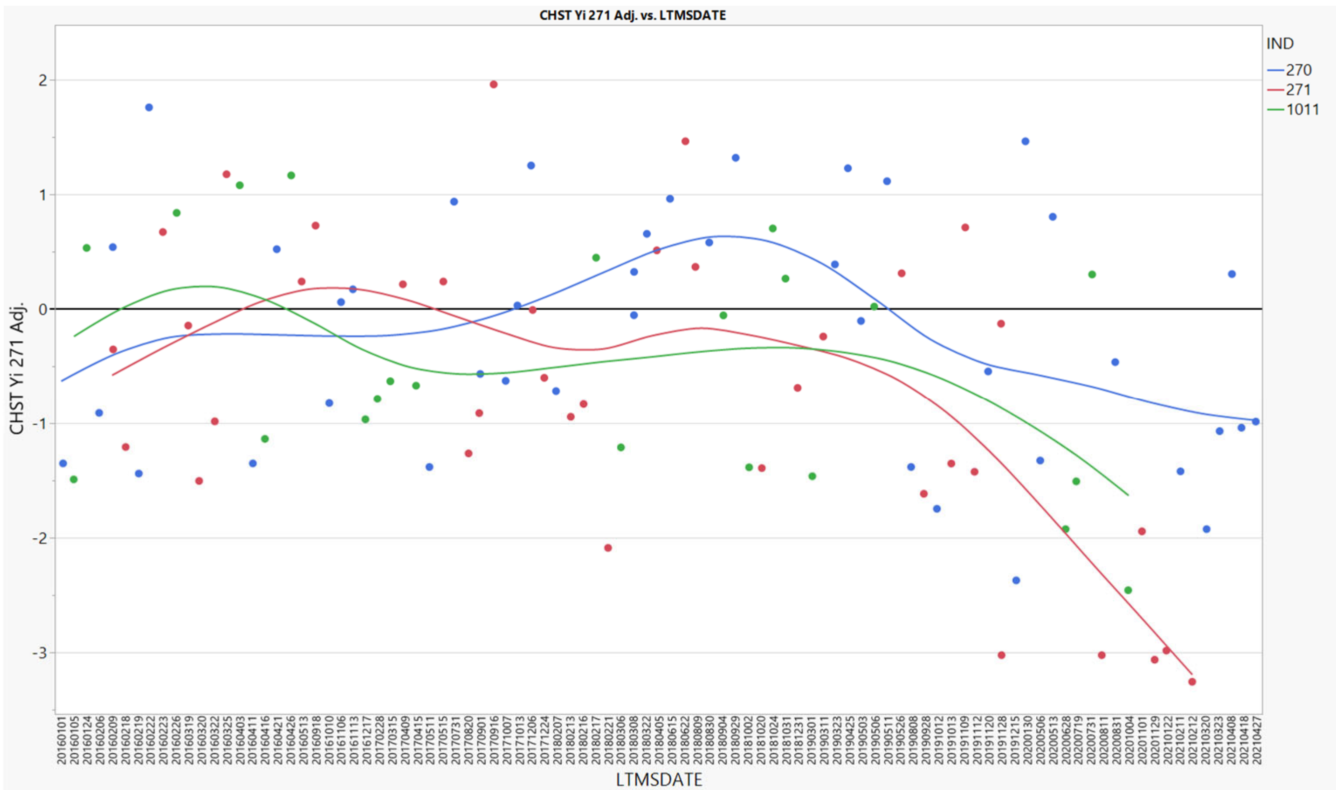
Oil	CHST Mean	Standard deviation
271	0.0735	0.0125

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

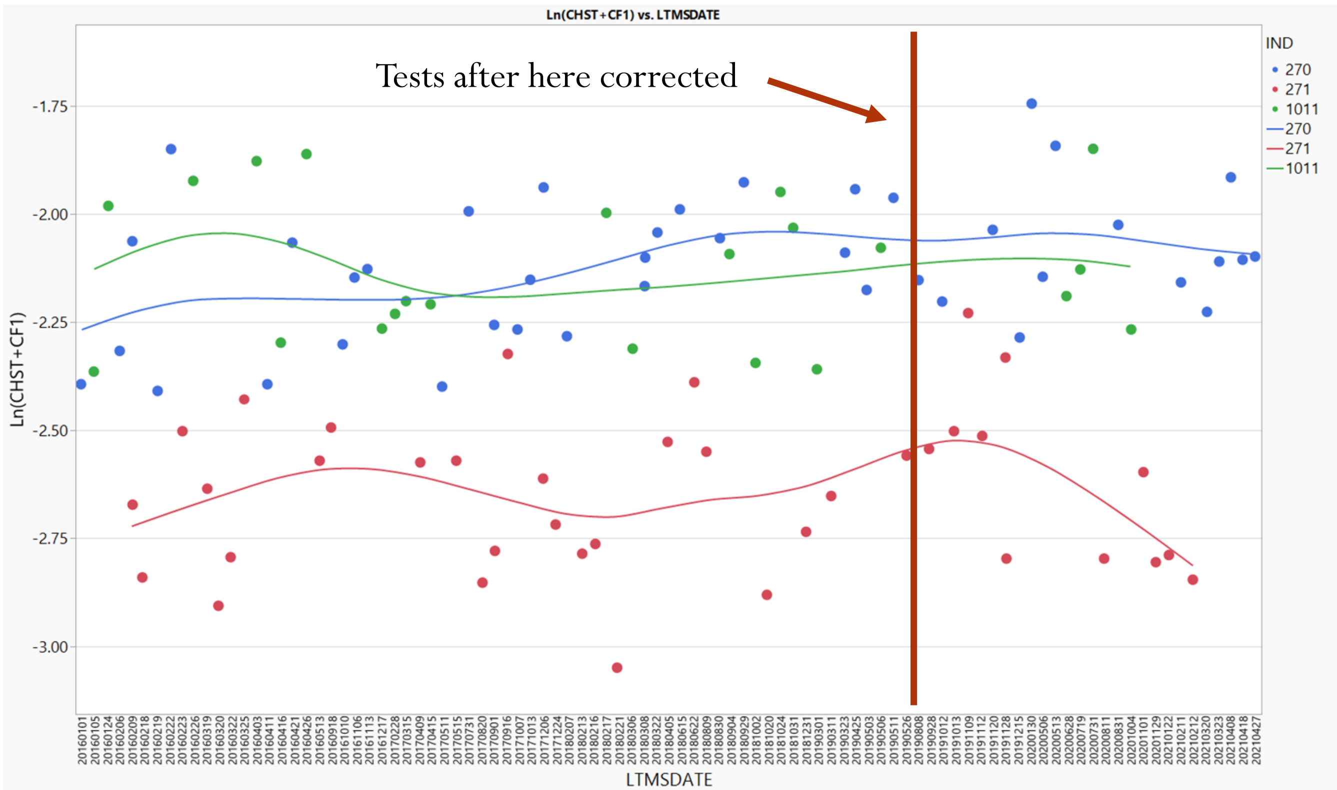
Below are some options for corrections to be applied to all tests depending on when you choose to identify the start of the shift and the type of correction factor you wish to apply (before of after transformation).

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).

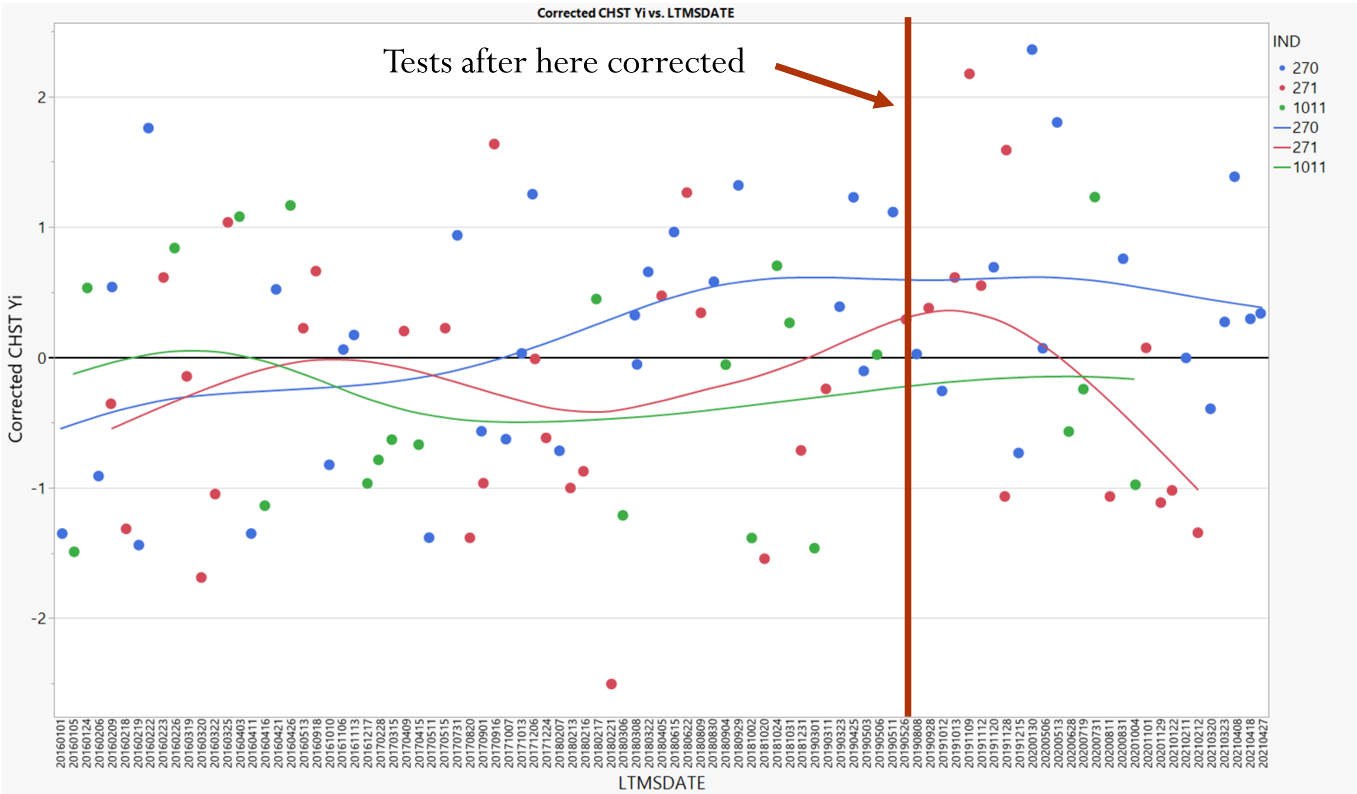
Ln(CHST+CF) with Measurement Correction Factor #1 -Corrected To Target

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



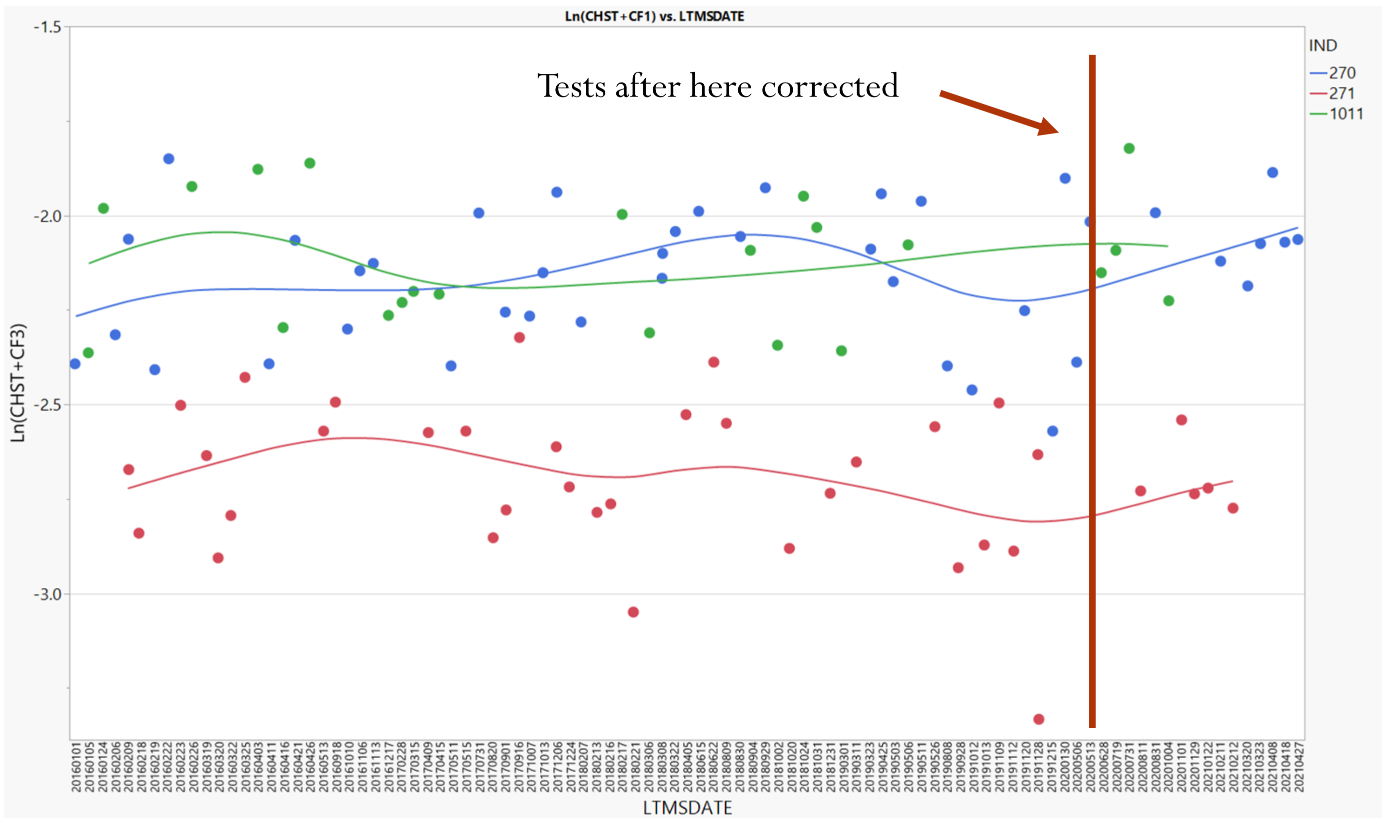
LN(CHST+CF) with Measurement C.F. #1

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



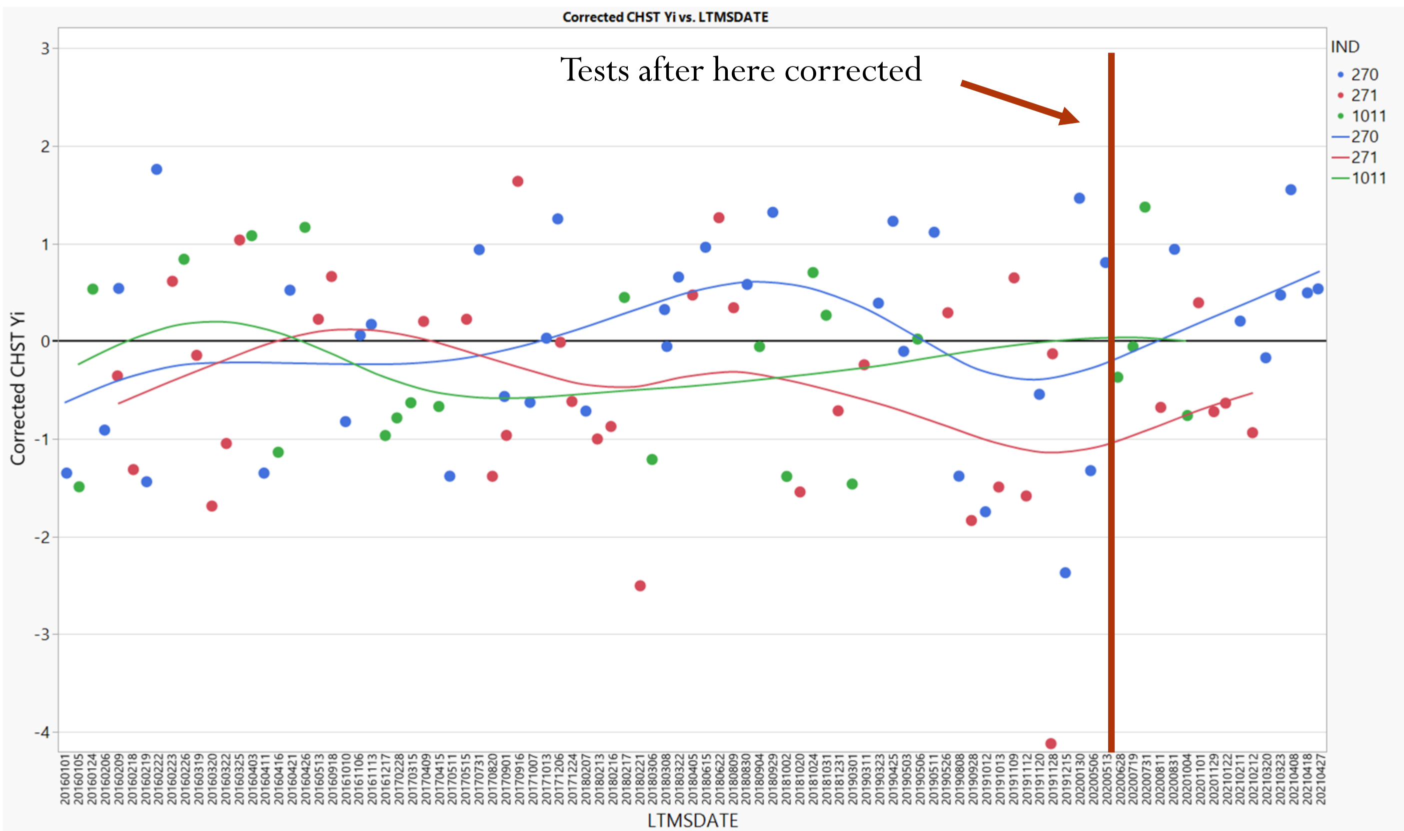
Ln(CHST+CF) with Measurement Correction Factor #3 -Corrected To Target

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.

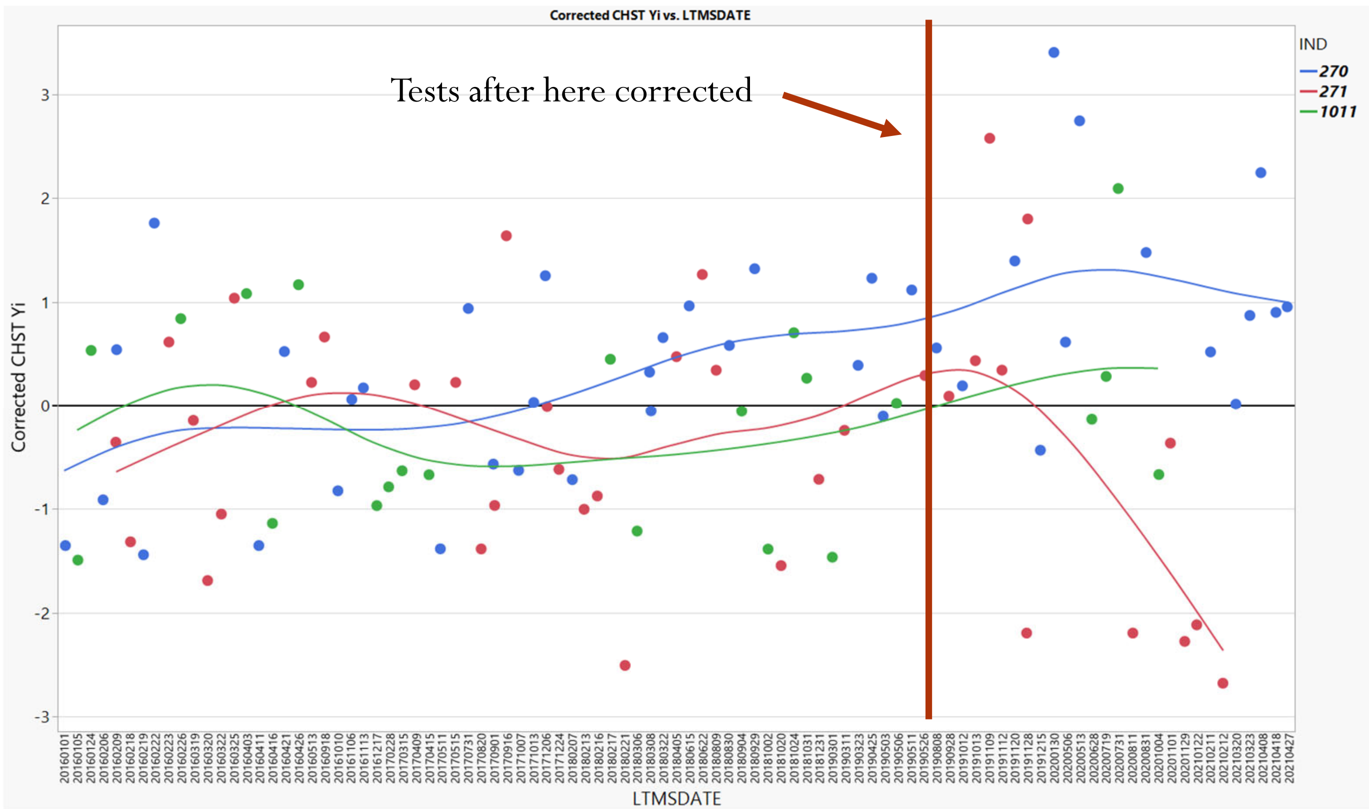


Ln(CHST)+CF with Correction Factor #4

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

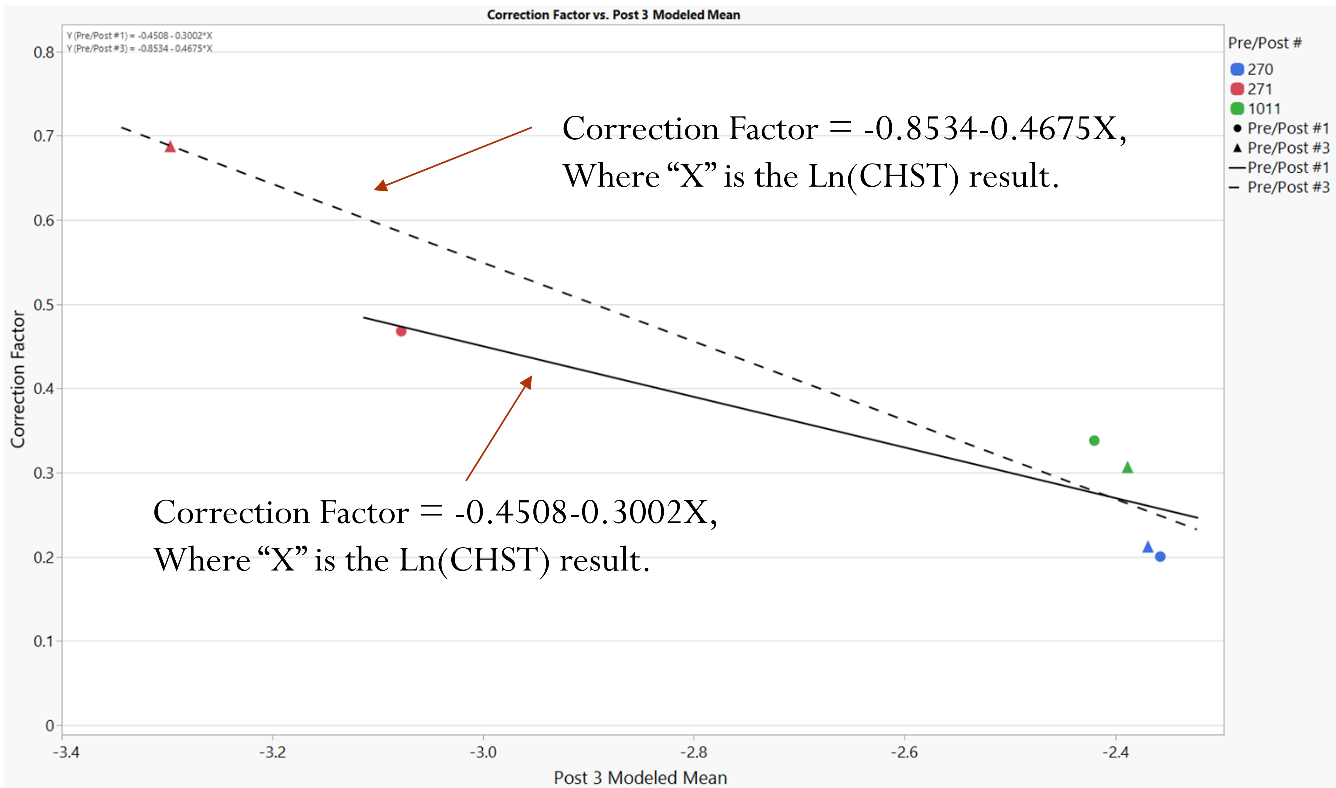
Ln(CHST)+CF with Correction Factor #4

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.



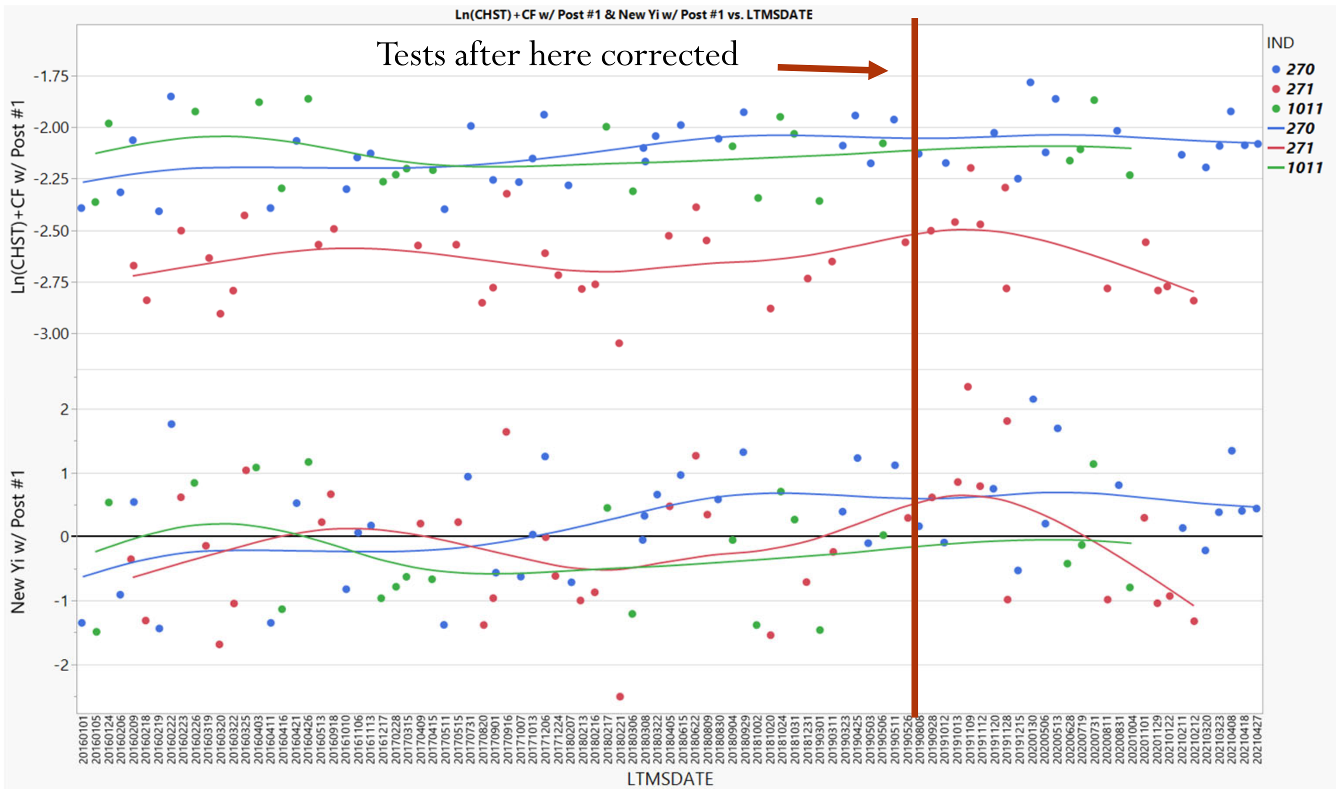
Correction factors by CHST Level

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

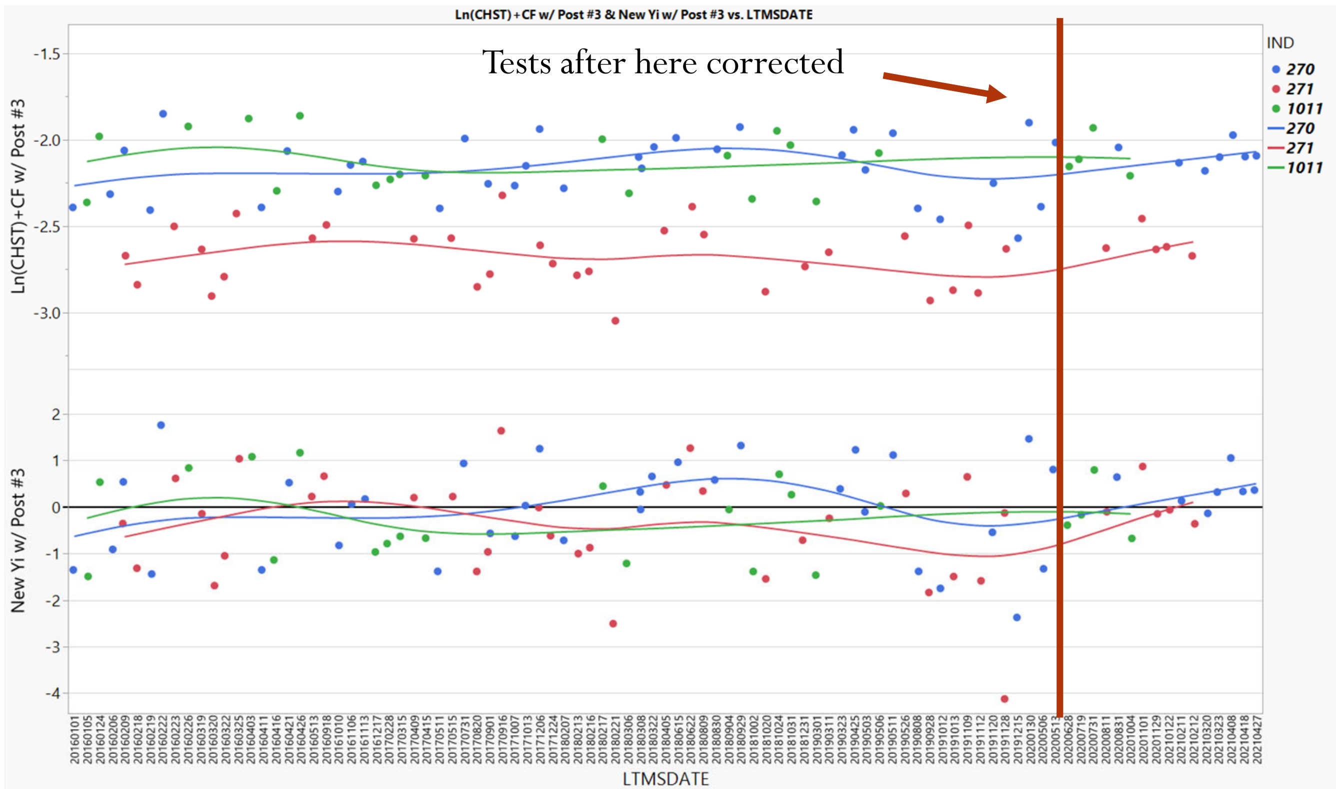
New Ln(CHST) and Yi w/ Post #1

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

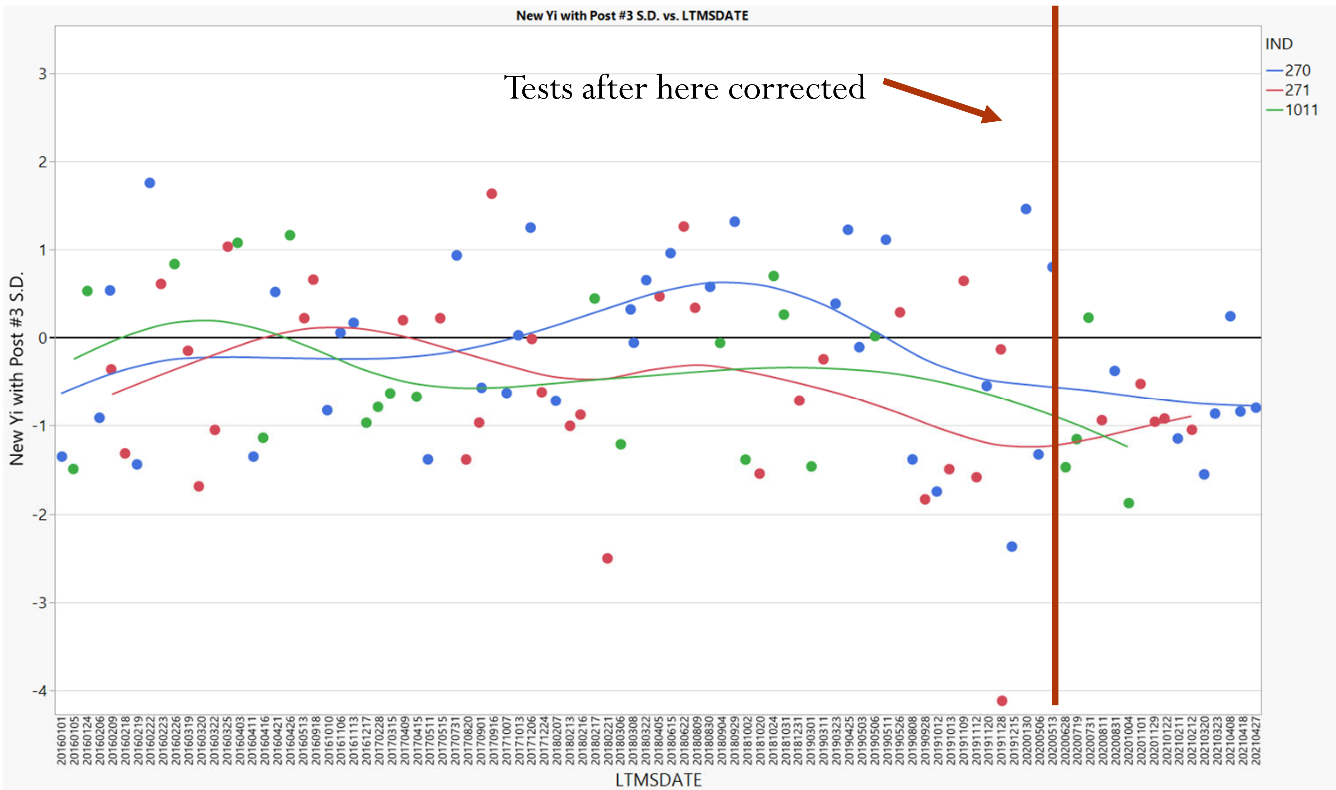
The table below shows how data after 06/28/2020 would change with the level-dependent correction factor.



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.