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COMMITTEE D02 on PETROLEUM PRODUCTS, LIQUID FUELS, AND LUBRICANTS

Issued: August 27, 2020
Reply to: Dan Worcester

Southwest Research Institute
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San Antonio, TX 78238
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These are the unapproved minutes of the 8.25.2020 Sequence VI Conference Calls.

The meeting was called to order at 9:03 AM Central Time by Chair Andrew Stevens.

1.0 The Agenda is Attachment 1.
2.0 Roll Call. Attendance is Attachment 2. There were no member changes.

3.0 Old Business

MOTION: Approve minutes from the 07.17 and 07.21.2020 combined conference calls. Andrew, Adrian second. Approval was unanimous.

4.0 New Business

4.1 Andrew reviewed the issue that the procedure was not clear on the intake air pressure port. Here is what the VIE procedure says:

6.12.6 Intake Air—Measure the intake air pressure at the location shown in Fig. A5.16. Use a sensor/readout accuracy of 2 % of full scale with resolution of 5.0 Pa.

4.1.1 Figure A5.16 is actually the exhaust probe. There was discussion on the intent and the original designed was based on a similar probe for the intake air pressure parallel to the flow.

4.1.2 The decision was made for a motion to clarify the probe and location.

MOTION: Use probe as described in A5.16 oriented to center of intake air flow. Install as shown in A5.12.
Andrew, Adrian second. The motion passed unanimous.

4.2 Fuel Testing Historical Analysis

4.2.1 Todd Dvorak presented slide that compared batches of fuel with 314 results to look for fuel parameters that may affect test severity or variation. See Attachment 3.

4.2.2 60 results have complete hydrocarbon analysis but one result was removed as an outlier.

4.2.3 The data shows the test is sensitive to baseline blends. BL-3 was used for the Precision Matrix. We are on BL-5 now. Engine hours also has a definite effect and the engine uses less fuel as the engine ages.

4.2.4 Other items that showed statistical significance were Dist_T50, Dist_T90, Residue and Sulfur.

4.2.5 Rich commented that labs run a comparison matrix for each new batch compared back to BL-2.

4.2.6 Net heating value shows sensitivity but it has tight limits on the measurement procedure.

4.2.7 One recommendation would be to develop a DOE [design of experiment] to reduce possible interactions.

4.2.8 It was noted that analysis results are strongly dependent on the lab running the tests and all data for this analysis was run by Haltermann's lab. One concern is there may be more engine/lab variation that would override this data.

4.3 Fuel Round Robin Analysis

4.3.1 There are many holes in the data. Of the seven columns of data, 5 were run at the same lab. SwRI ran additional analysis to complete the fields on tanks 180A and 180B, but did not run those tests for the other labs fuels.

4.3.2 There was also an issue that different procedures were used, and again variation of results may be for individual labs, not in the fuel.

4.3.3 Some results used converted measurements, or the wrong units were used.

ACTION: Labs will work to fill in all the blanks and the next meeting will be scheduled for data review when that work is completed. Work should focus on parameters that were shown as significant in Todd's analysis.

Discussion of the Fuel Round Robin Data will continue at another meeting to be scheduled.

The meeting adjourned at 10:35 AM.

Sequence VI Surveillance Panel Call Meeting Agenda
August 25, 2020 @ 10:00-11:30 EST

Webex Meeting Details Below Agenda

1. Roll Call (start 10:05 EST)

1.1. SP Membership changes and additions

2. Old Business

2.1	Approve Minutes from 7/16, 7/21 calls	Andrew Stevens

3. New Business

3.1	Intake Air Pressure Clarification (See Appendix)	Andrew Stevens
3.2	Fuel Testing Round Robin Update	Panel

4. Next Meeting

4.1. SP Meeting: TBD

5. Meeting Adjourned

APPENDIX

Andrew Stevens:

Not clear if below section requires a probe to be used or not. Intake air pressure section of procedure (6.12.6) refers to A5.16 in Appendix which details the exhaust probe. A5.12 shows location of intake probes and a shape that could be assumed to be a probe but is not specifically called out. 6.12.6 also only refers to a measurement location and not the use of a probe. Clarification/corrections need to be made.

6.12.6 Intake Air—Measure the intake air pressure at the location shown in Fig. A5.16. Use a sensor/readout accuracy of 2 % of full scale with resolution of 5.0 Pa.

ASTM SEQUENCE VI

Name	Email	Company	Attend

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Amol Savant	acsavant@valvoline.com	Valvoline	ATTEND

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Haiying Tang				
Tracey King				
Ron Romano				
Paul Rubas				
Jim Carter				
Aleise Gauer				
Prasad Tumati				
Andy Ritchie				
Adrian Alfonso				
Andrew Stevens				
Jason Bowden				
Jeff Hsu				
Dan Worcester				
Dan Lanctot				
Rich Grundza				
Teri Kowalski				
Amol Savant				

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Jeff Hsu				
Dan Worcester				
Dan Lanctot				
Rich Grundza				
Teri Kowalski				
Amol Savant				

VIE – EEE Fuel Properties Data Review

Todd Dvorak

July 14, 2020

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Executive Summary

- **Stepwise Regression Analysis performed on FEI1Yi, FEI2Yi, and (BLB1+BLB2+BLA) fuel consumed parameters**
  - Statistically significant for BL1+BL2+BLA (fuel consumed) include Engine Hrs, Baseline Oil Batch, Dist_T50, Dist_T90, Residue, and Sulfur
  - Statistically significant fuel effects for FEI1Yi and FEI2Yi include Lab, Baseline Oil Batch, Dist_T10, Dist_T50, Sensitivity, and NHV_D2401, and NHV-D33382
  - A number of the listed fuel property factors trend with calendar date and could be correlated with other unknown (coincidental) root causes

Overview of Dataset and Analysis Approach

Overview of Dataset and Analysis Approach

Data Available for Analysis

- Selected Chartable VIE test results with the same FBID at SOT and EOT (314 results)
- Dependent variables analyzed:
  - *FEI1Yi and FEI2Yi*
    - Standardized FEI test results which includes engine hour adjustments, reference oil adjustments, and industry correction factors
  - *BLB1+BLB2+BLA*
    - Sum represents the total fuel consumed during the baseline phases
- Analysis Method:
  - Mixed (forward and backward) stepwise regression analysis with $p \leq 0.10$

Overview of Data and Analysis Approach

- **Complete Hydrocarbon Analysis data was available for only (60) of the 313 test results**
  - Regression models excluded this data from the analysis
  - Plots of all fuel variable data are included at the end of this document
- **Independent variable data included in the Stepwise Regression Analysis are listed below**
  - Note – Stand nested in Lab not included (due to data limitations)

BLB1+BLB2+BLB3 *(only)*

EngVar
EngHrEnd

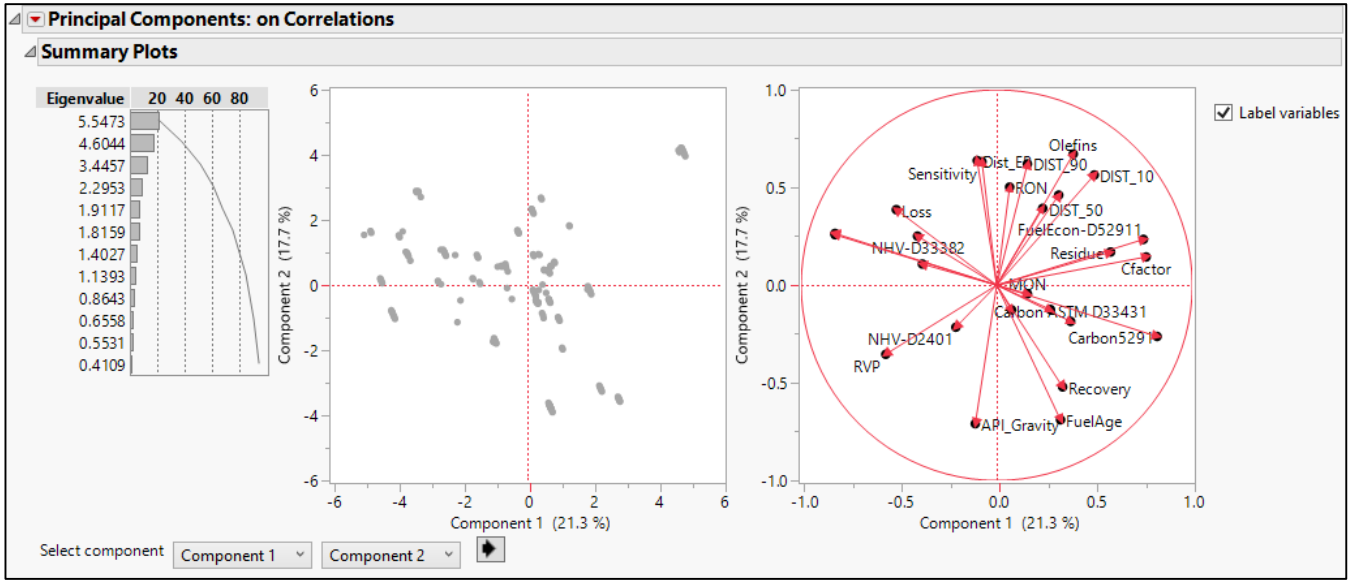
BL Oil Variable
BL3
BL4
BL5

Lab Variables
Lab A
Lab B
Lab C
Lab D
Lab F
Lab G

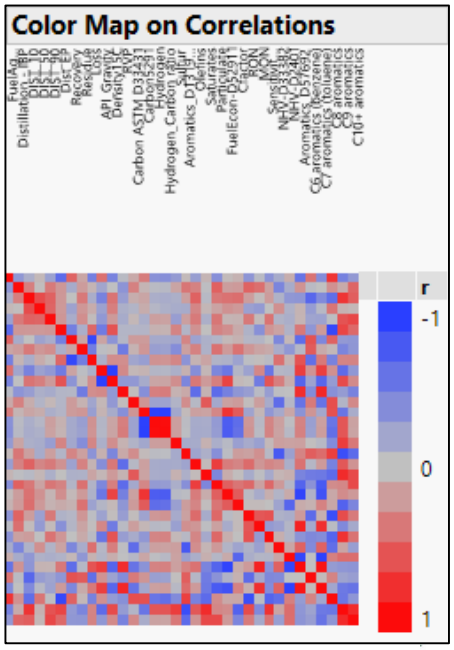
Fuel Related Variables
FuelAge
Distillation - IBP
DIST_10
DIST_50
DIST_90
Dist_EP
Recovery
Residue
Loss
API_Gravity
RVP
Carbon ASTM D33431
Carbon5291
Hydrogen
Hydrogen/Carbon ratio
Sulfur
Aromatics_D13192
Olefins
Saturates
FuelEcon-D52911
Cfactor
RON
MON
Sensitivity
NHV-D33382
NHV-D2401

Overview of Data and Analysis Approach

- **Need to be cautious when interpreting regression analysis results of variables - due to Multicollinearity**
  - Principal Component Analysis (PCA) and color map indicates collinear relationships between the fuel property variables
    - PCA indicates that 80% of the variation is explained in 7 Factors
    - Red/Blue colors in Correlation Map indicate high *(r)* correlations



PCA Summary



Correlation Map

Stepwise Regression Analysis of Fuel Consumed Data
(BLB1 + BLB2 + BLB3)

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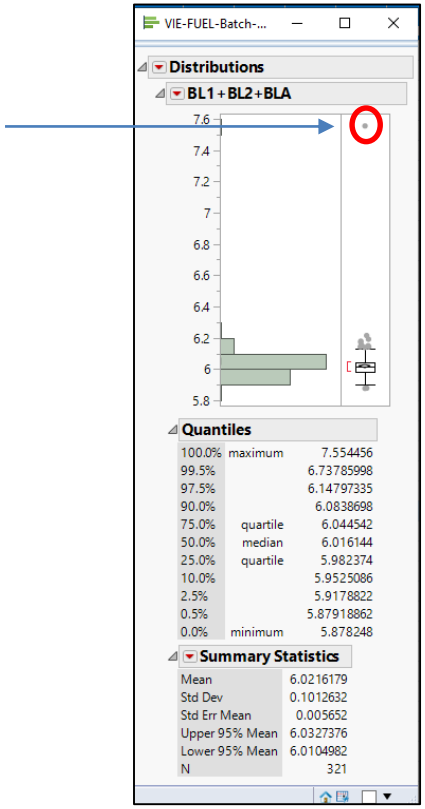
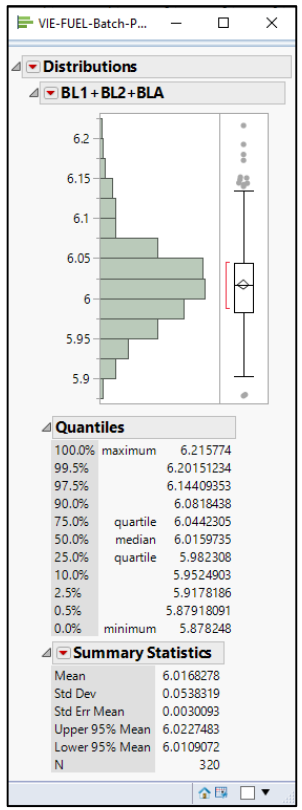
Stepwise Regression Analysis of Fuel Consumed Data

Histogram of data suggests 1 result with a high (BLB1+BLB2+BLA) Result

- High result will be removed from analysis (Test Key 142366-VIE)



With High Result



High Result Omitted

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Stepwise Regression Analysis of Fuel Consumed Data

Stepwise regression results (mixed selection with $p \leq 0.10$)

- Model suggests some fuel parameters are statistically significant
- Due to multicollinearity, it is difficult to determine if the identified fuel parameters are the true source of systemic variance

Response BL1+BL2+BLA

Whole Model

ENHREND | BL5OIL | DIST_50 | DIST_90 | Residue | Sulfur

- Actual by Predicted Plot
- Effect Summary
- Lack Of Fit
- Residual by Predicted Plot

Summary of Fit

RSquare	0.224612
RSquare Adj	0.209408
Root Mean Square Error	0.046512
Mean of Response	6.017887
Observations (or Sum Wgts)	313

Analysis of Variance

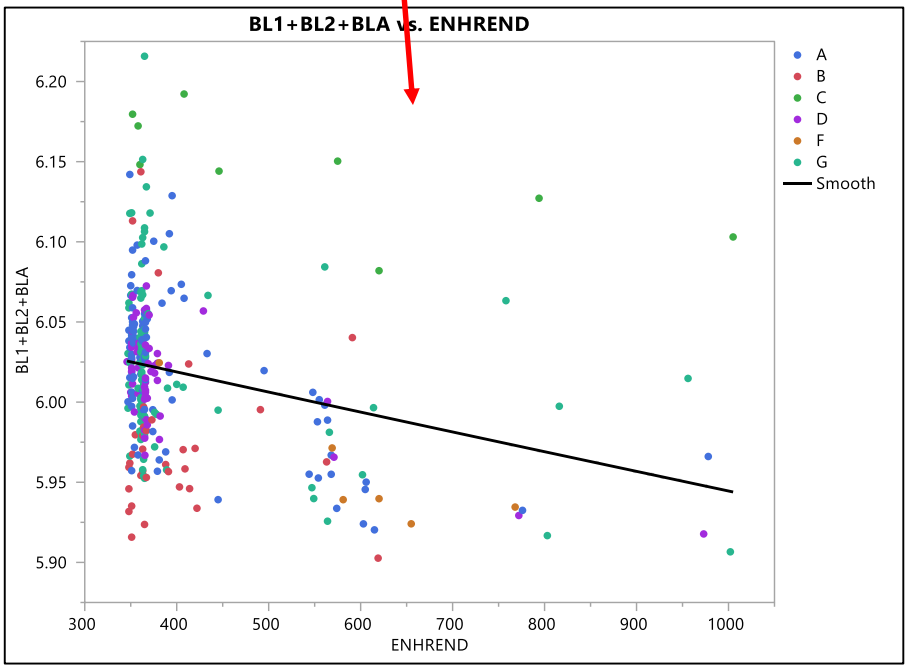
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	0.19176260	0.031960	14.7735
Error	306	0.66198832	0.002163	Prob > F
C. Total	312	0.85375092		<.0001*

Parameter Estimates

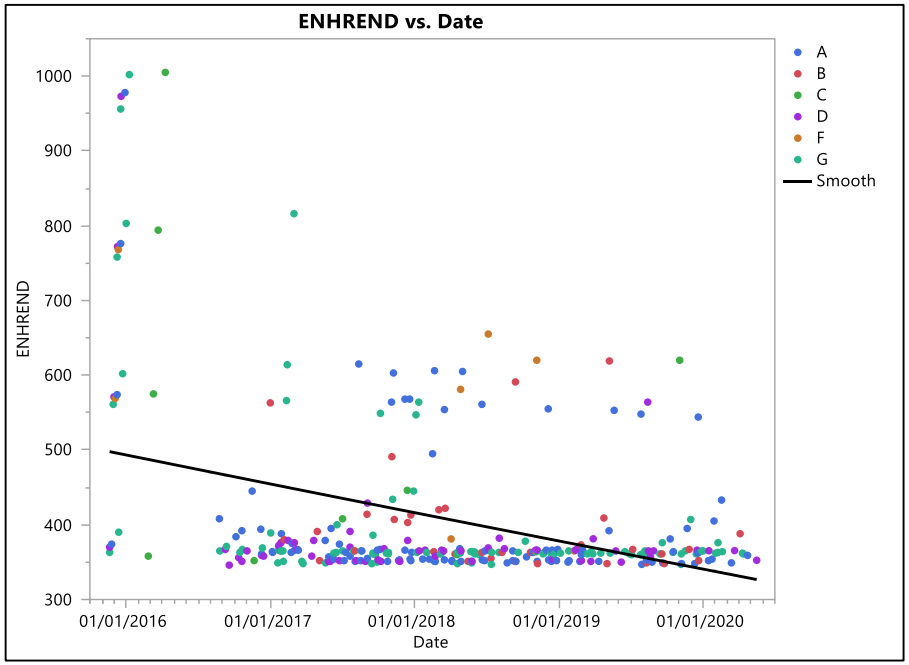
Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	5.5267709	0.362695	15.24	<.0001*	.
ENHREND	-0.000184	2.425e-5	-7.58	<.0001*	1.1383722
BL5OIL	-0.017313	0.00626	-2.77	0.0060*	1.382813
DIST_50	0.0112893	0.003357	3.36	0.0009*	1.7679525
DIST_90	-0.004385	0.002276	-1.93	0.0550	1.4652713
Residue	0.0882942	0.020113	4.39	<.0001*	1.2678828
Sulfur	0.0044035	0.002013	2.19	0.0294*	1.3867529

Stepwise Regression Analysis of Fuel Consumed Data

- **Higher Engine Hours trends with a declining fuel consumption (for BLB1+BLB2+BLA)**



BLB1+BLB2+BLA vs. Engine Hours



Engine Hours vs. Date

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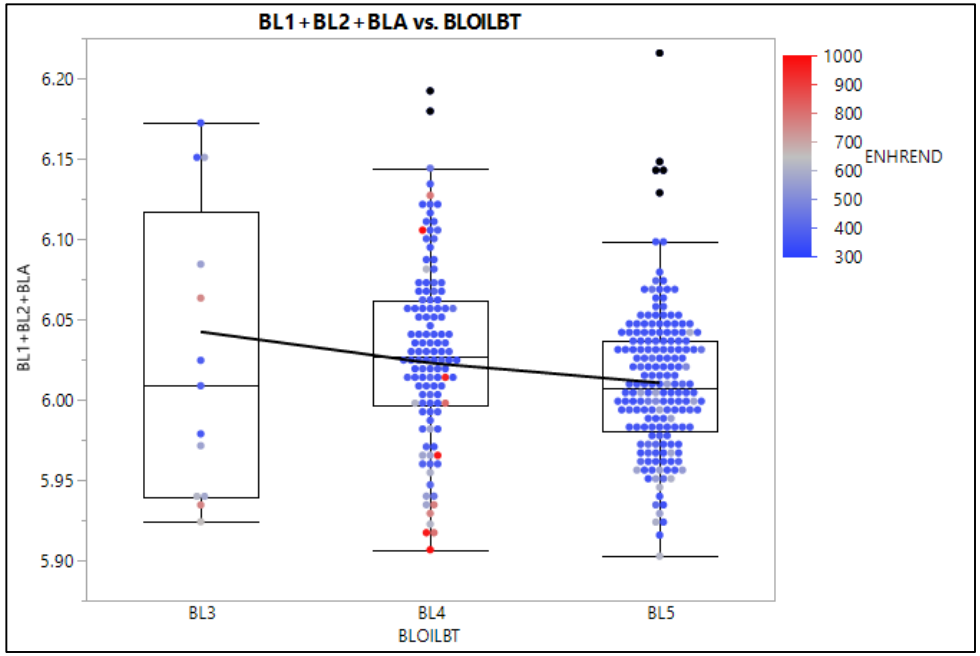
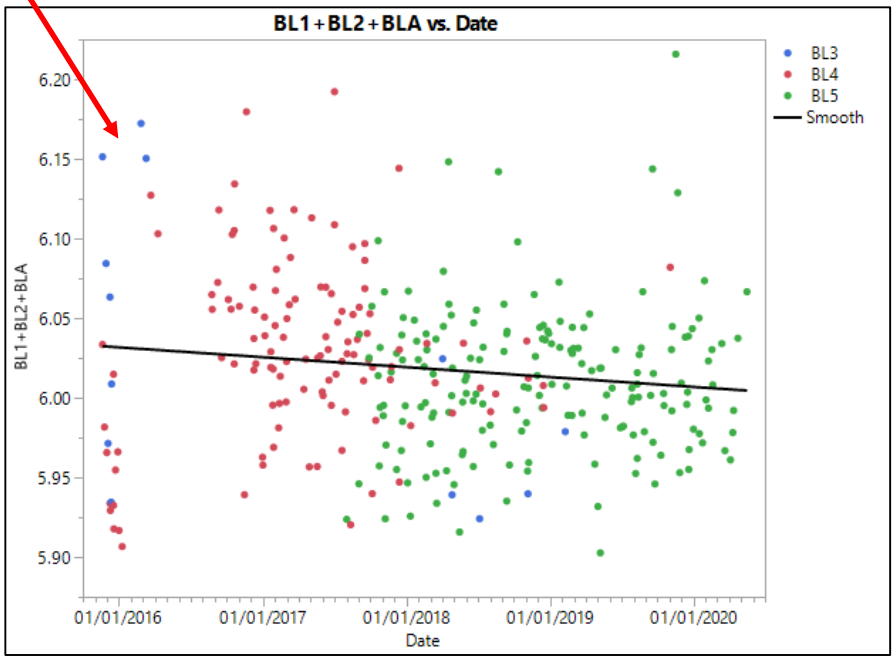
Stepwise Regression Analysis of Fuel Consumed Data

Plots of significant variables – Baseline Oil Batch

- BL Batch correlated with calendar date



BLB1+BLB2+BLA by BL Batch



BL Batch vs. Date

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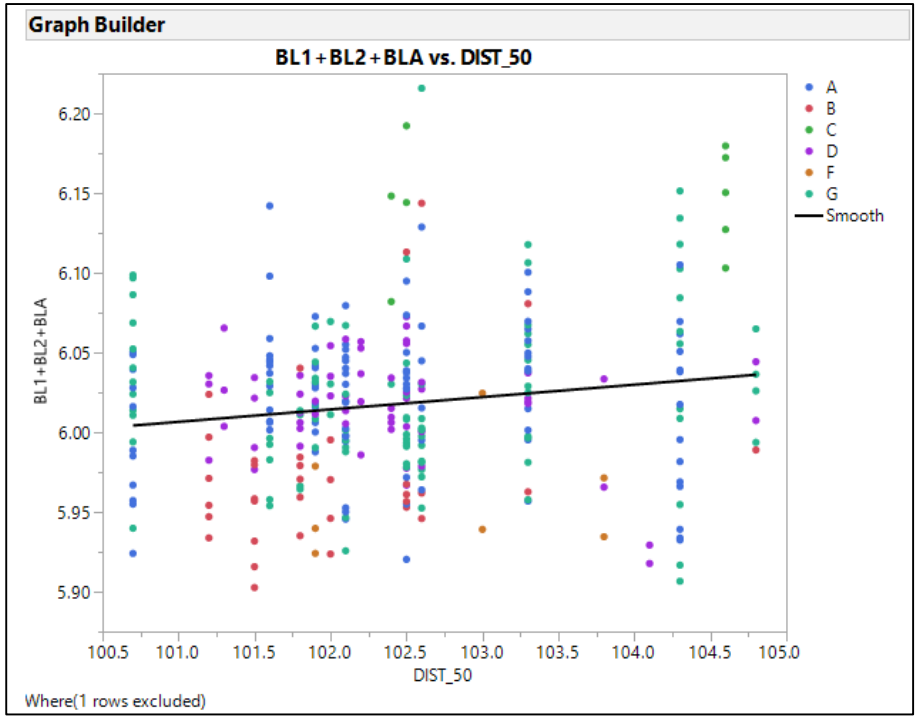
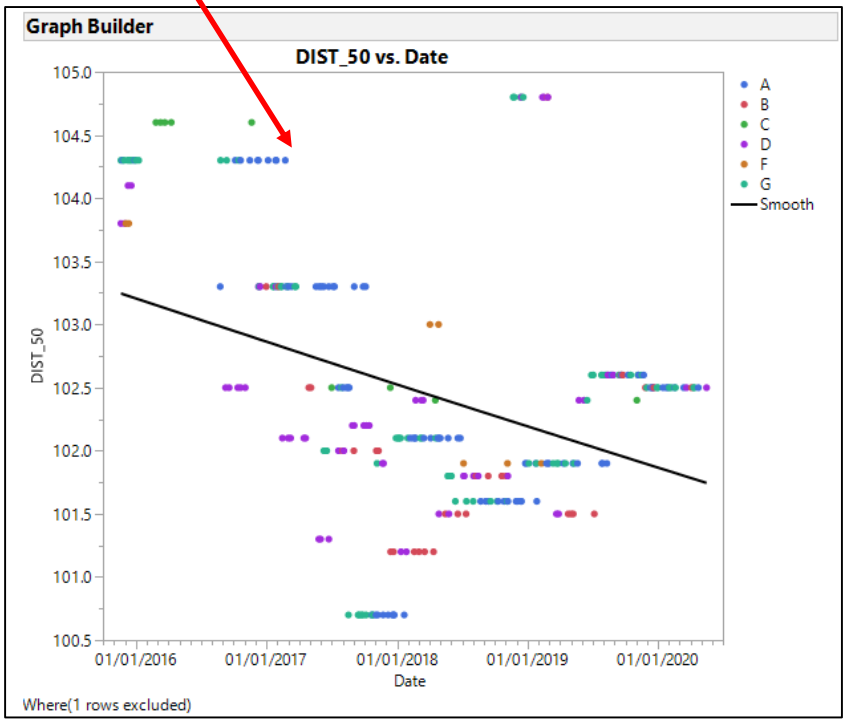
Stepwise Regression Analysis of Fuel Consumed Data

Plots of significant variables – Dist_T50

- Range of Dist_T50: 100.7 – 104.8
- Dist_T50 exhibits some relationship with calendar date



Dist_T50 vs. BLB1+BLB2+BLA

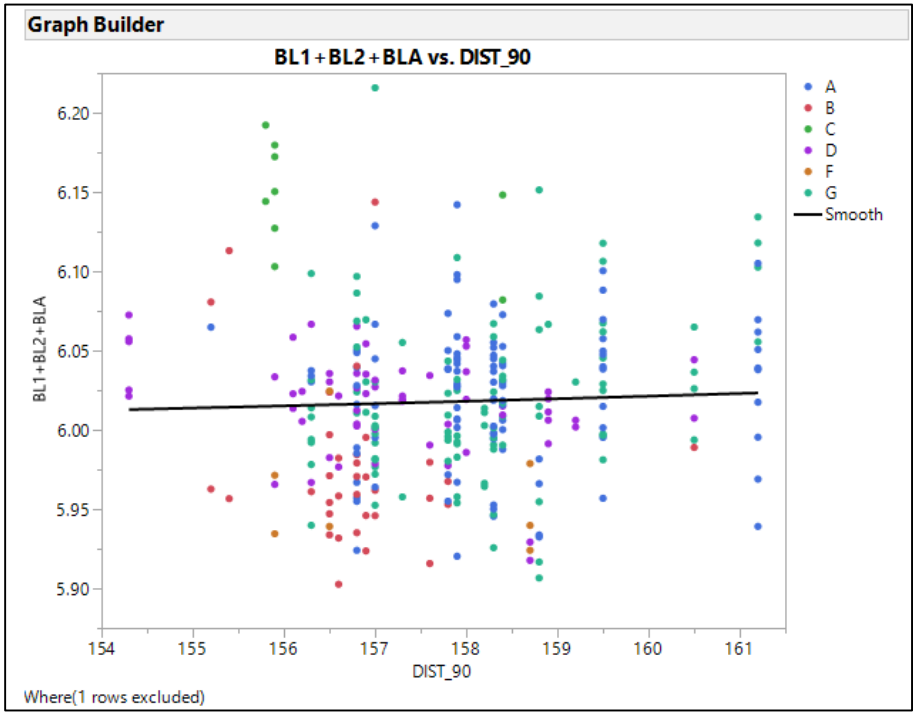


Dist_T50 vs. Date

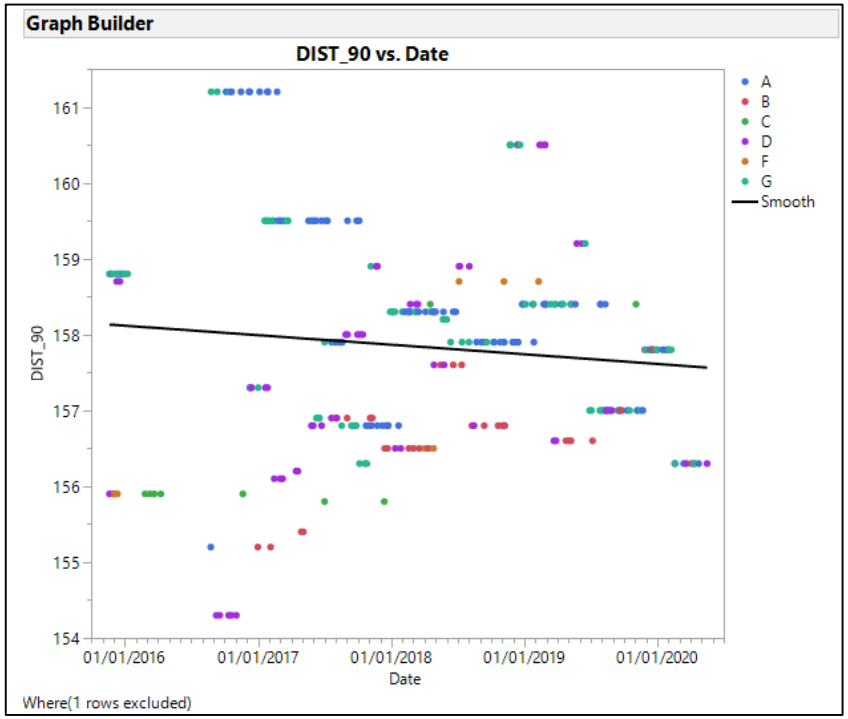
Stepwise Regression Analysis of Fuel Consumed Data

Plots of significant variables – Dist_T90

- Range of Dist_T90: 154.3 – 161.2



Dist_T90 vs. BLB1+BLB2+BLA

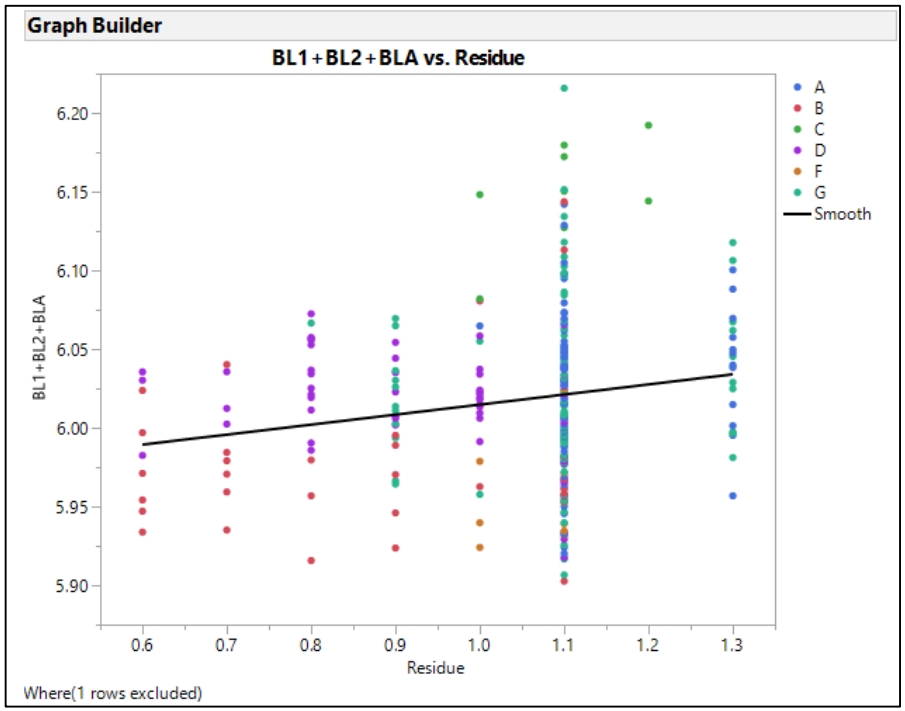


Dist_T90 vs. Date

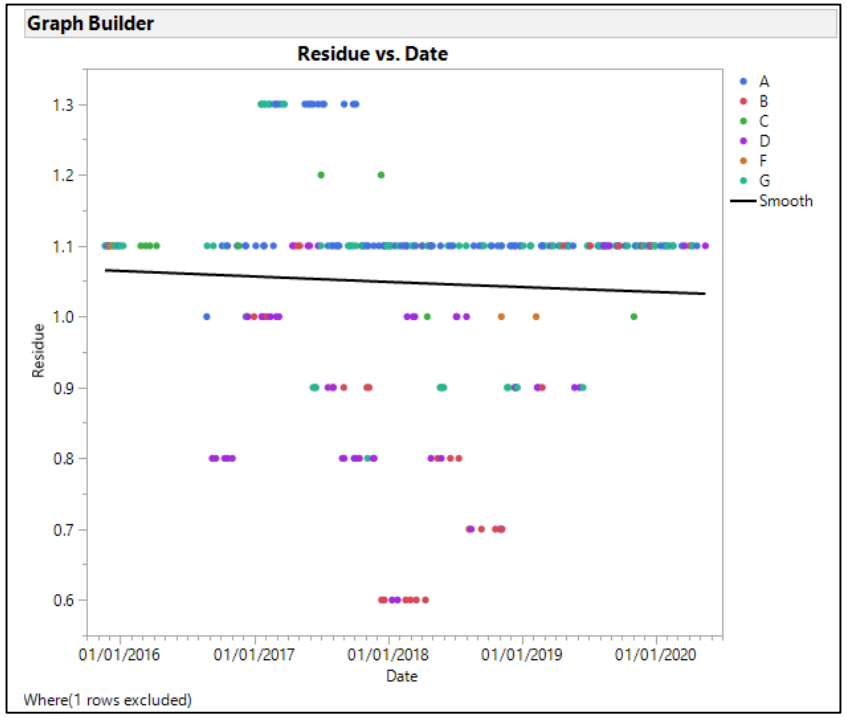
Stepwise Regression Analysis of Fuel Consumed Data

Plots of significant variables – Residue

- Range of Residue: 0.6 – 1.3



Residue vs. BLB1+BLB2+BLA



Residue vs. Date

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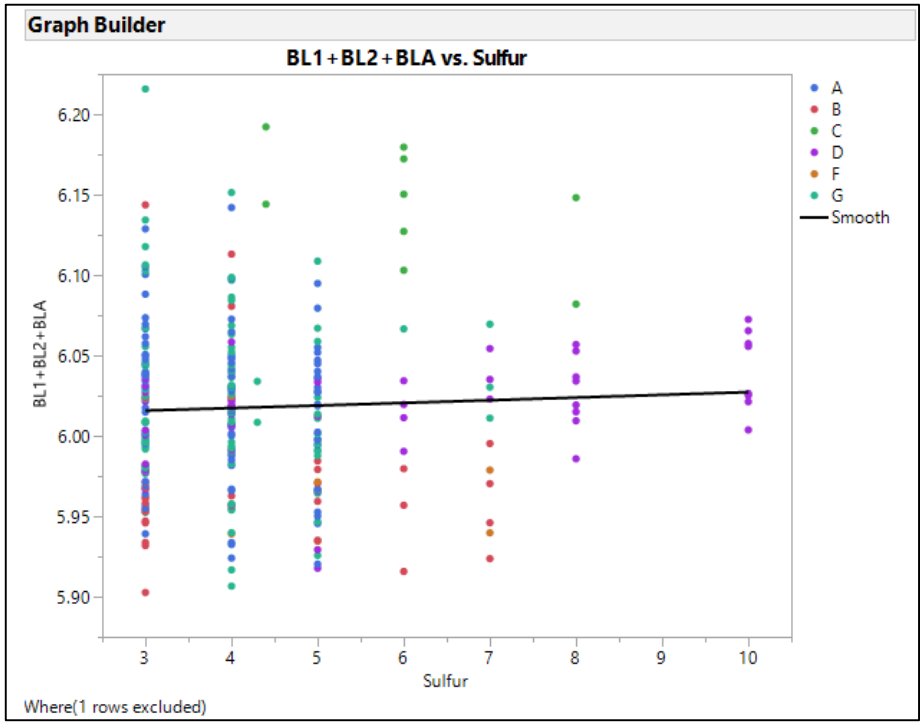
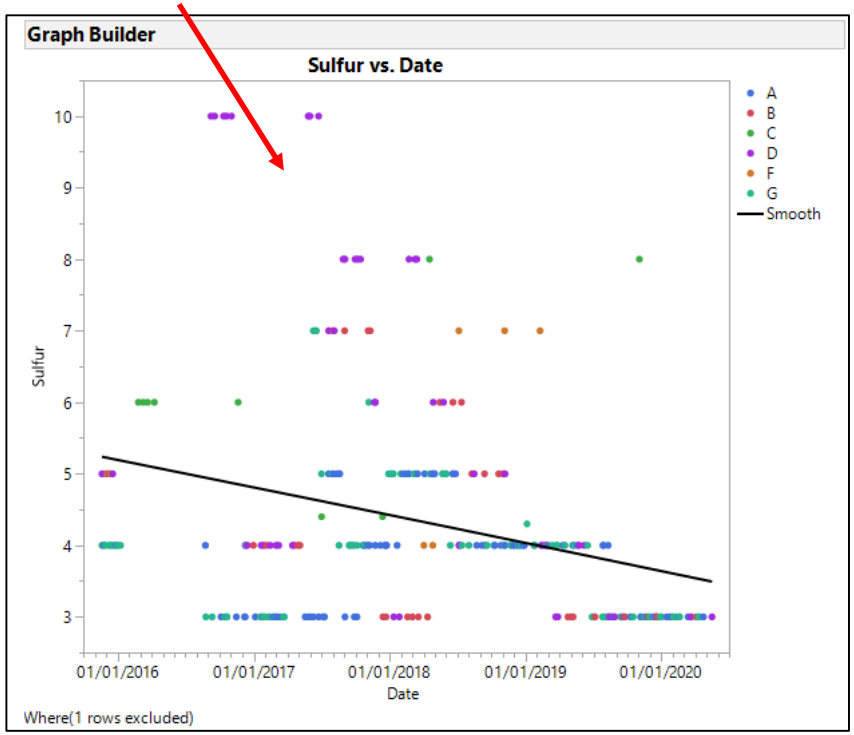
Stepwise Regression Analysis of Fuel Consumed Data

Plots of significant variables – Sulfur

- Range of Sulfur: 3 – 10
- Sulfur exhibits some relationship with calendar date



Sulfur vs. BLB1+BLB2+BLA



Sulfur vs. Date

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Stepwise Regression Analysis of Fuel Consumed Data

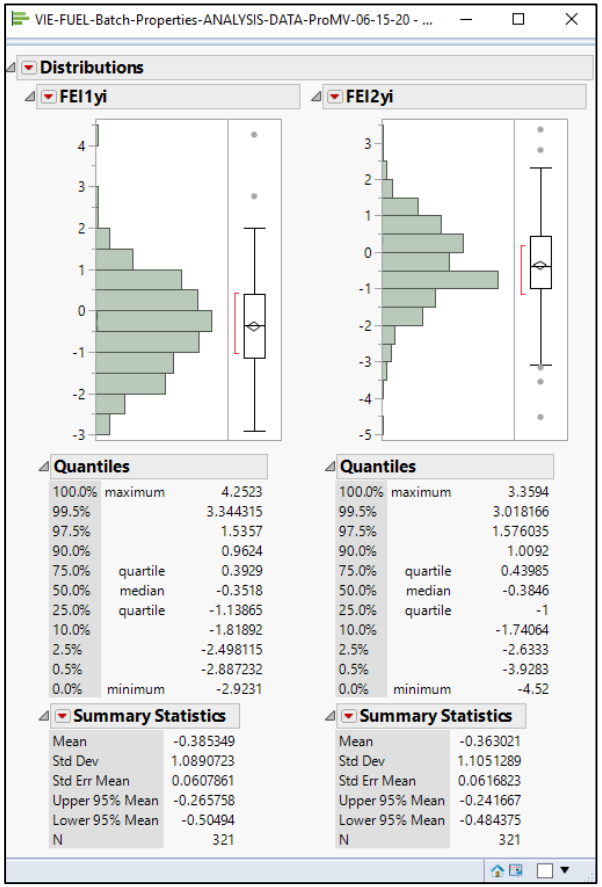
Analysis Highlights:

- Identified significant factors have a declining slope with calendar date, which could be correlated with other unknown severity root causes
- Due to the multicollinearity relationships between fuel properties, follow-on designed experiments would be necessary to provide additional evidence to confirm conclusions found in this analysis
- This analysis is not to be confused to FEIs – which are based on calculated ratios of Candidate and BL fuel consumption data

Stepwise Regression Analysis of FEI1Yi and FEI2Yi Data

Stepwise Regression Analysis of FEI1Yi and FEI2Yi Data

- **Histogram of all FEI1Yi and FEI2Yi data available for analysis**
  - No unusual observations identified in plot



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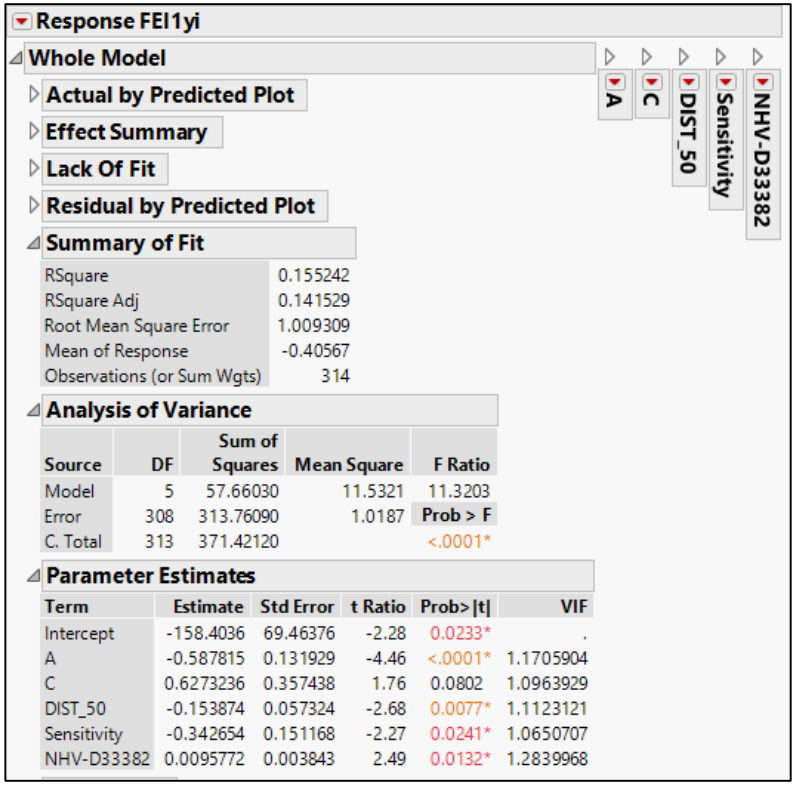
Stepwise Regression Analysis of FEI1Yi and FEI2Yi Data

Stepwise regression results (mixed selection with $p \leq 0.10$)

- Model suggests some fuel parameters are statistically significant
- Designed experiments would be required to confirm results



Response FEI1yi

Whole Model

A | C | DIST_50 | Sensitivity | NHV-D33382

Actual by Predicted Plot

Effect Summary

Lack Of Fit

Residual by Predicted Plot

Summary of Fit

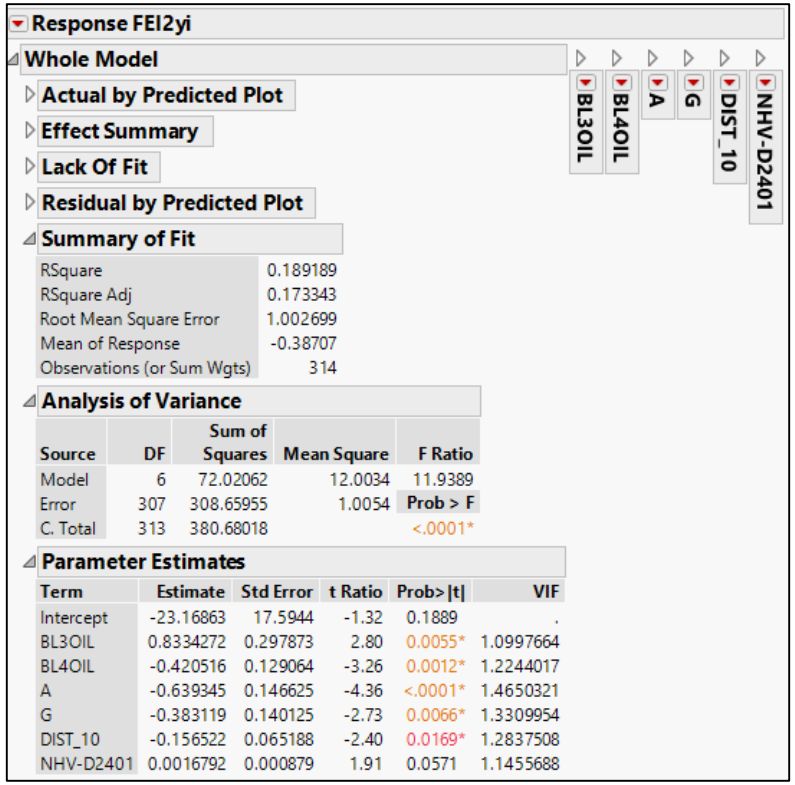
RSquare	0.155242
RSquare Adj	0.141529
Root Mean Square Error	1.009309
Mean of Response	-0.40567
Observations (or Sum Wgts)	314

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	57.66030	11.5321	11.3203
Error	308	313.76090	1.0187	Prob > F
C. Total	313	371.42120		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	-158.4036	69.46376	-2.28	0.0233*	.
A	-0.587815	0.131929	-4.46	<.0001*	1.1705904
C	0.6273236	0.357438	1.76	0.0802	1.0963929
DIST_50	-0.153874	0.057324	-2.68	0.0077*	1.1123121
Sensitivity	-0.342654	0.151168	-2.27	0.0241*	1.0650707
NHV-D33382	0.0095772	0.003843	2.49	0.0132*	1.2839968



Response FEI2yi

Whole Model

BL3OIL | BL4OIL | A | G | DIST_10 | NHV-D2401

Actual by Predicted Plot

Effect Summary

Lack Of Fit

Residual by Predicted Plot

Summary of Fit

RSquare	0.189189
RSquare Adj	0.173343
Root Mean Square Error	1.002699
Mean of Response	-0.38707
Observations (or Sum Wgts)	314

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	72.02062	12.0034	11.9389
Error	307	308.65955	1.0054	Prob > F
C. Total	313	380.68018		<.0001*

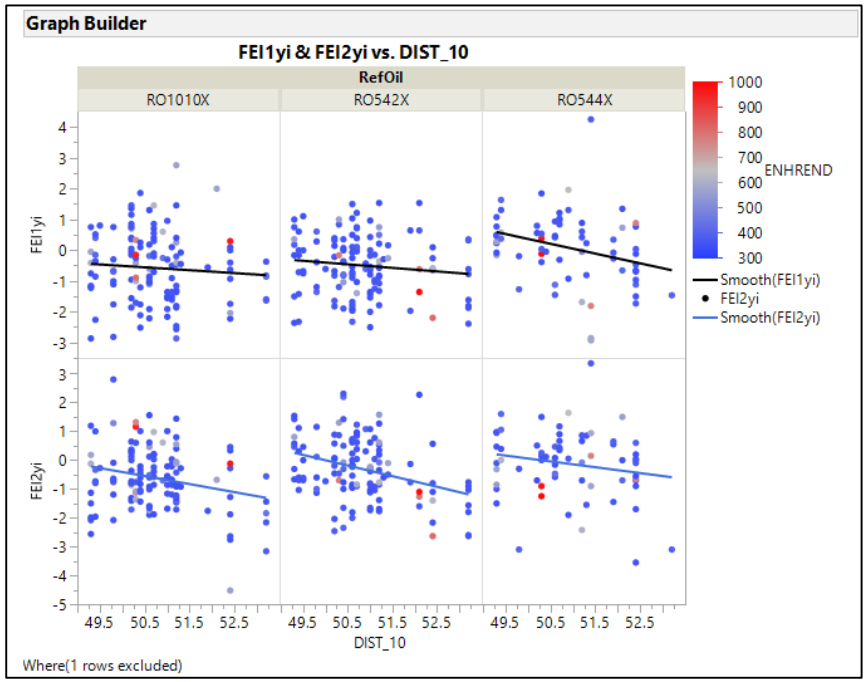
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	-23.16863	17.5944	-1.32	0.1889	.
BL3OIL	0.8334272	0.297873	2.80	0.0055*	1.0997664
BL4OIL	-0.420516	0.129064	-3.26	0.0012*	1.2244017
A	-0.639345	0.146625	-4.36	<.0001*	1.4650321
G	-0.383119	0.140125	-2.73	0.0066*	1.3309954
DIST_10	-0.156522	0.065188	-2.40	0.0169*	1.2837508
NHV-D2401	0.0016792	0.000879	1.91	0.0571	1.1455688

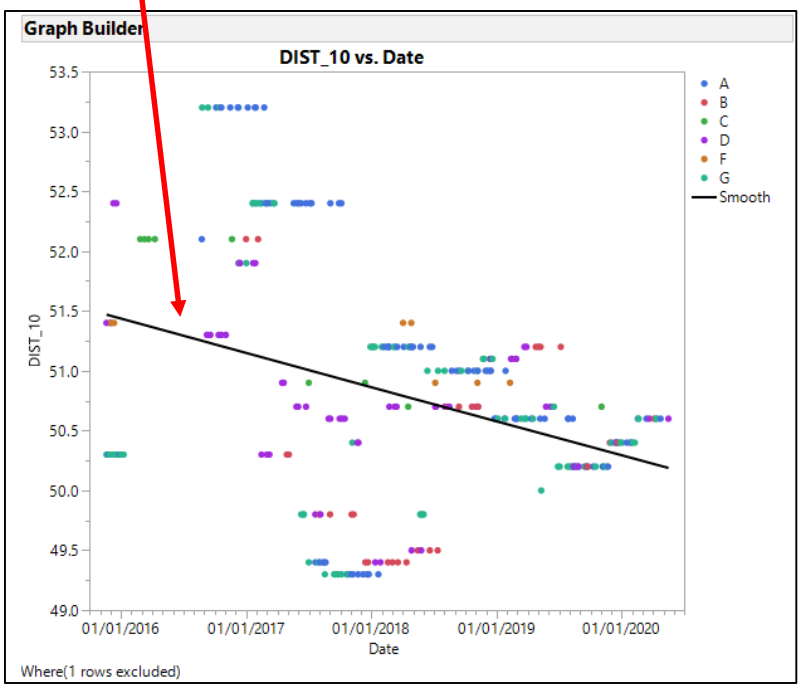
Stepwise Regression Analysis of FEI1Yi and FEI2Yi Data

Plots of significant variable – Dist_T10

- Range of Dist_T10: 49.3 – 53.6
- Dist_T10 exhibits some relationship with calendar date



Dist10 vs. FEIYi



Dist10 vs. Date

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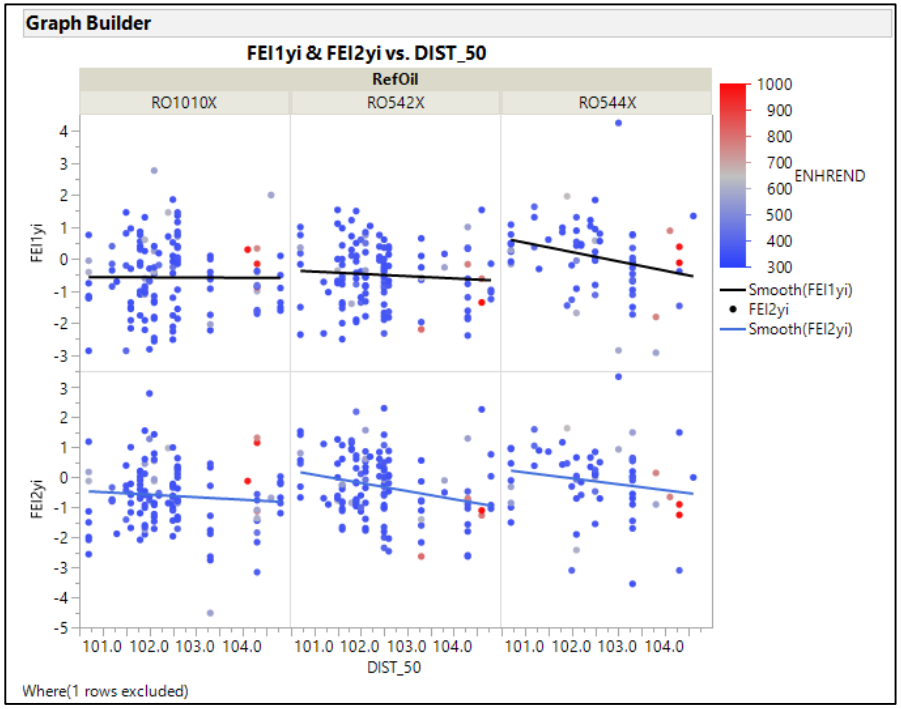
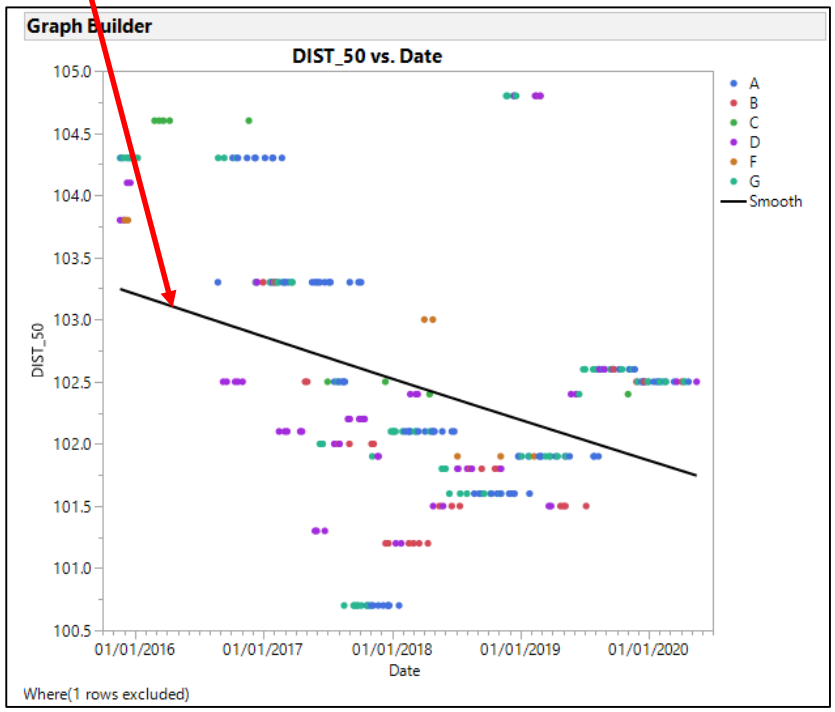
Stepwise Regression Analysis of FEI1Yi and FEI2Yi Data

Plots of significant variable – Dist_T50

- Range of Dist_T50: 100.7 – 104.8
- Dist_T50 exhibits some relationship with calendar date



Dist_T50 vs. FEIYi

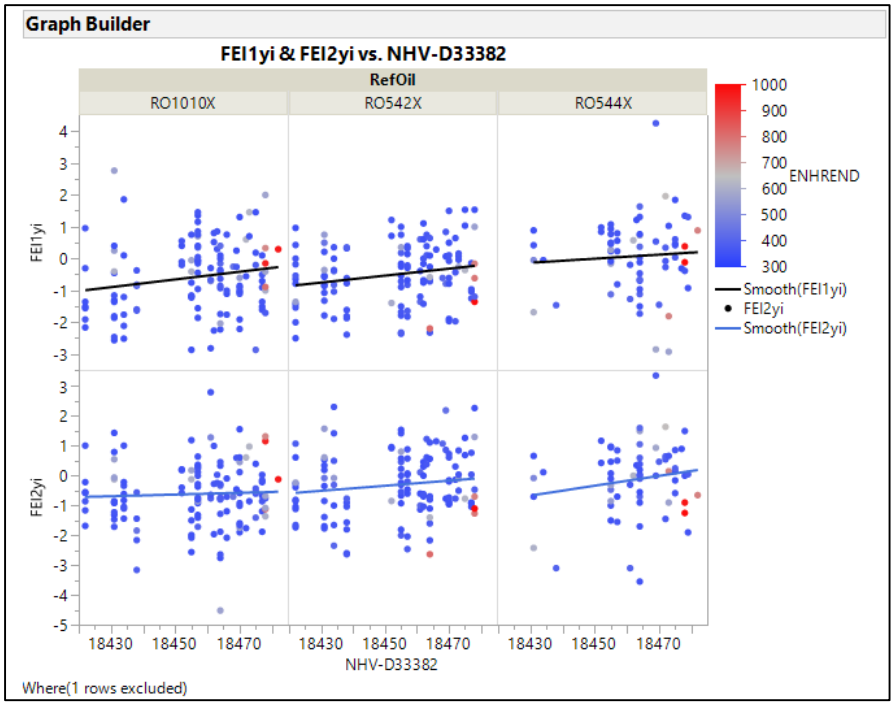


Dist_T50 vs. Date

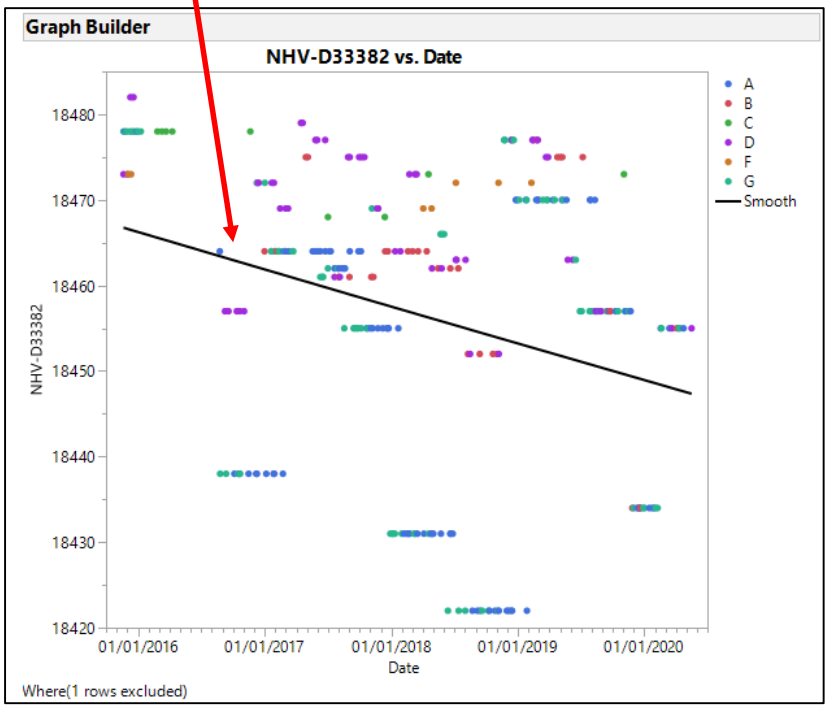
Stepwise Regression Analysis of FEI1Yi and FEI2Yi Data

Plots of significant variable – NHV-D33382

- Range of NHV-D33382 : 18422 – 18482
- NHV-D33382 exhibits some relationship with calendar date



NHV-D33382 vs. FEIYi



NHV-D33382 vs. FEIYi

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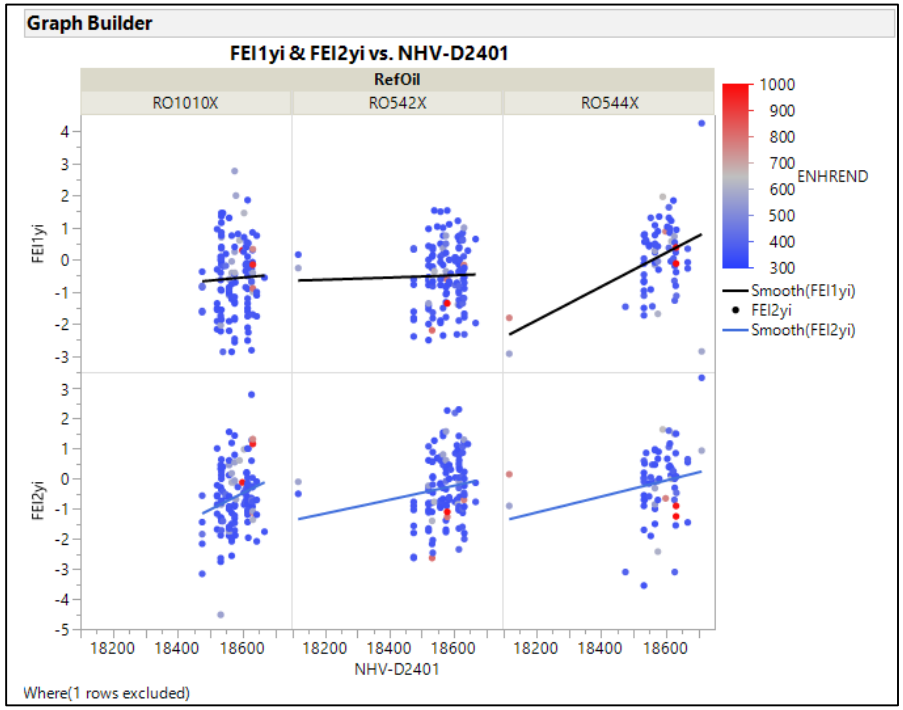
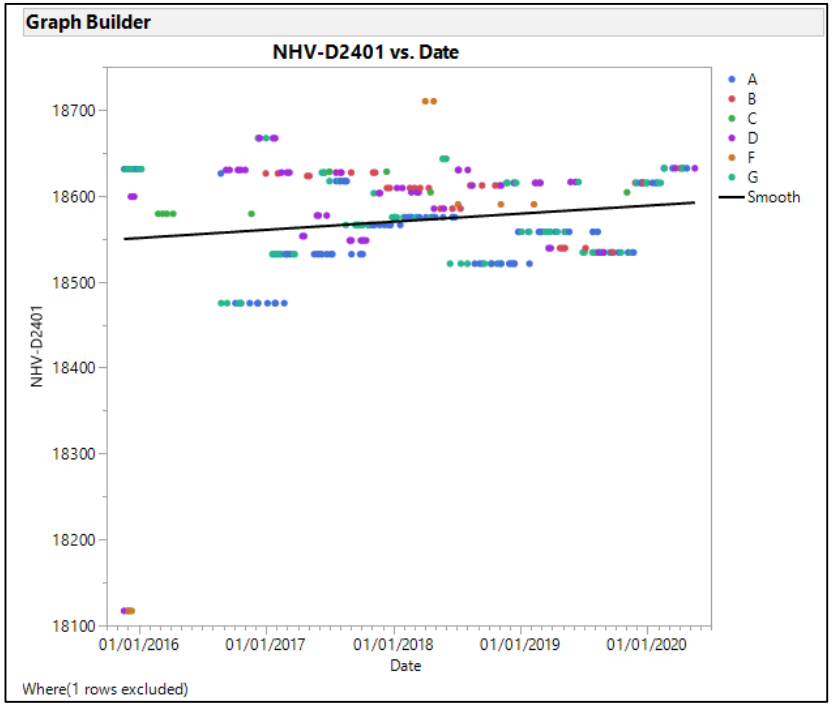
Stepwise Regression Analysis of FEI1Yi and FEI2Yi Data

Plots of significant variable – NHV-D2401

- Range of NHV-D2401: 18117 – 18710



NHV-D2401 vs. FEIYi



NHV-D2401 vs. Date

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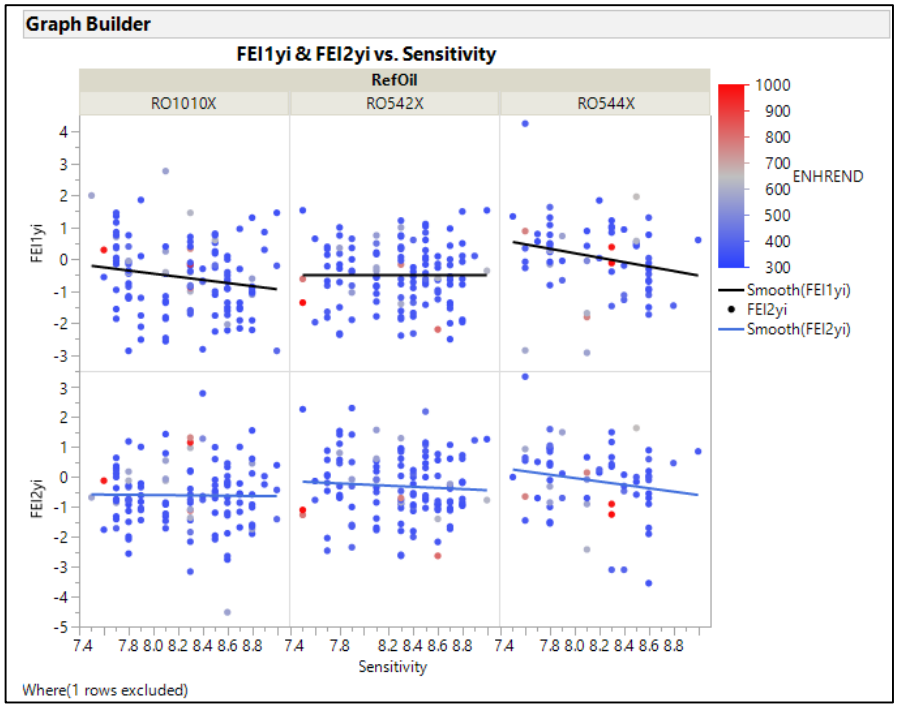
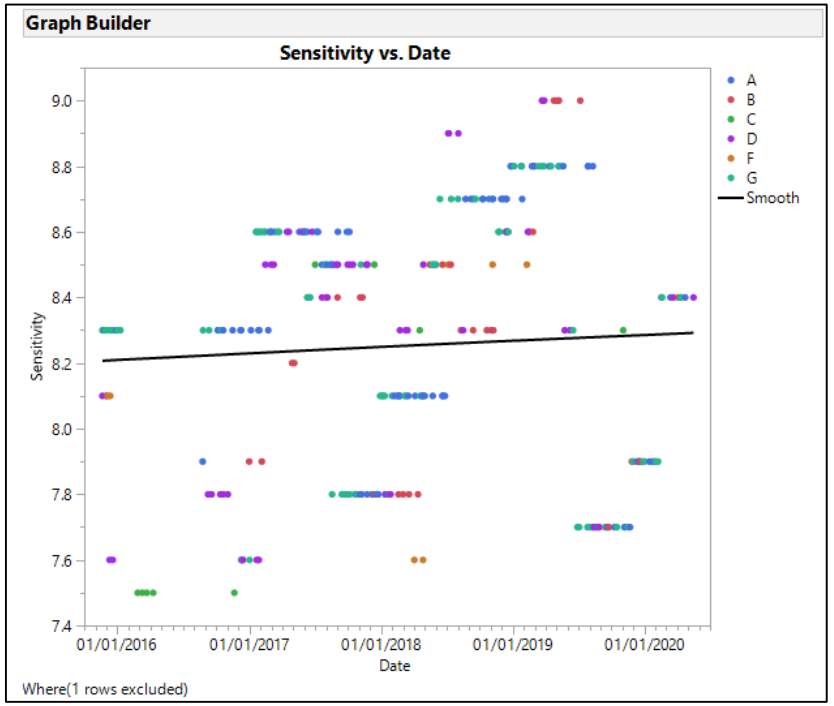
Stepwise Regression Analysis of FEI1Yi and FEI2Yi Data

Plots of significant variable – Sensitivity (RON-MON)

- Range of Sensitivity : 7.5 – 9.0



Sensitivity vs. FEIYi



Sensitivity vs. Date

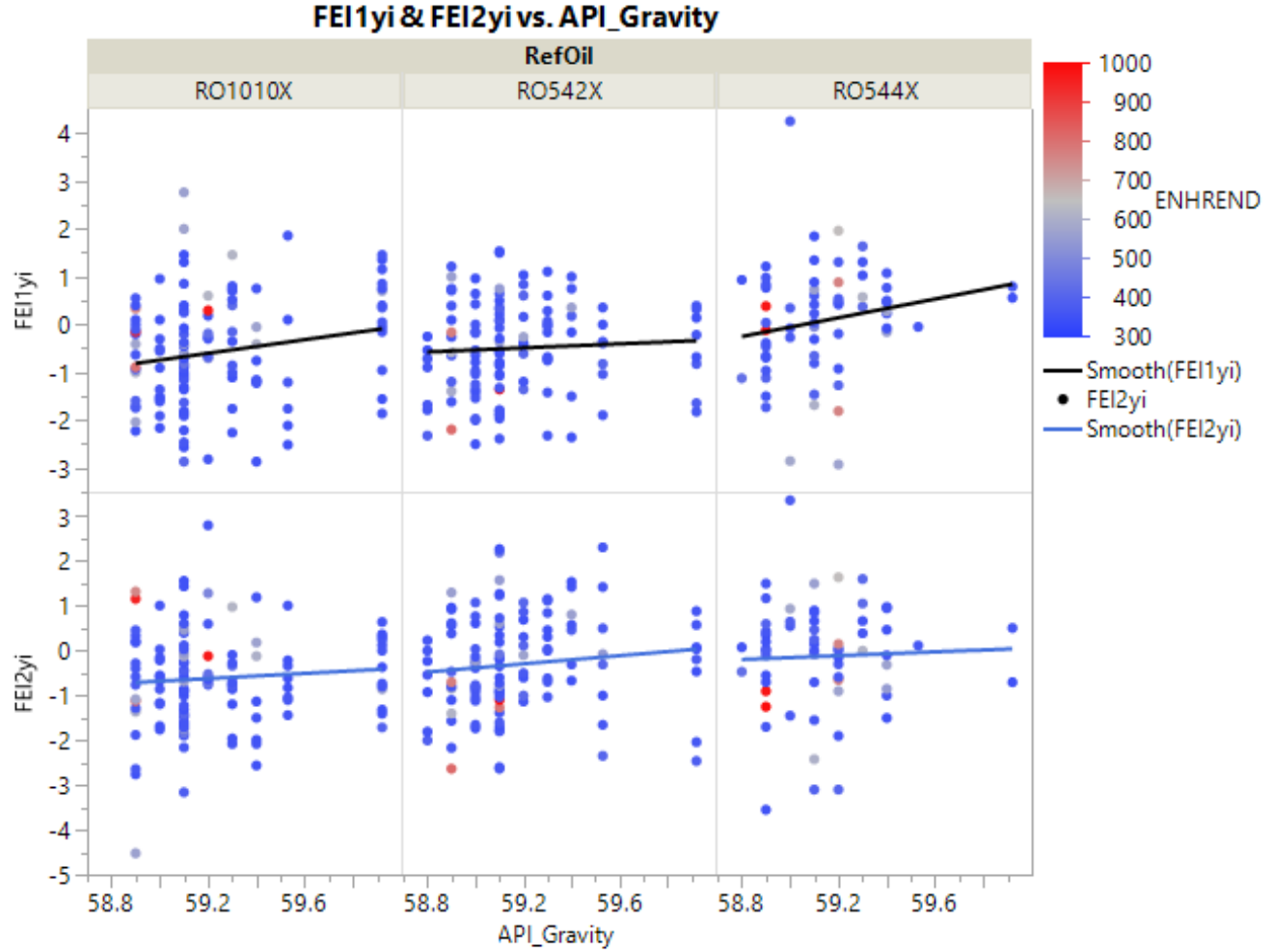
Stepwise Regression Analysis of Fuel Consumed Data

Analysis Highlights:

- Analysis suggests that there statistically significant variables that are related to FEIY1 and FEIY2
- Shifts in VIE performance could be correlated with other unknown (non-fuel) related severity related factors
- Due to the multicollinearity, it would be necessary follow-on with Designed Experiments to provide confirmation of the analysis conclusions

Appendix A - Plots of FEI1Yi and FEI2Yi Data

Graph Builder



Where(1 rows excluded)

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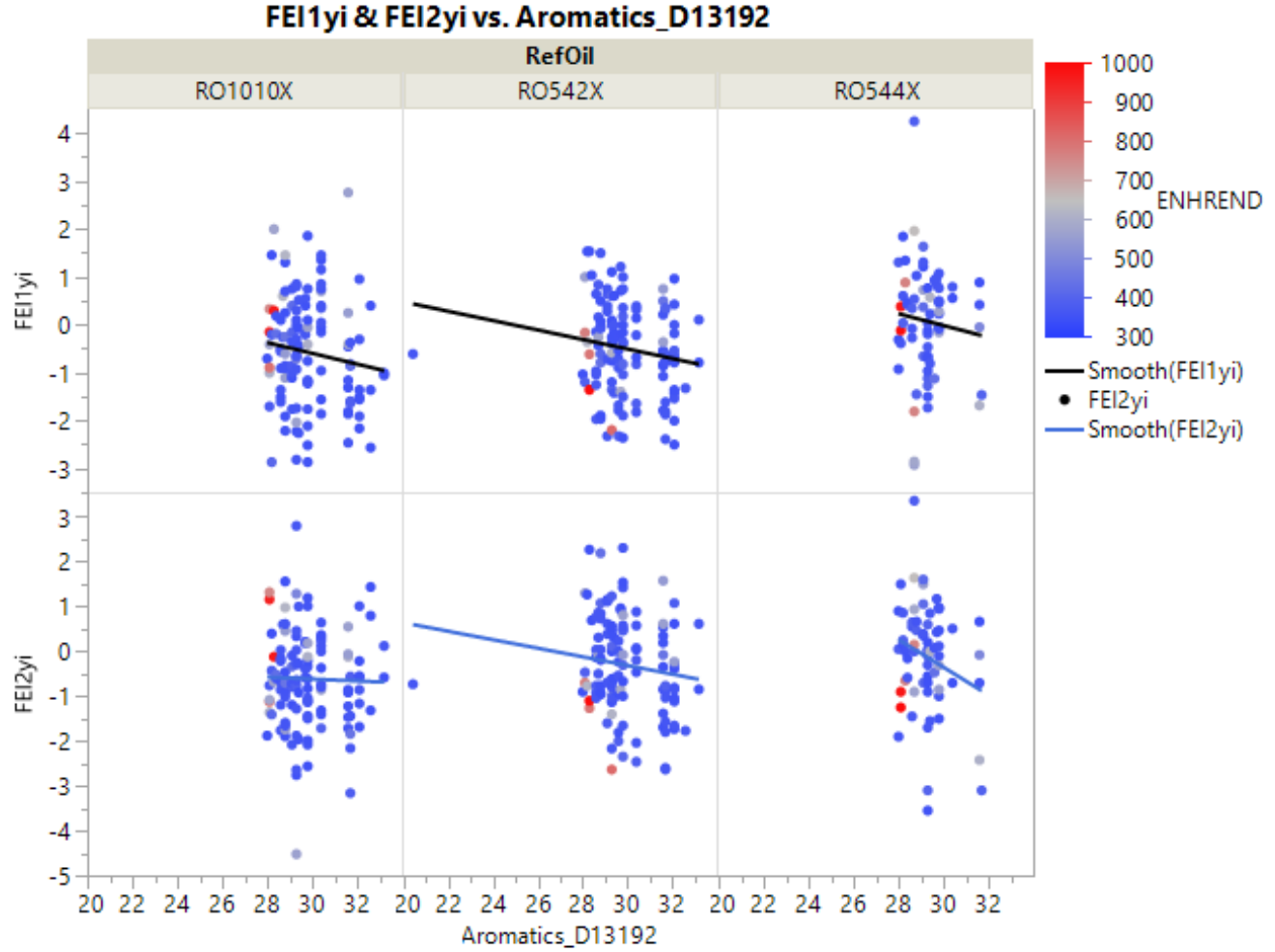
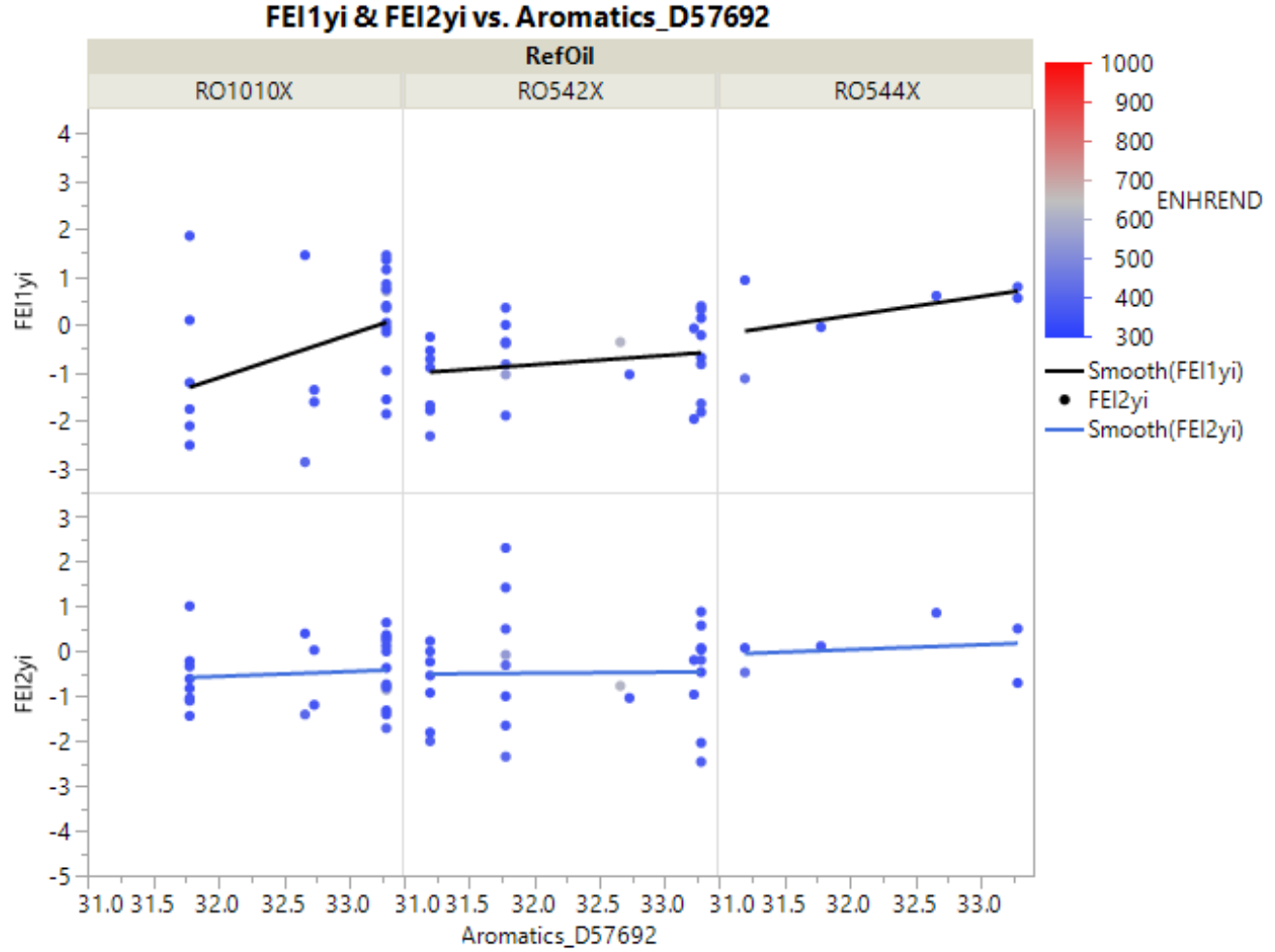
Graph Builder



Where(1 rows excluded)

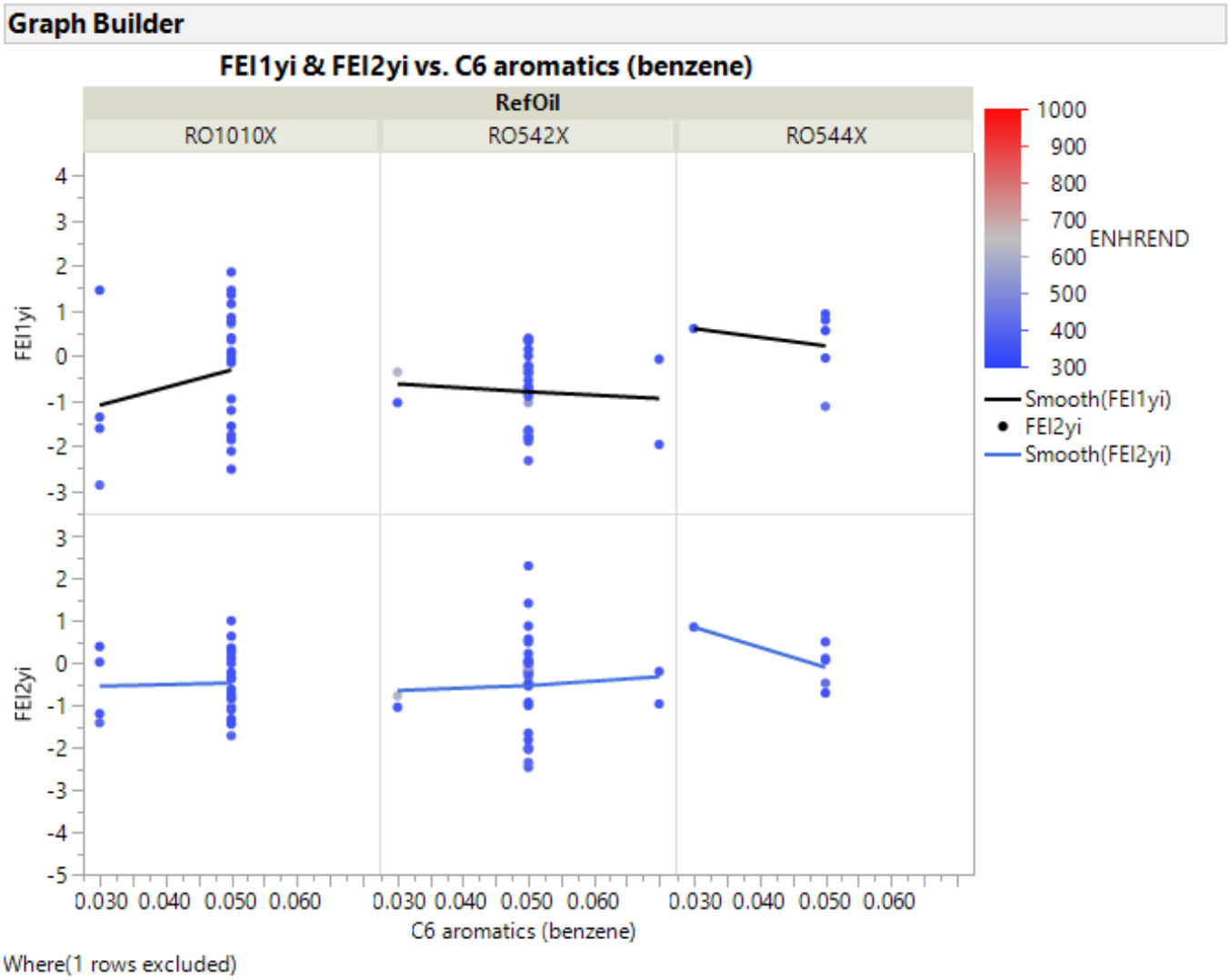
Afton CHEMICAL Passion for Solutions

Graph Builder

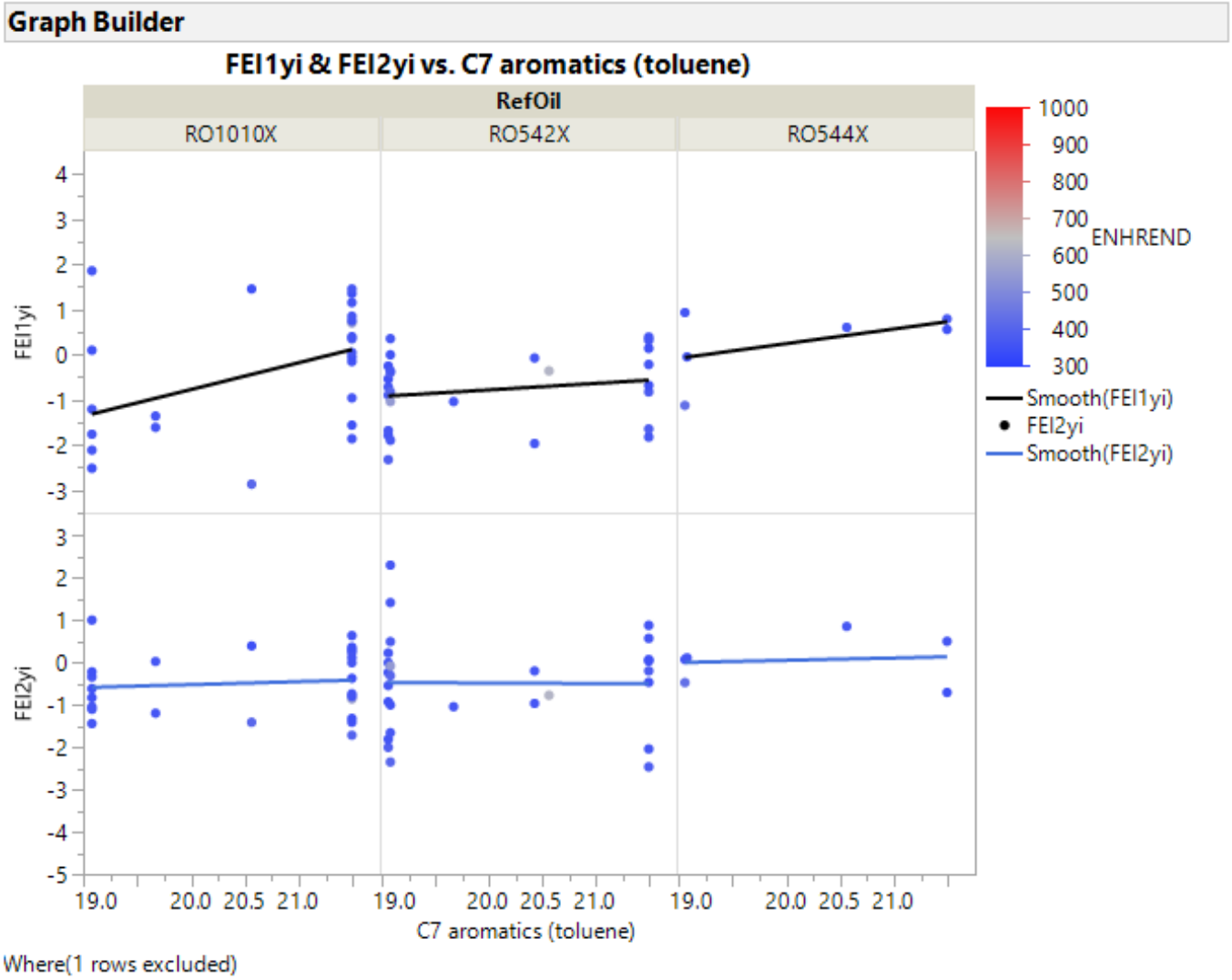


Where(1 rows excluded)

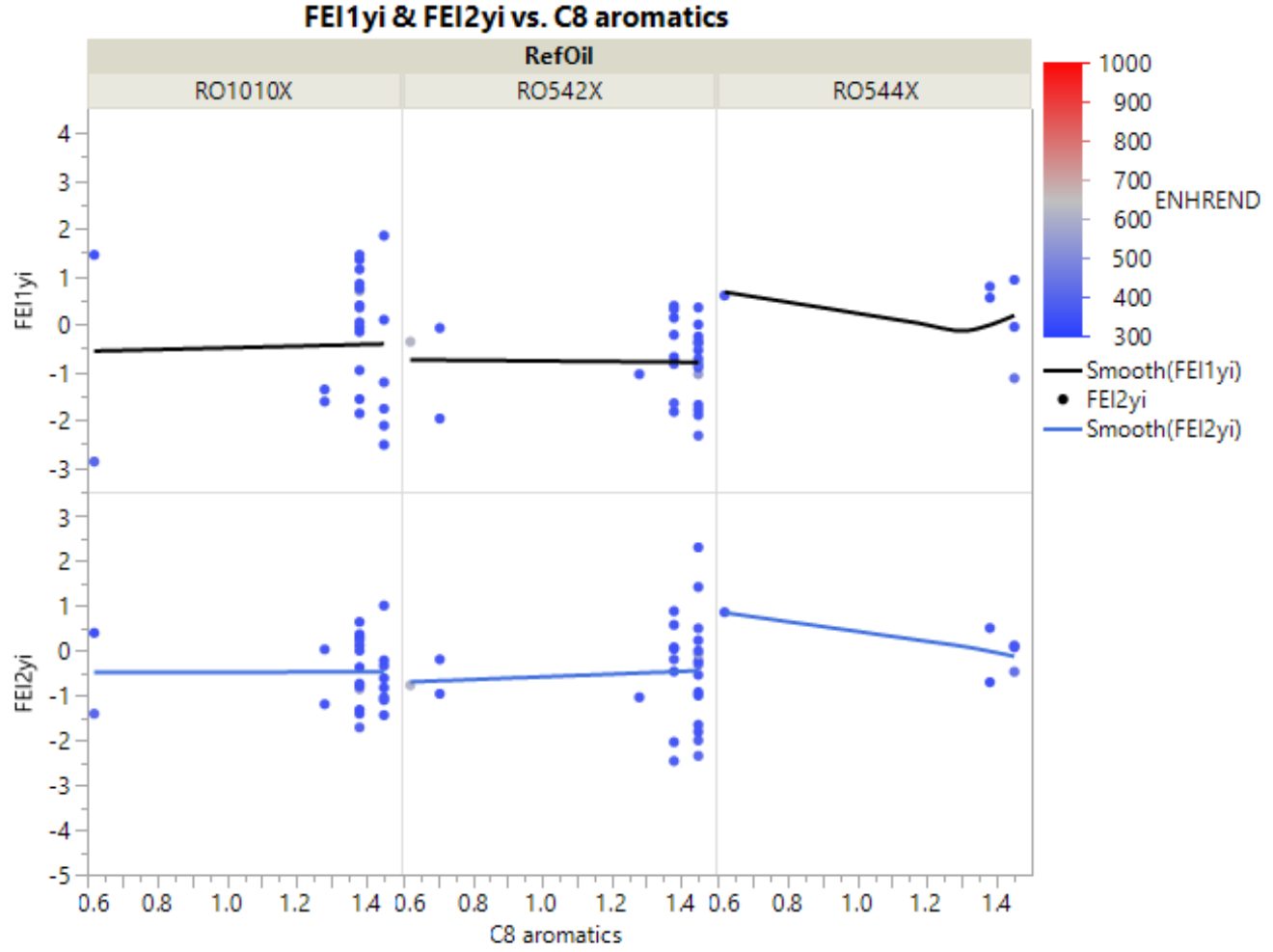
Afton CHEMICAL Passion for Solutions



Afton CHEMICAL Passion for Solutions

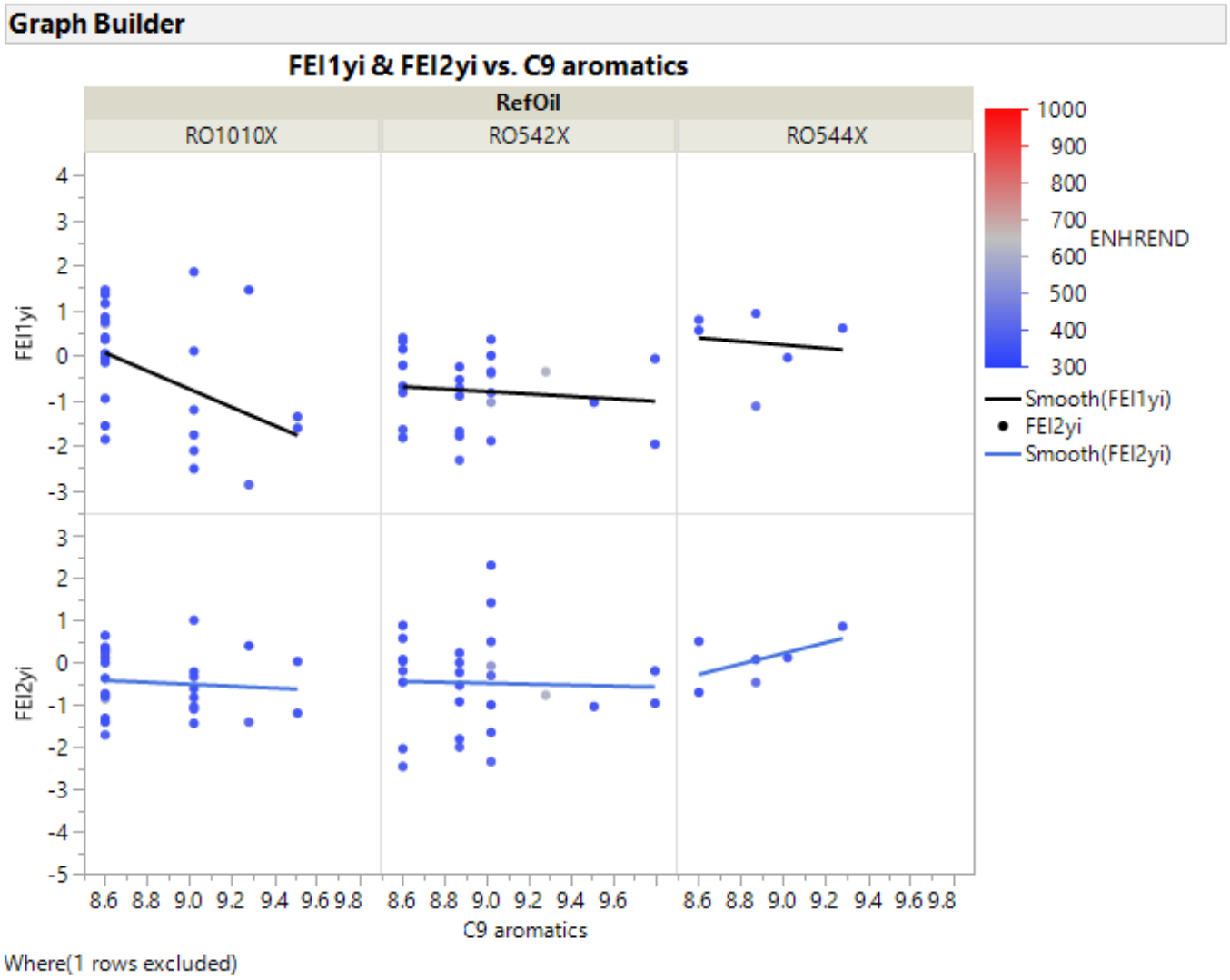


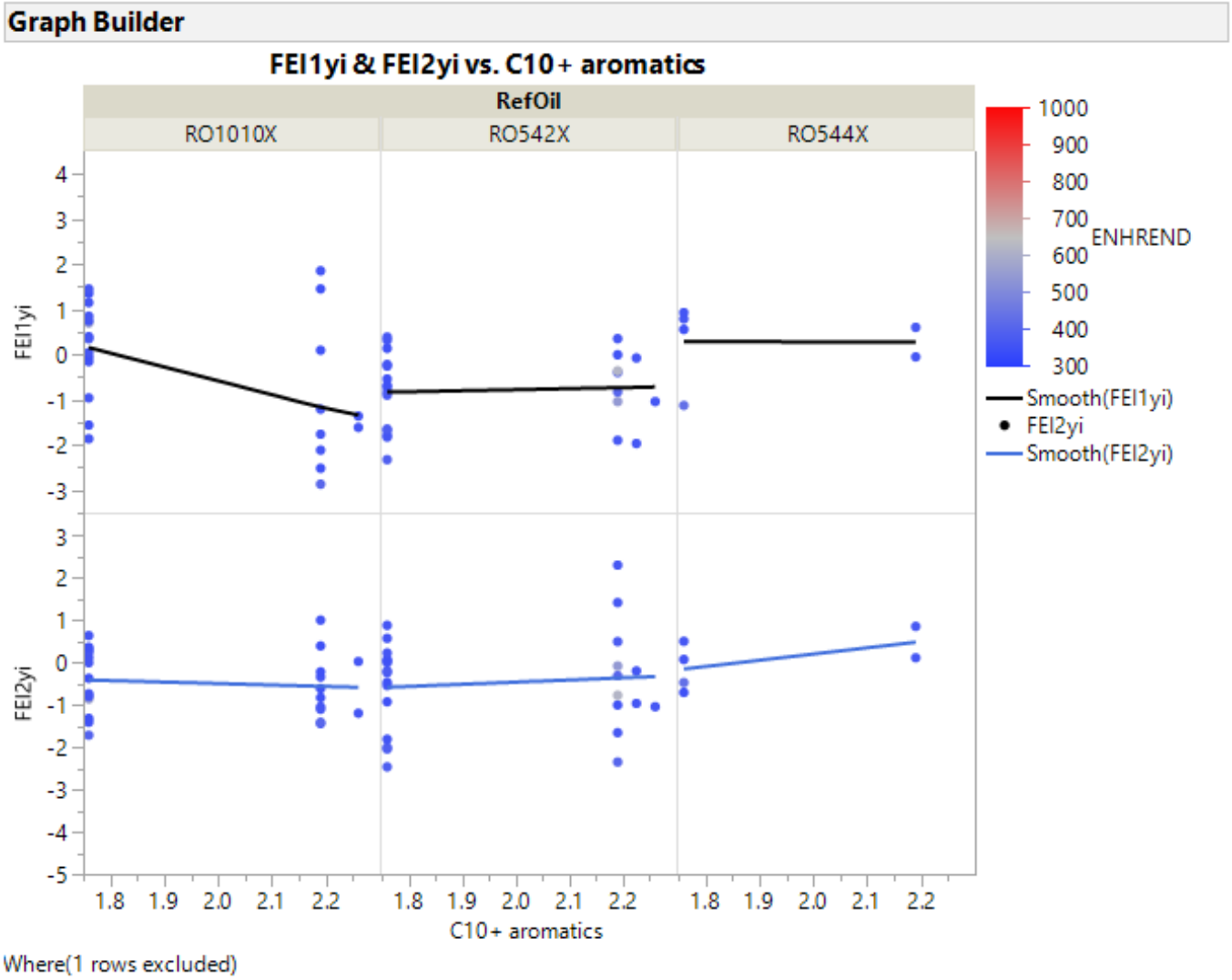
Graph Builder



Where(1 rows excluded)

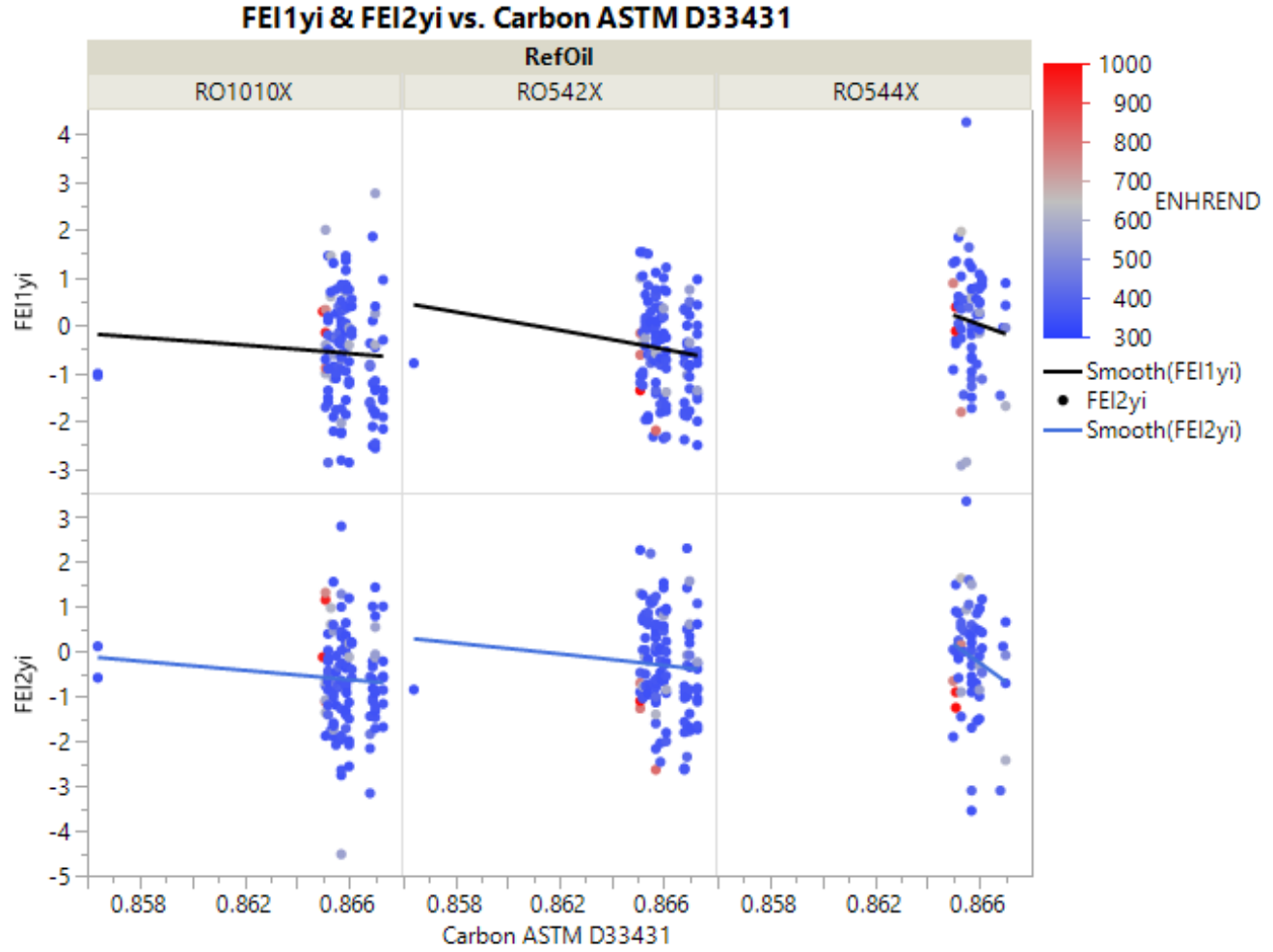
Afton CHEMICAL Passion for Solutions


Graph Builder
FEI1yi & FEI2yi vs. C9 aromatics
RefOil
RO1010X
RO542X
RO544X
FEI1yi
FEI2yi
C9 aromatics
ENHREND
1000
900
800
700
600
500
400
300
Smooth(FEI1yi)
FEI2yi
Smooth(FEI2yi)
Where(1 rows excluded)



Afton CHEMICAL Passion for Solutions

Graph Builder



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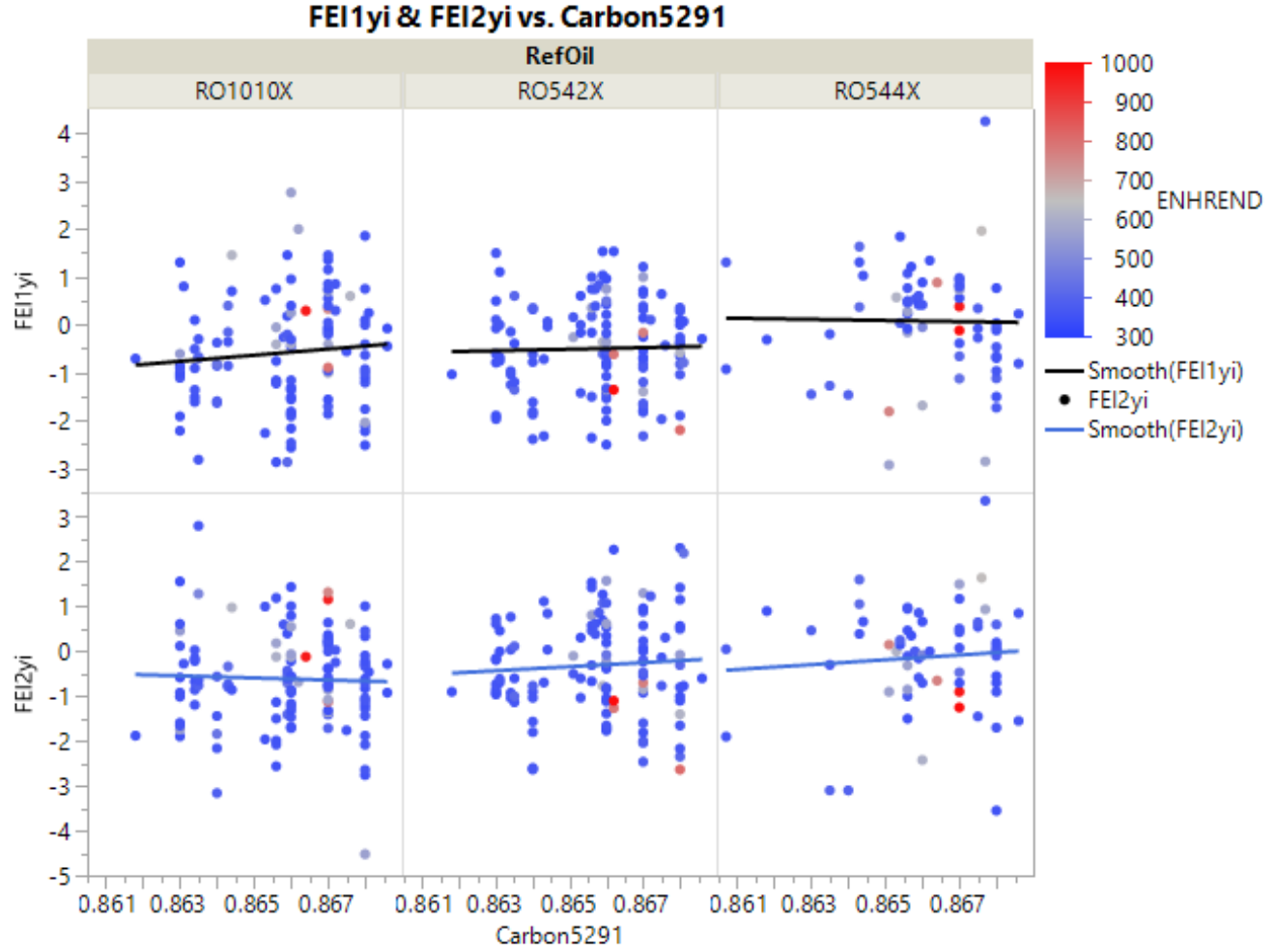

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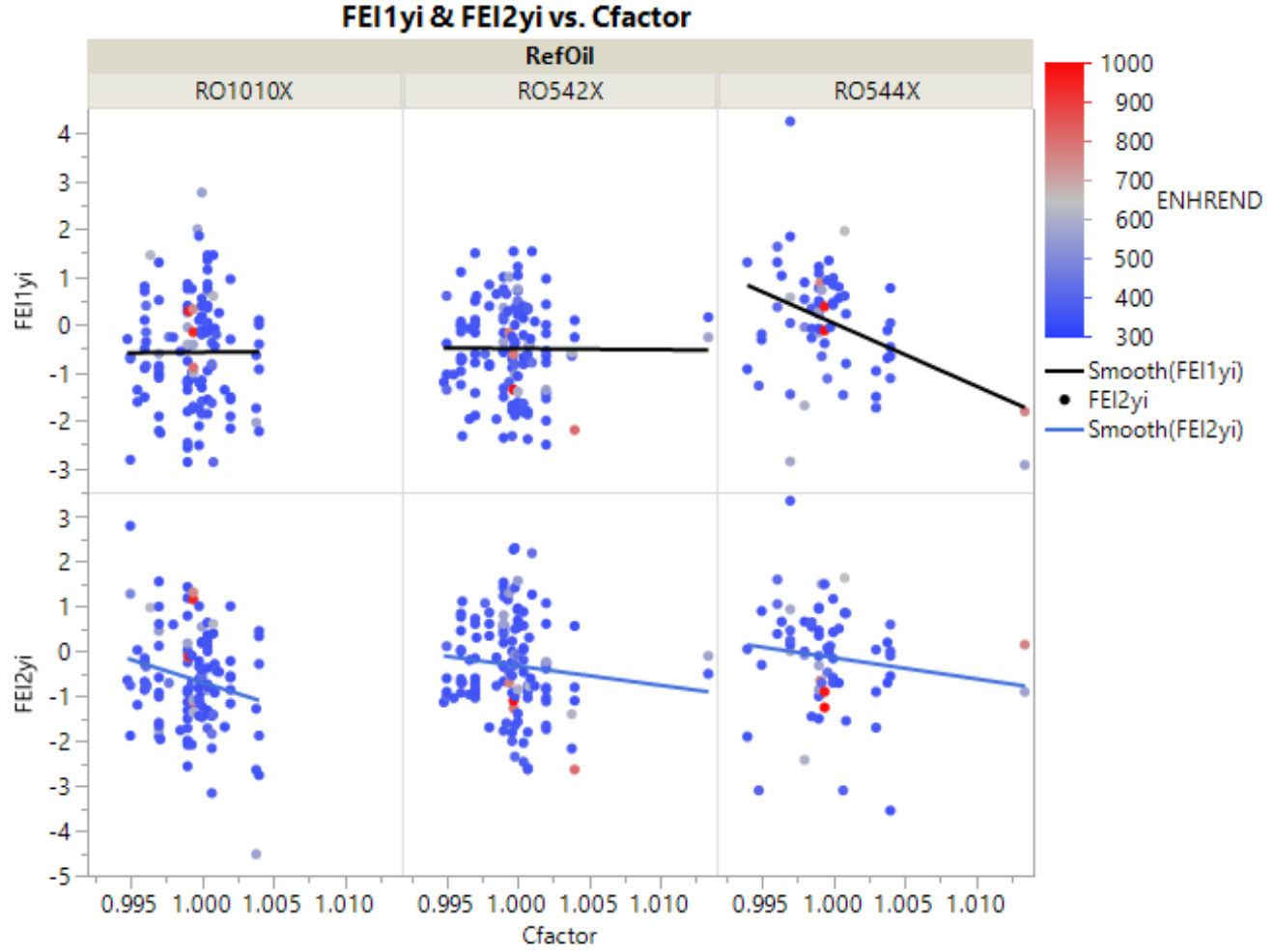
Graph Builder



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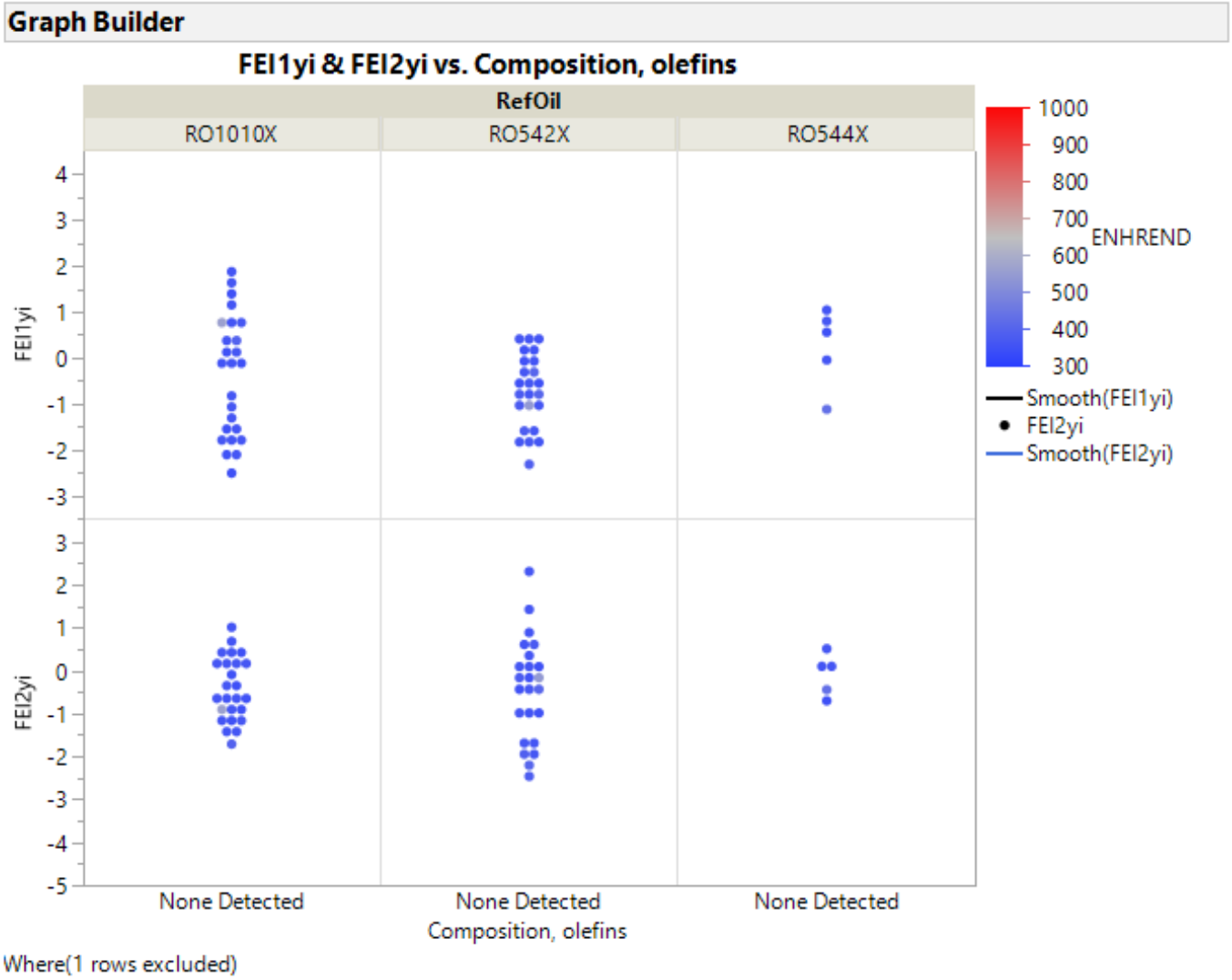

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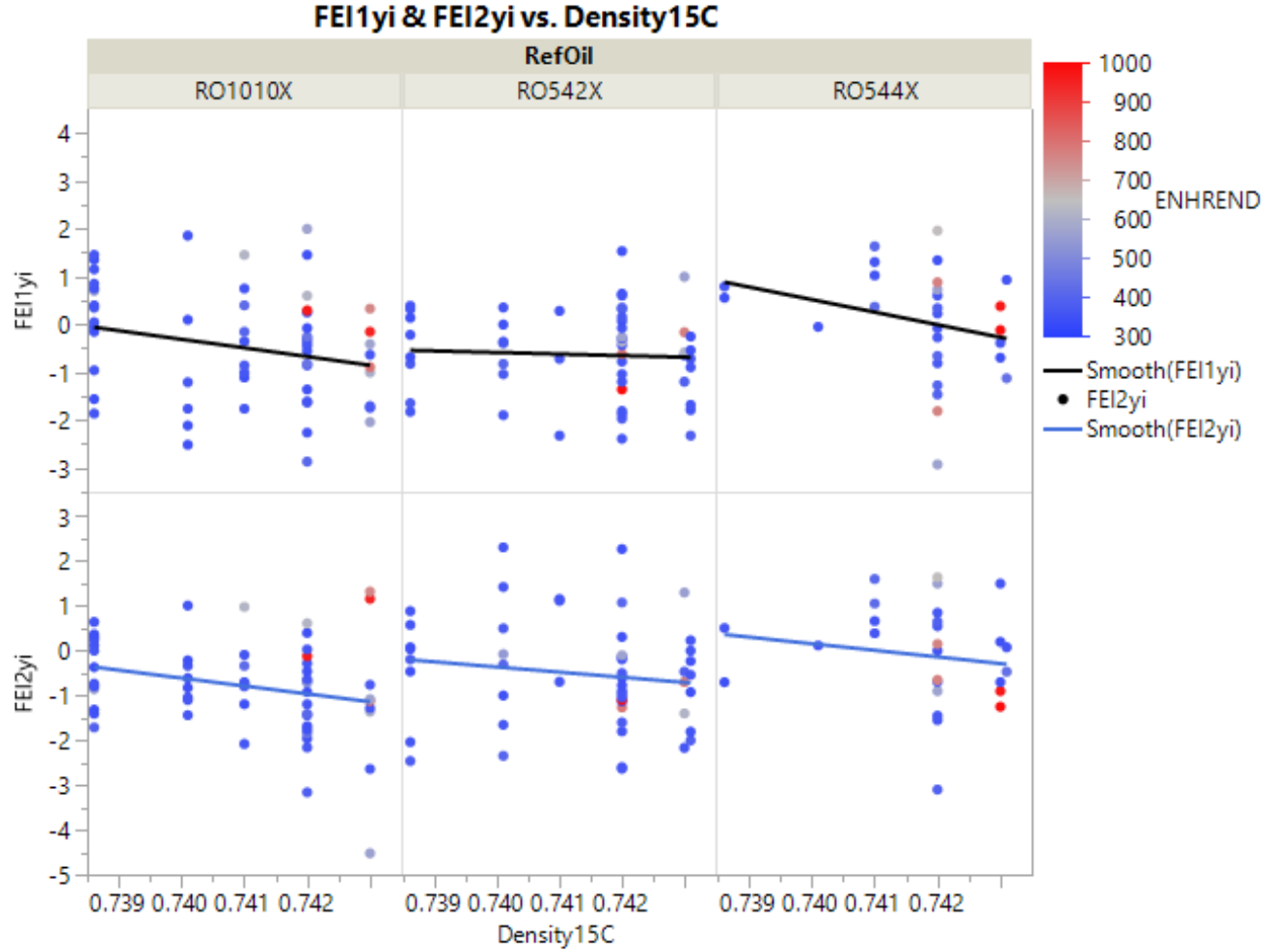
Graph Builder



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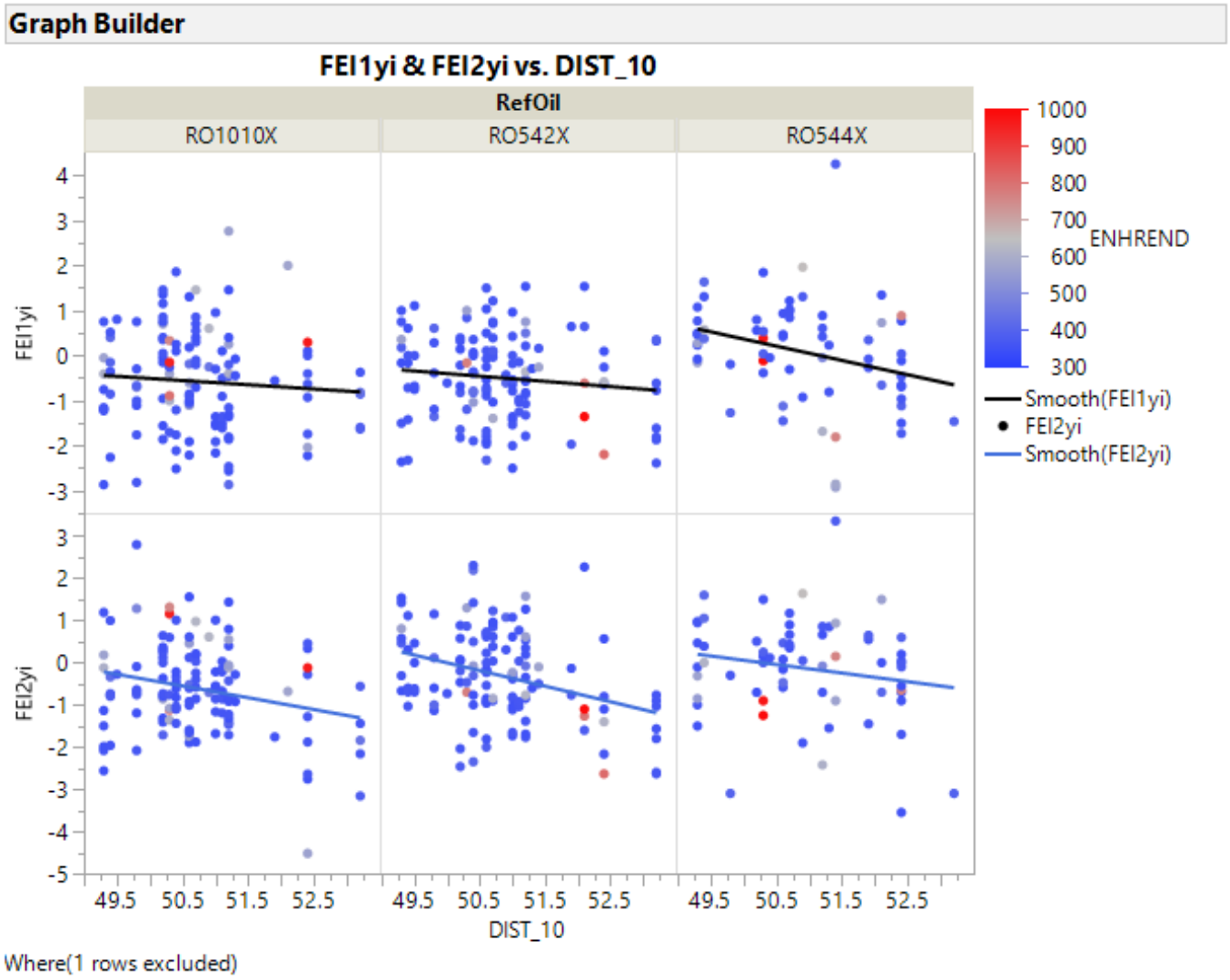
Afton CHEMICAL Passion for Solutions



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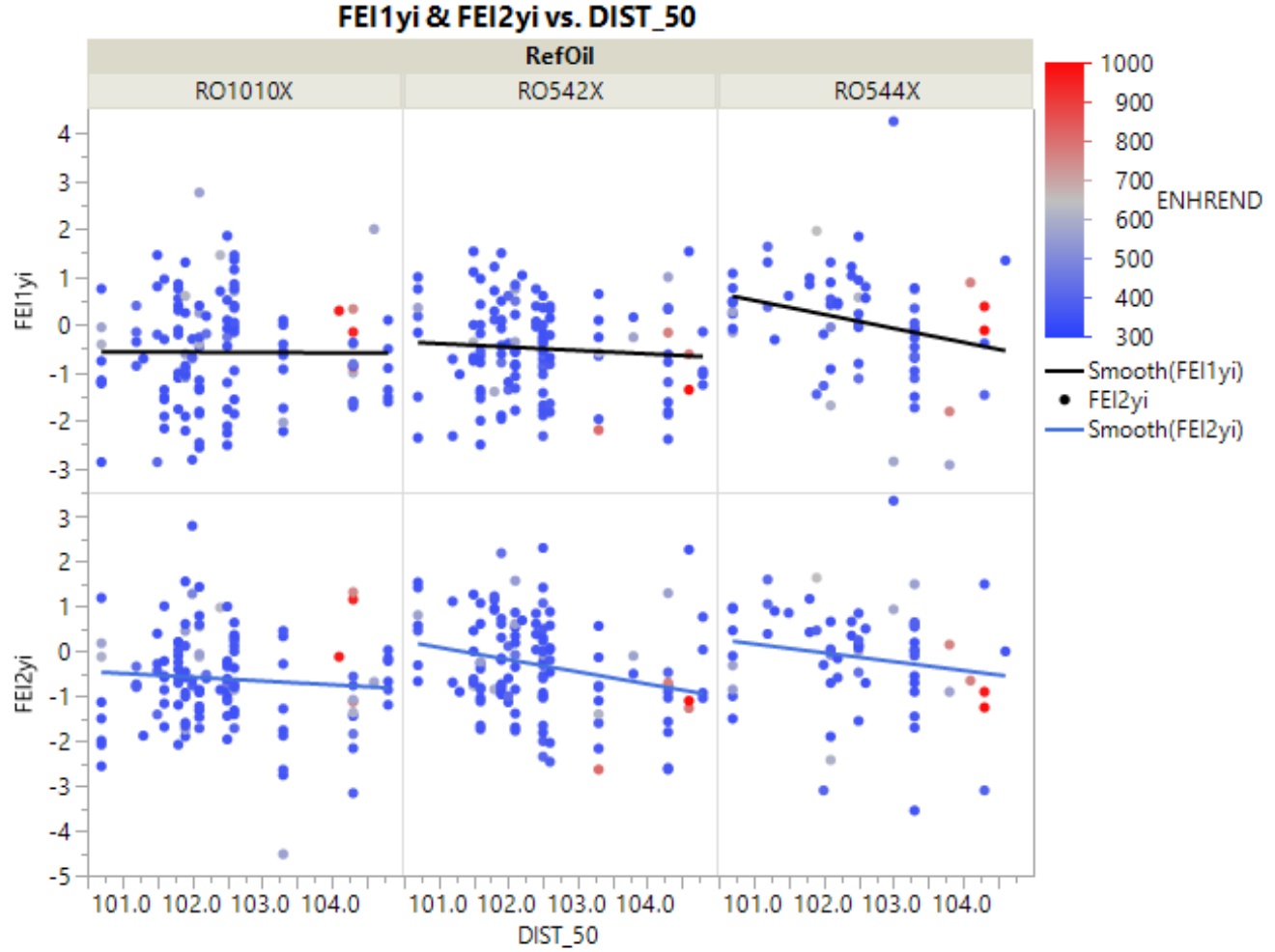
Graph Builder



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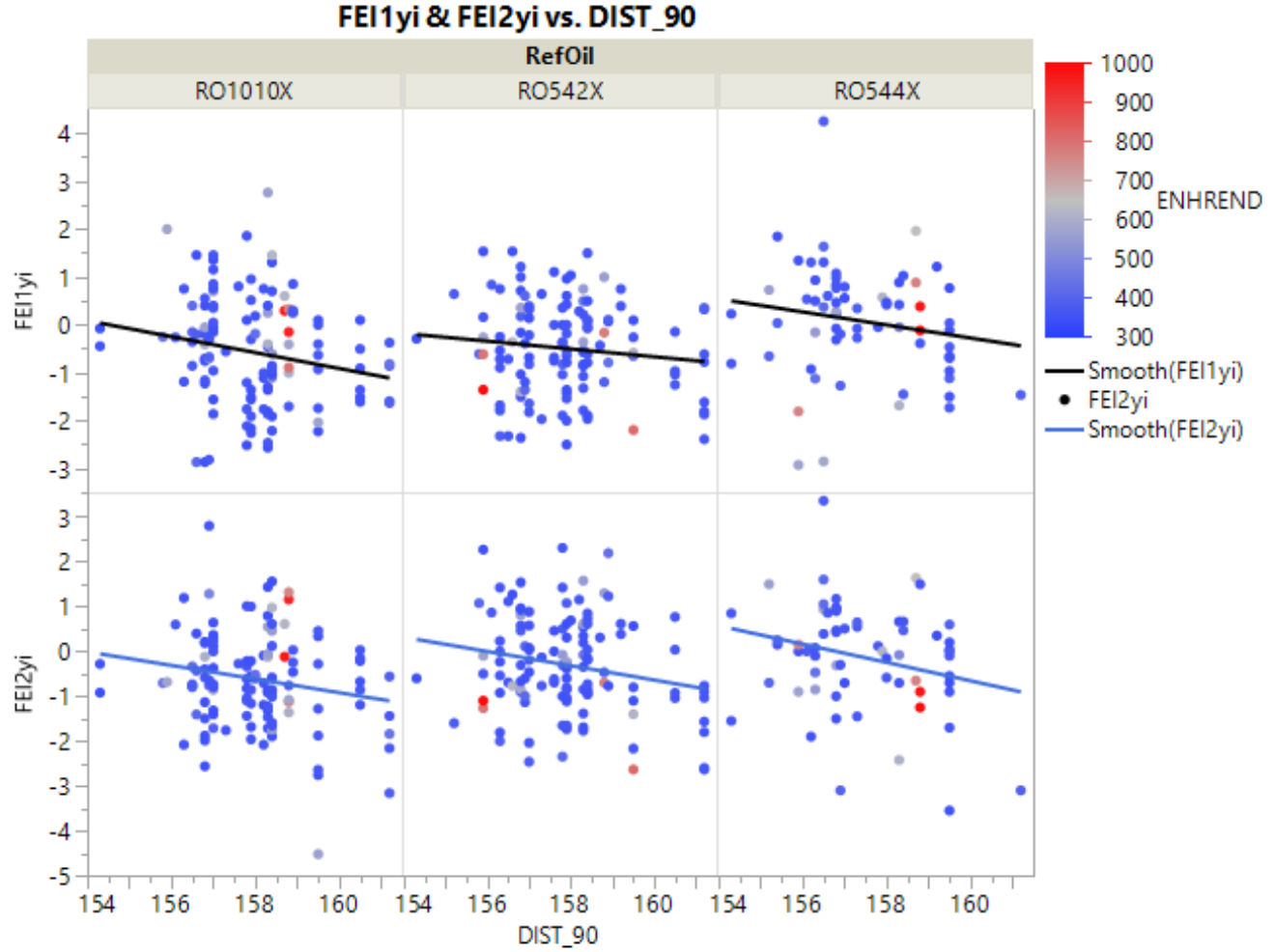
Graph Builder



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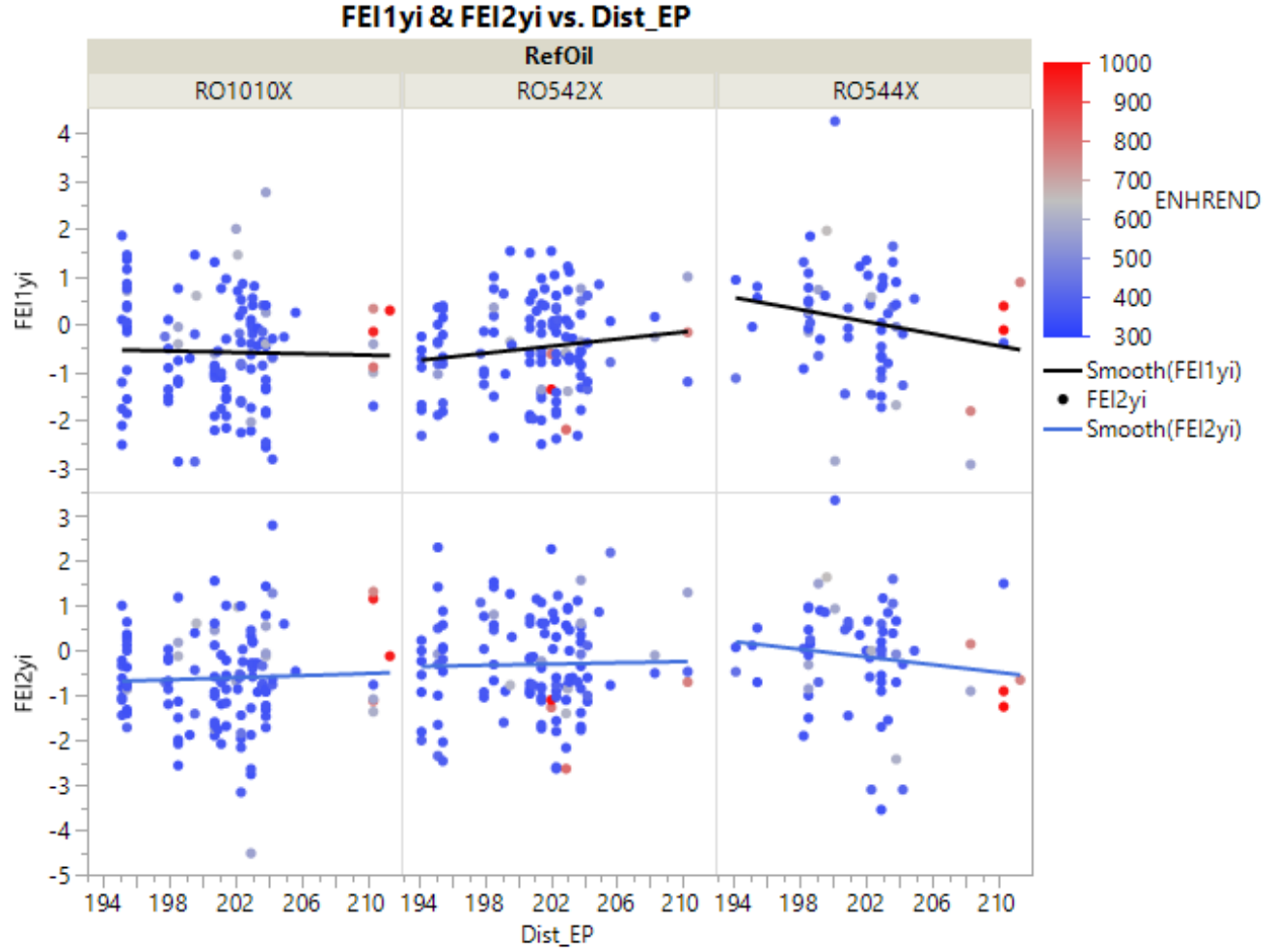
Graph Builder



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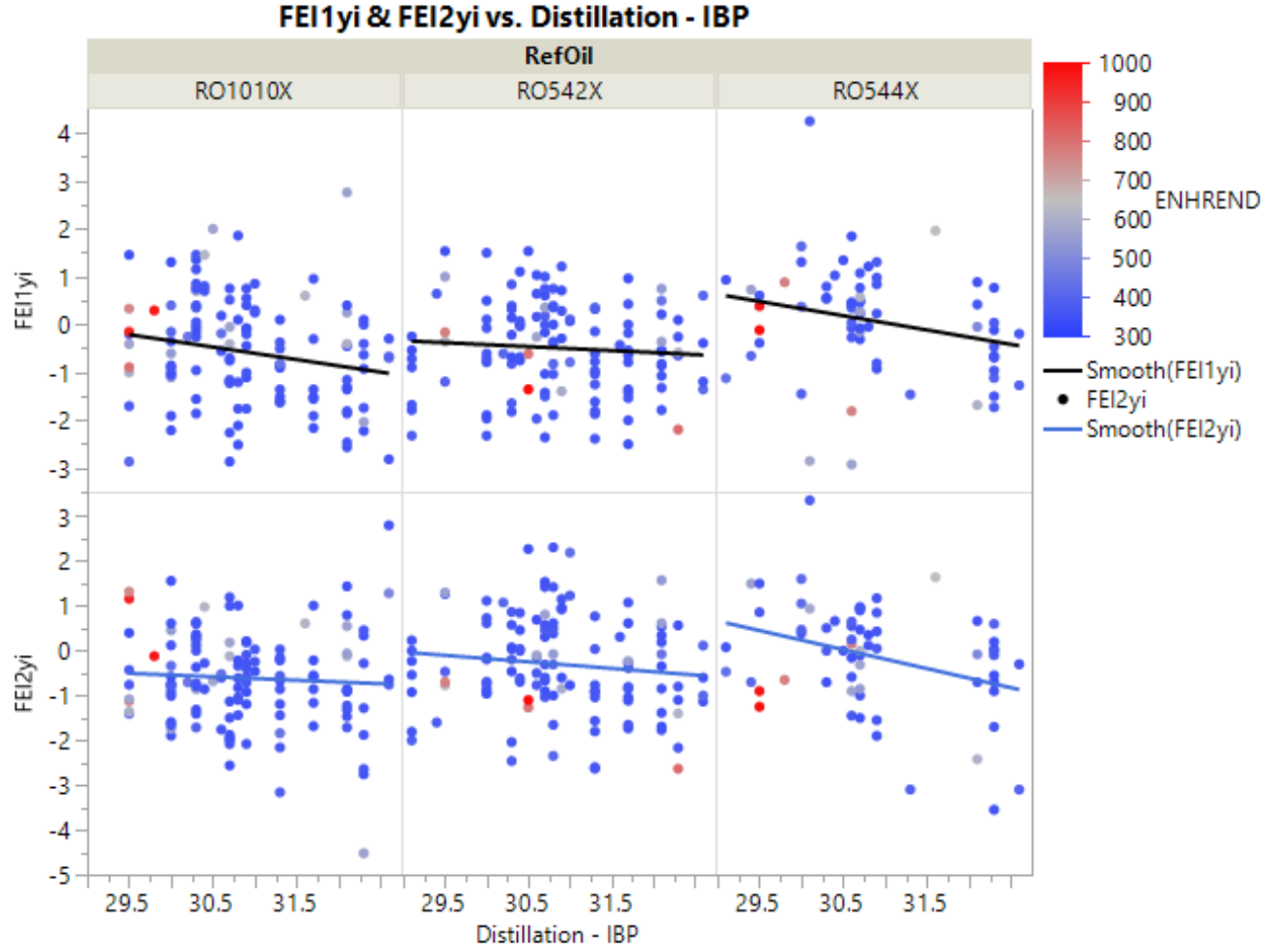

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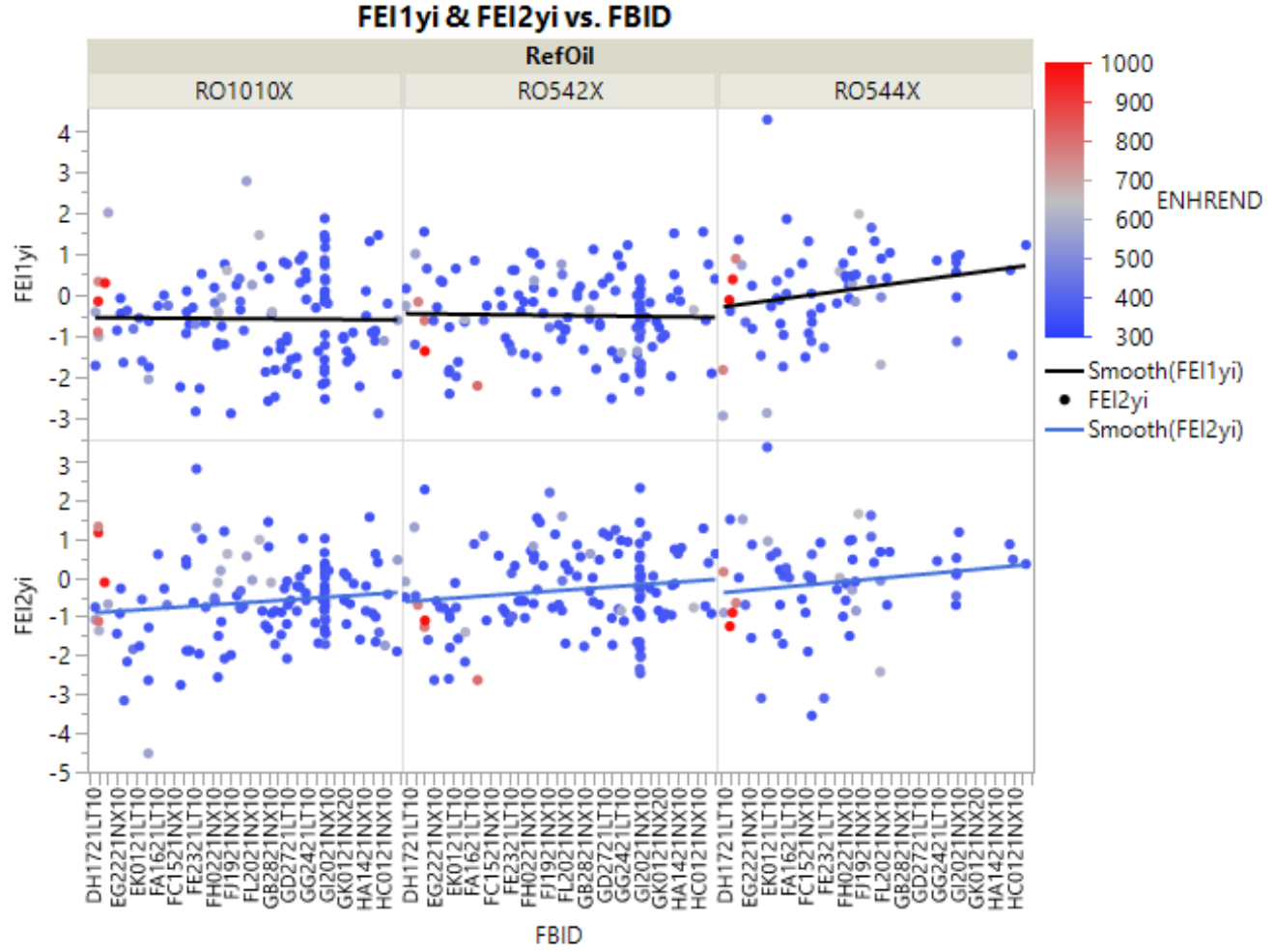

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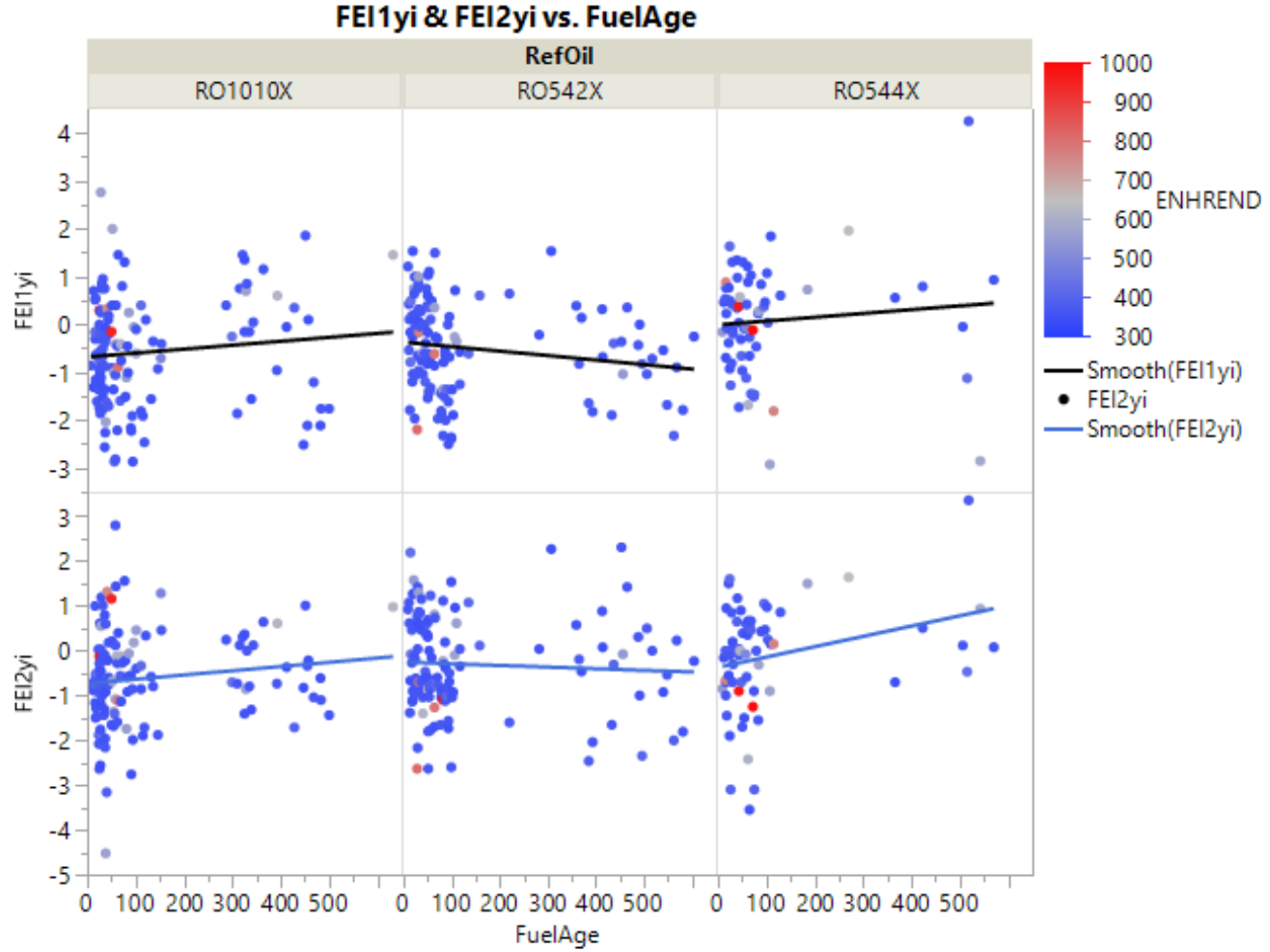

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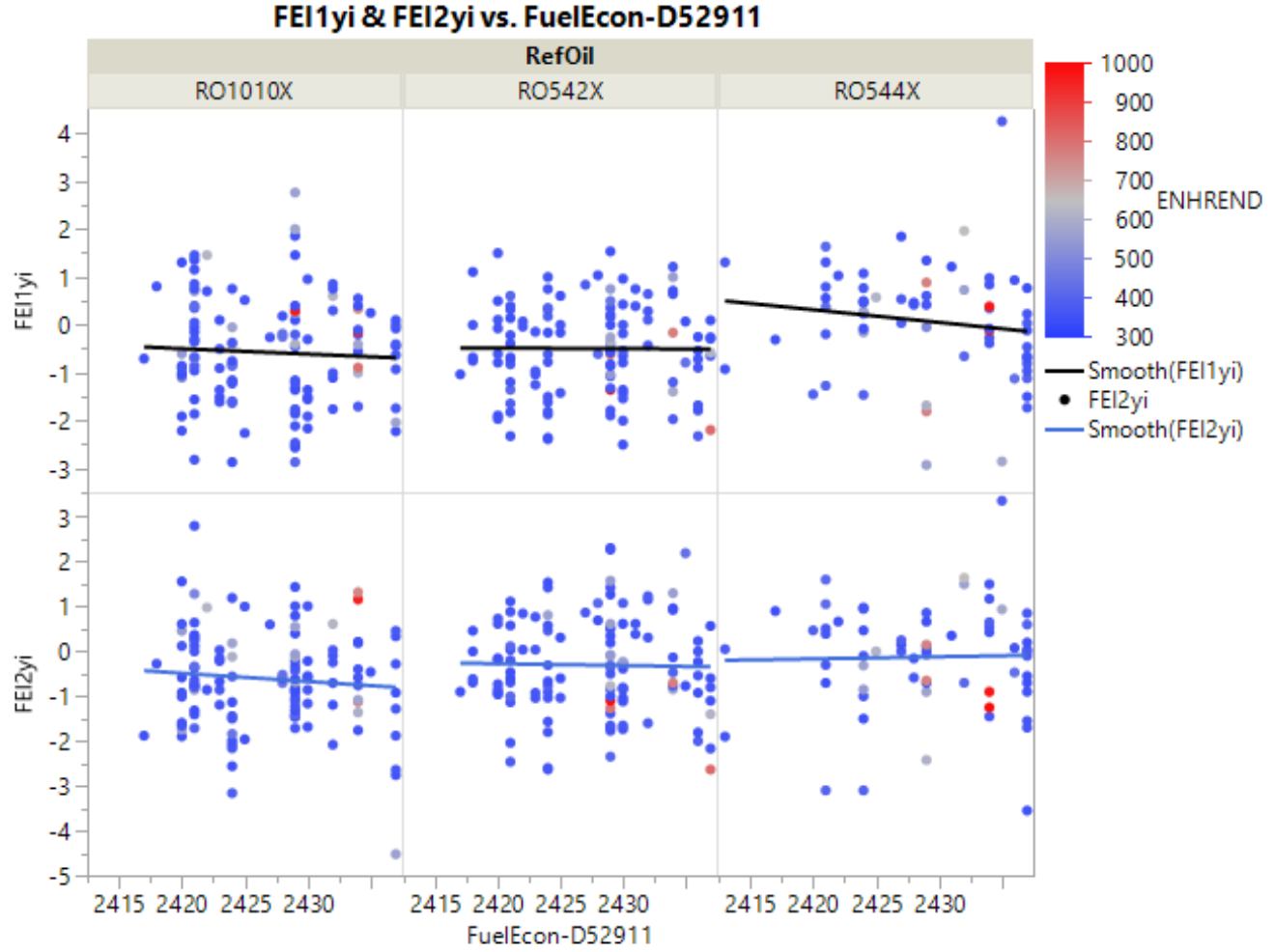

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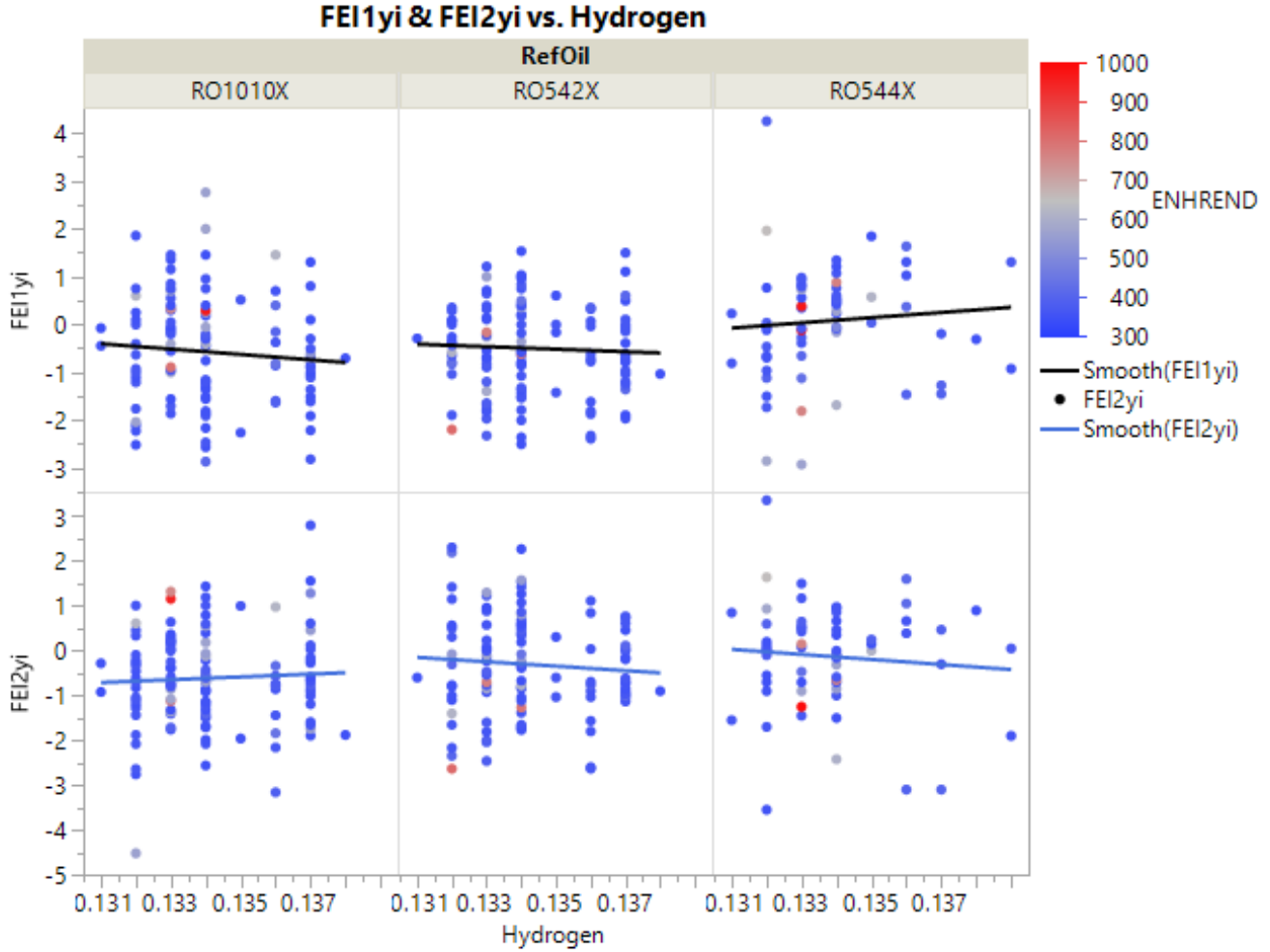

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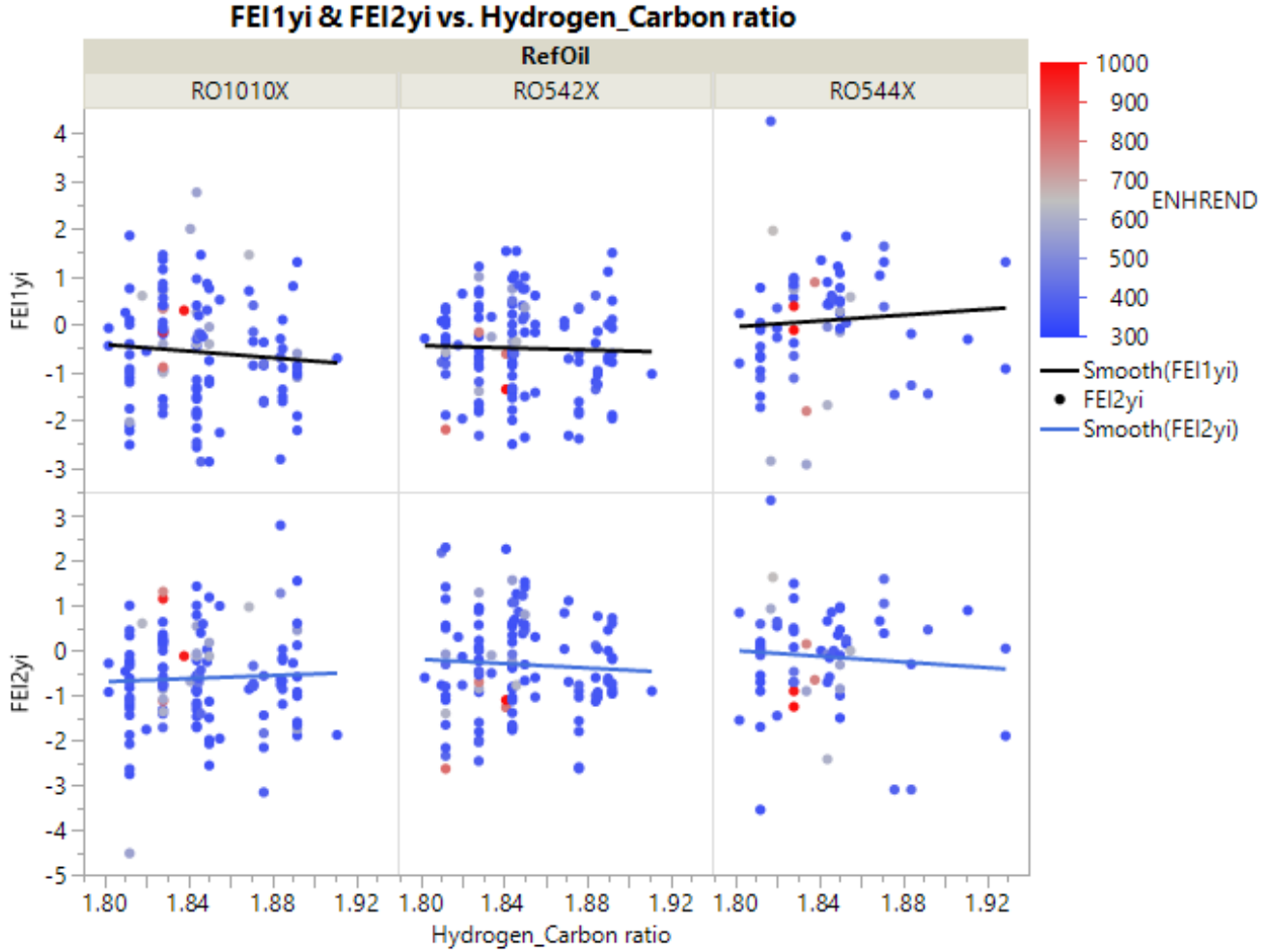

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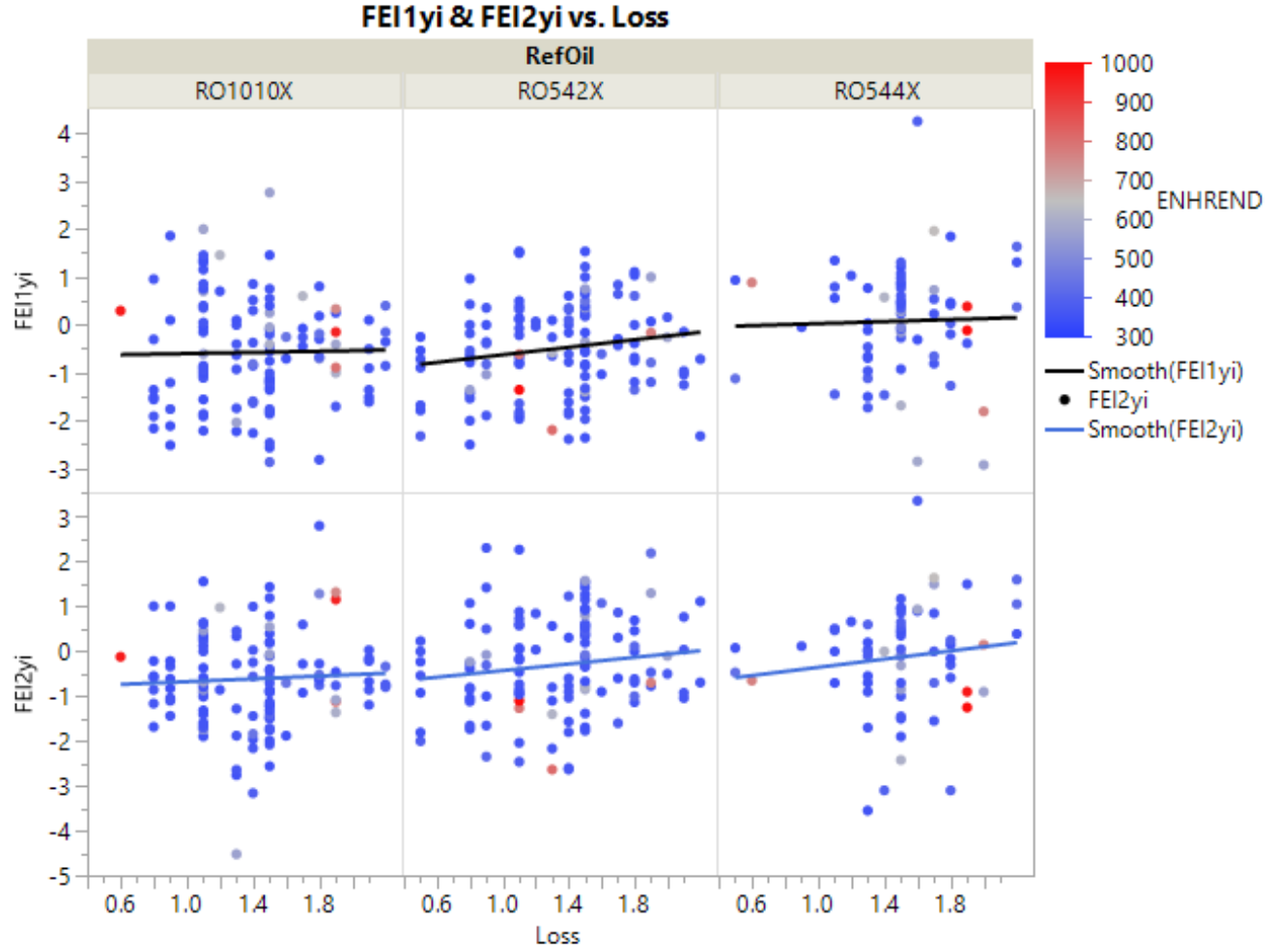

Afton CHEMICAL Passion for Solutions

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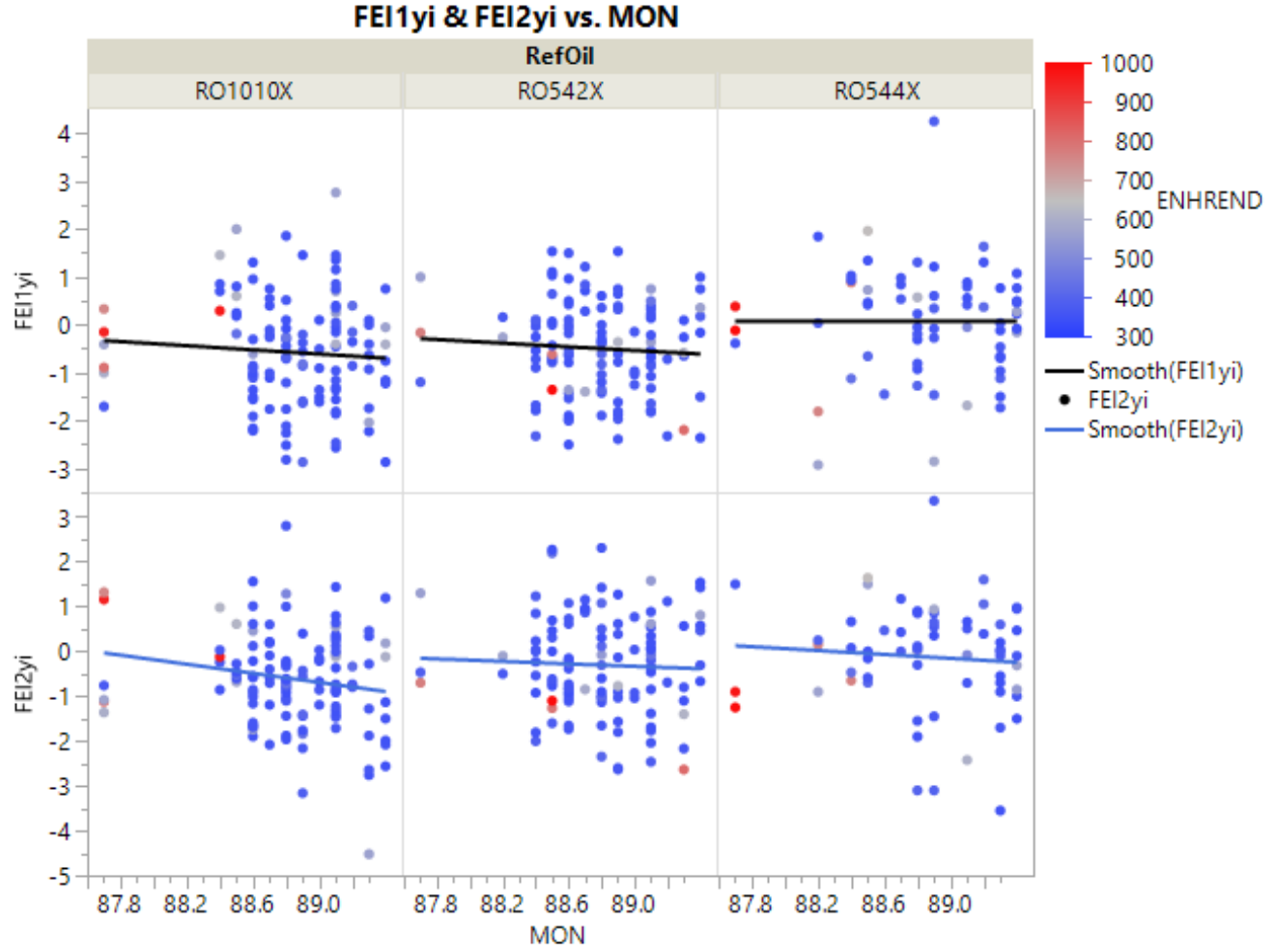

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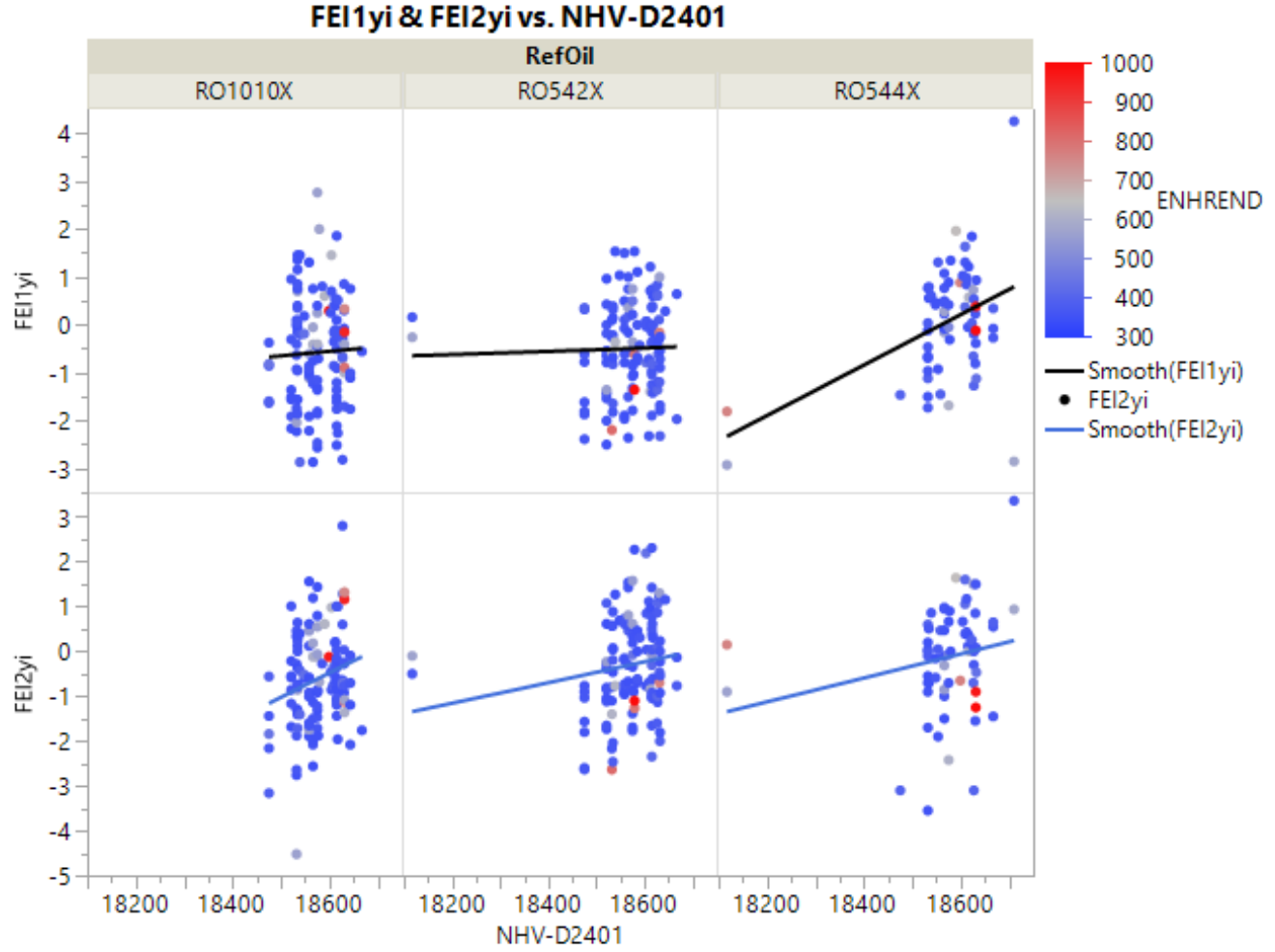

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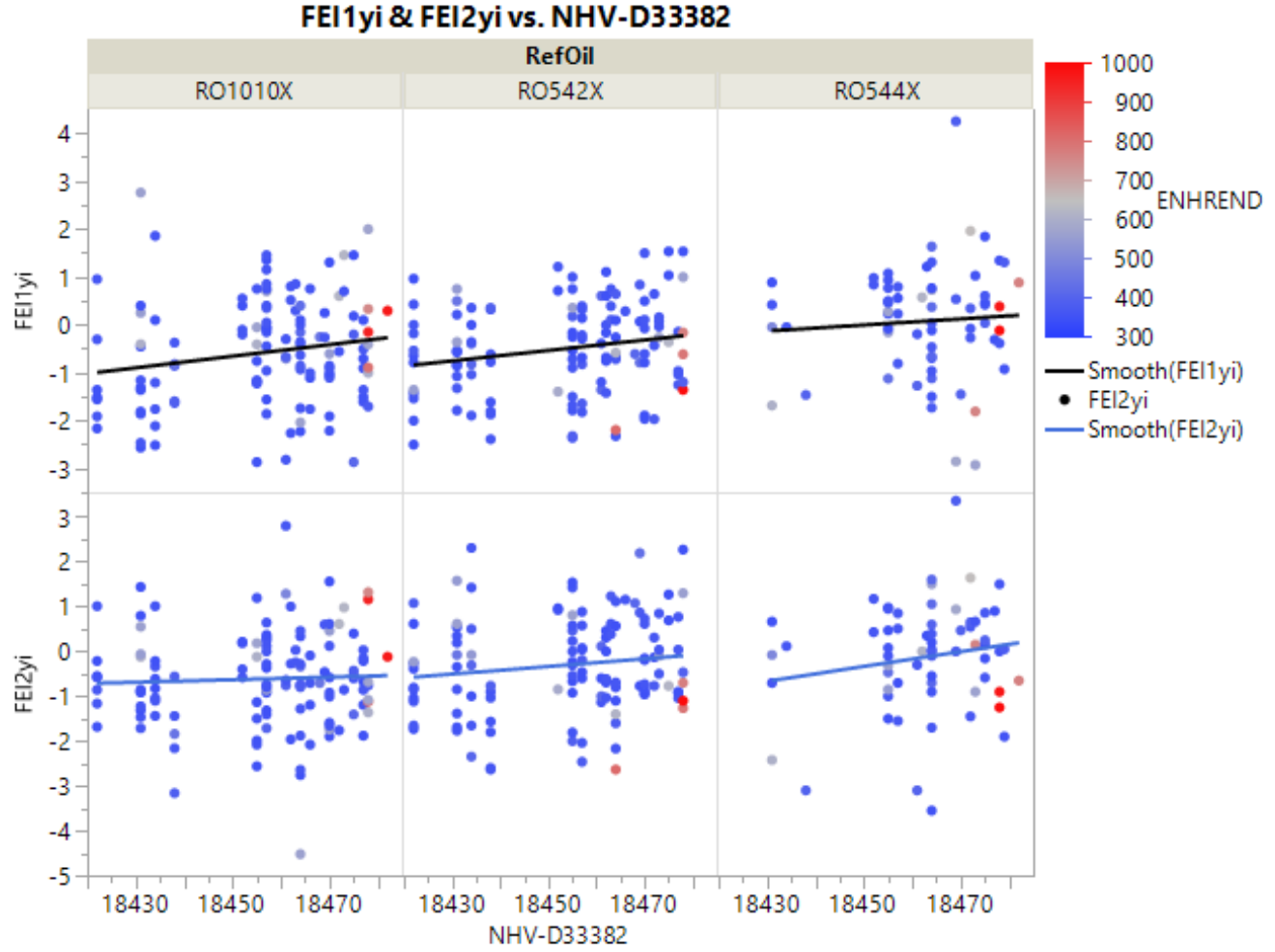
Afton CHEMICAL Passion for Solutions

Graph Builder



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Afton CHEMICAL Passion for Solutions

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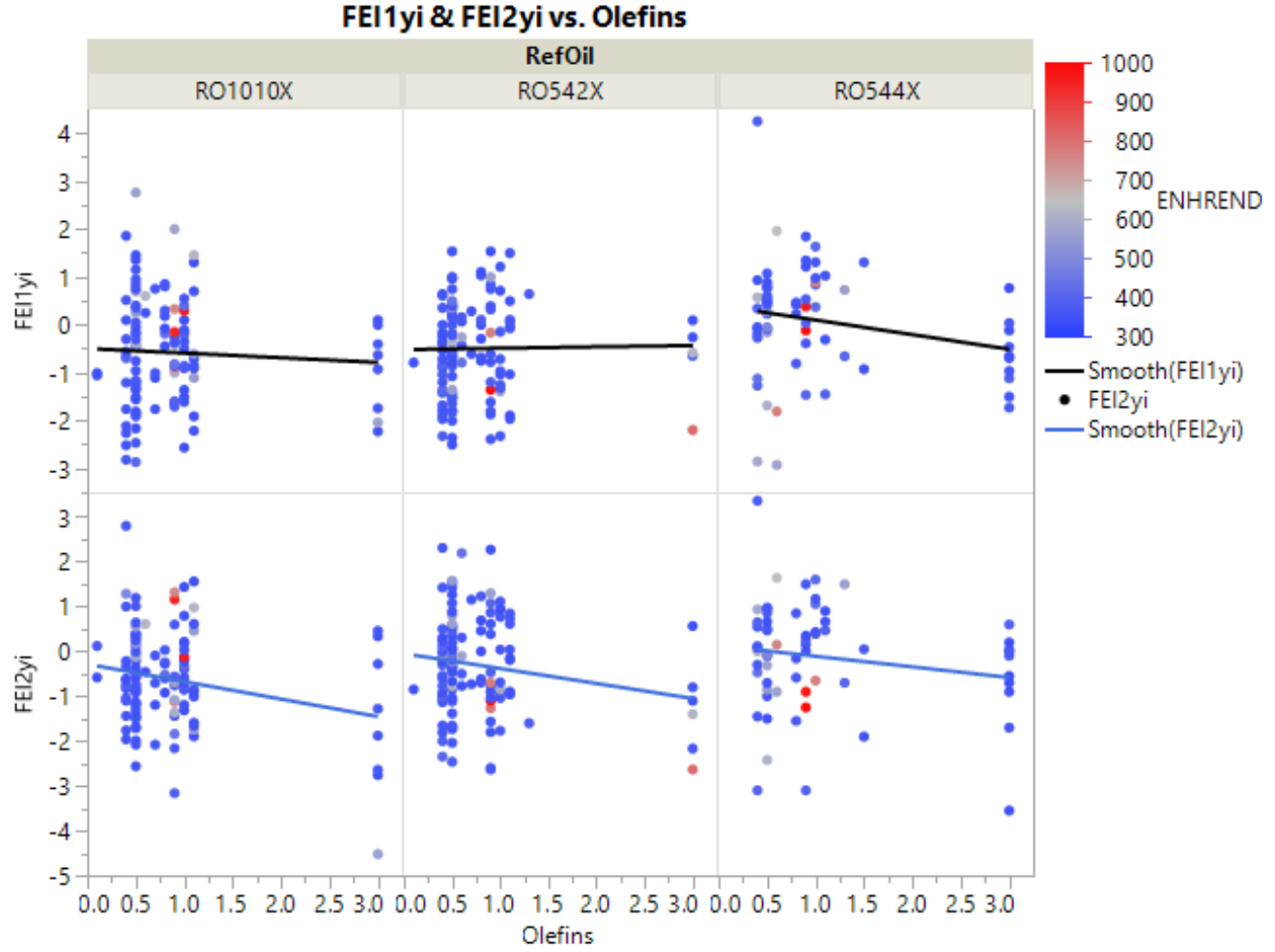

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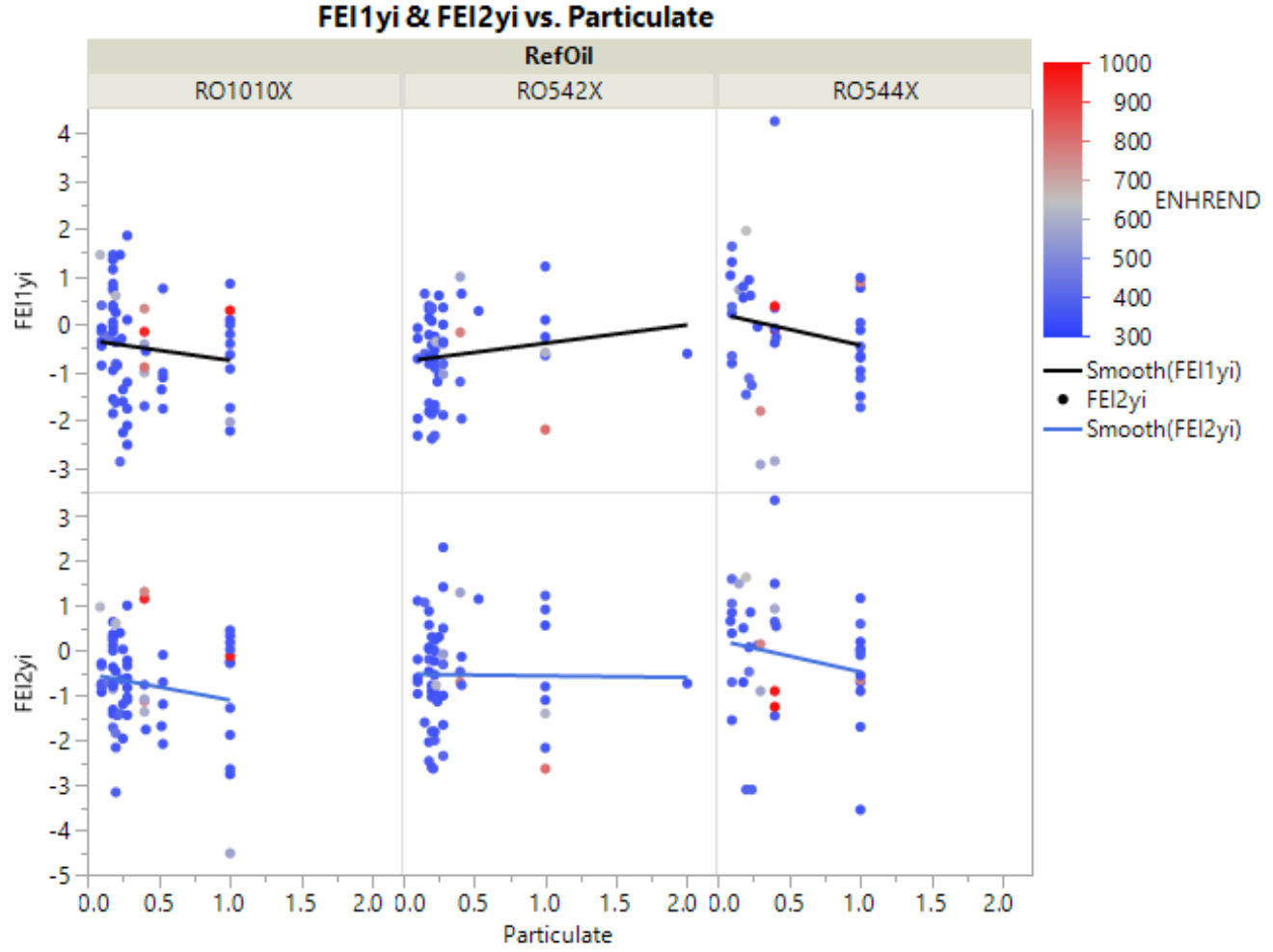
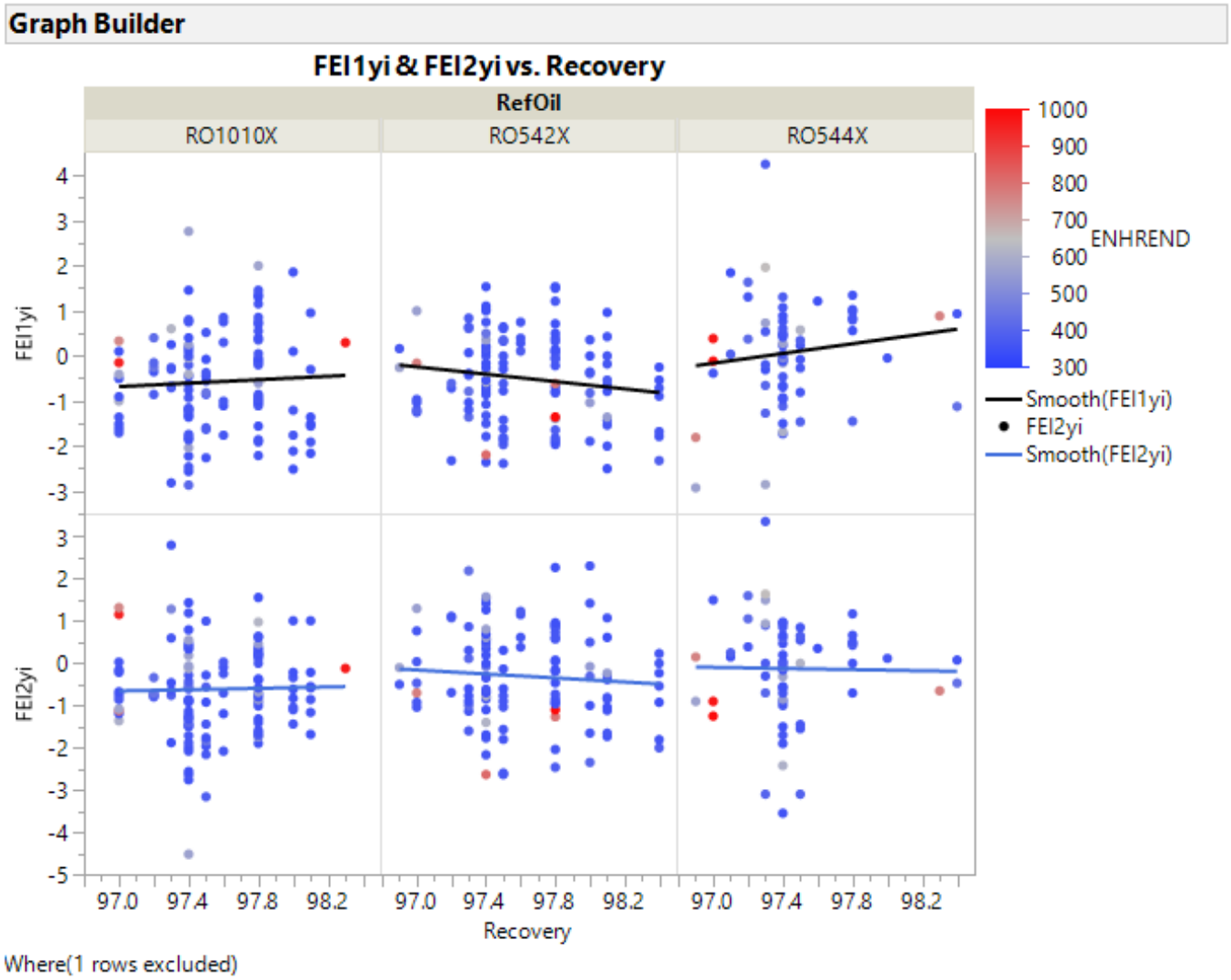
Afton CHEMICAL Passion for Solutions

Graph Builder

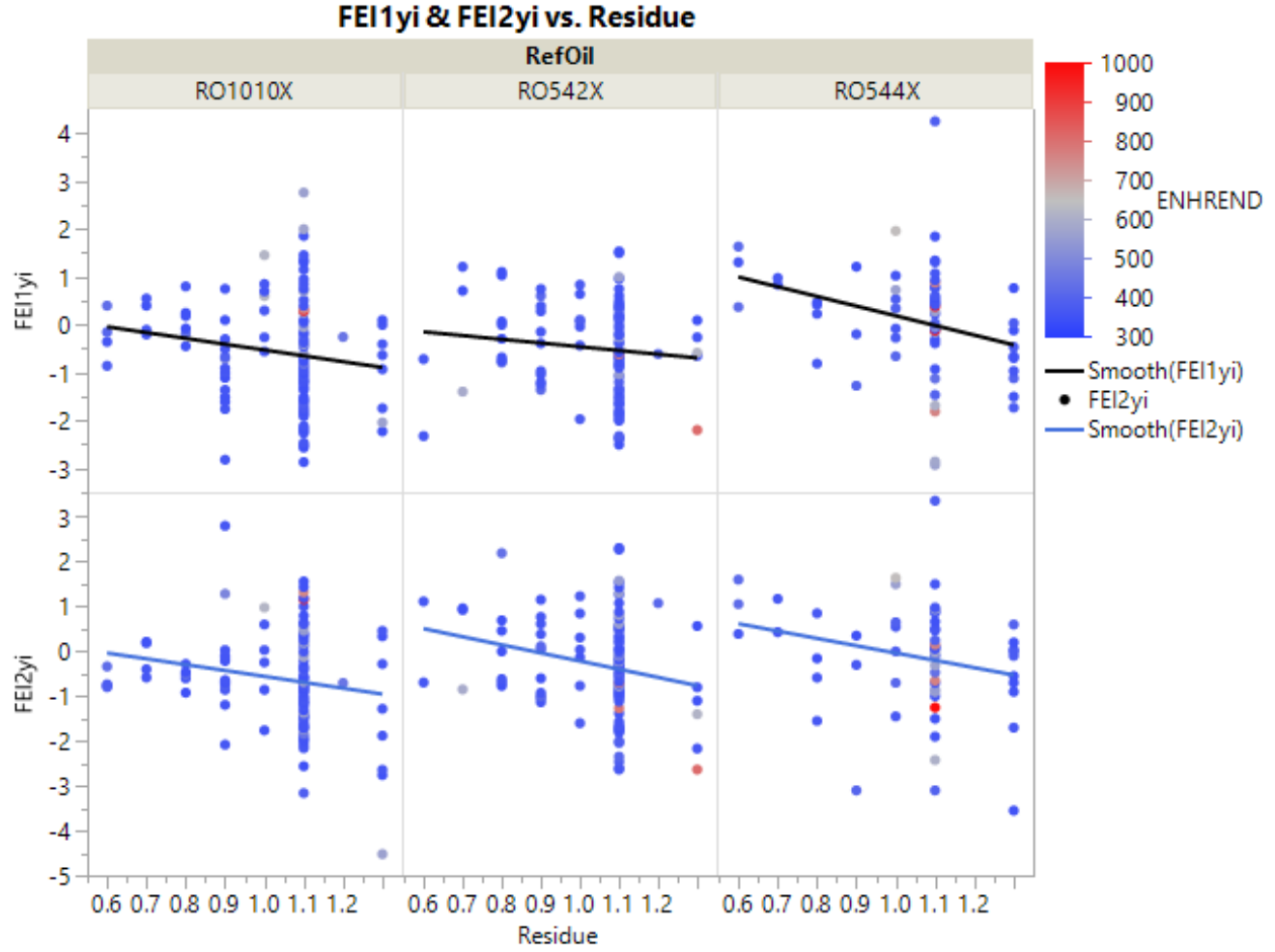


Where(1 rows excluded)

Afton CHEMICAL Passion for Solutions


Graph Builder
FEI1yi & FEI2yi vs. Recovery
RefOil
RO1010X
RO542X
RO544X
FEI1yi
FEI2yi
Recovery
ENHREND
1000
900
800
700
600
500
400
300
Smooth(FEI1yi)
FEI2yi
Smooth(FEI2yi)
Where(1 rows excluded)

Graph Builder



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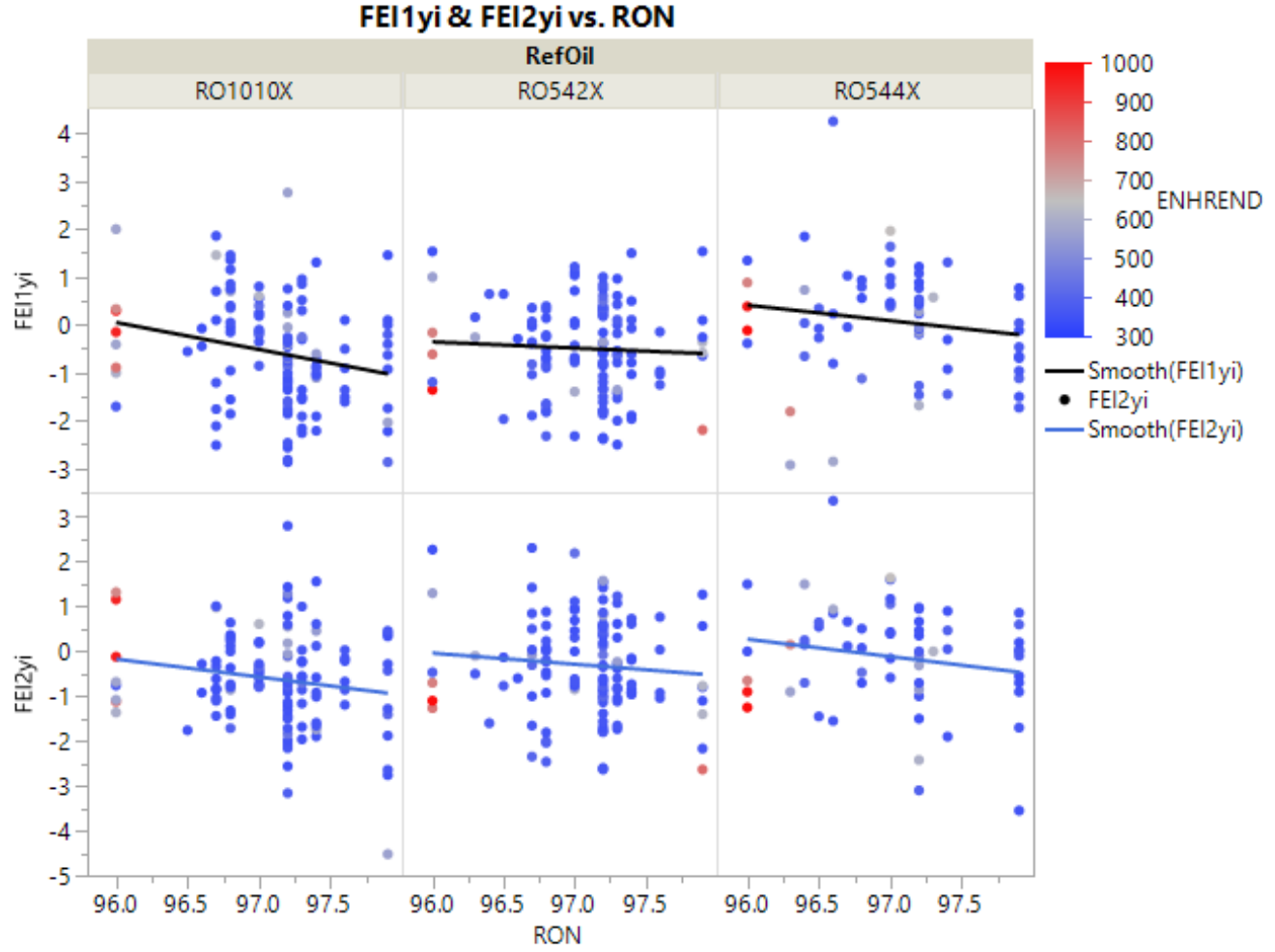
Afton CHEMICAL Passion for Solutions

Graph Builder



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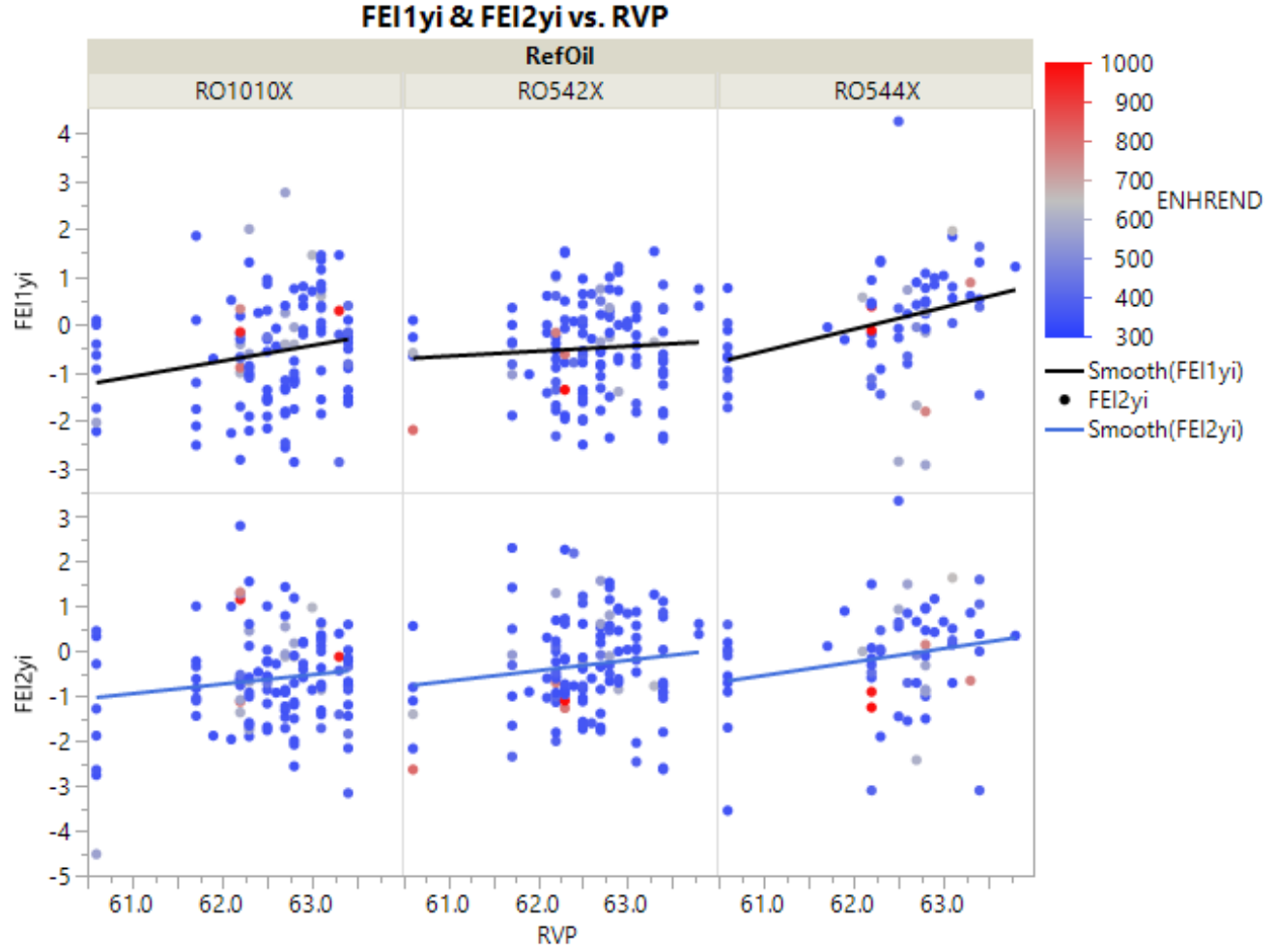

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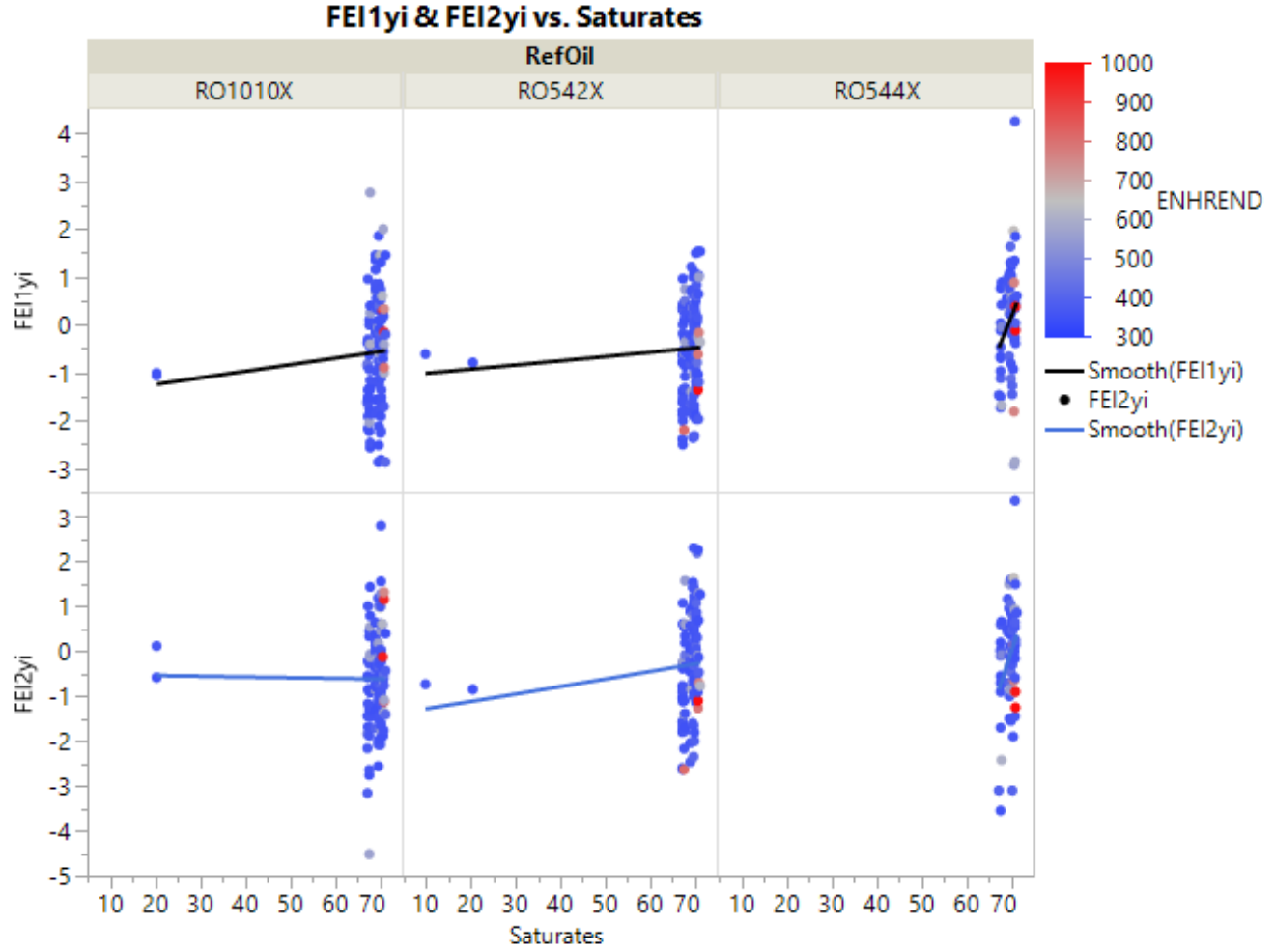
Afton CHEMICAL Passion for Solutions

Graph Builder



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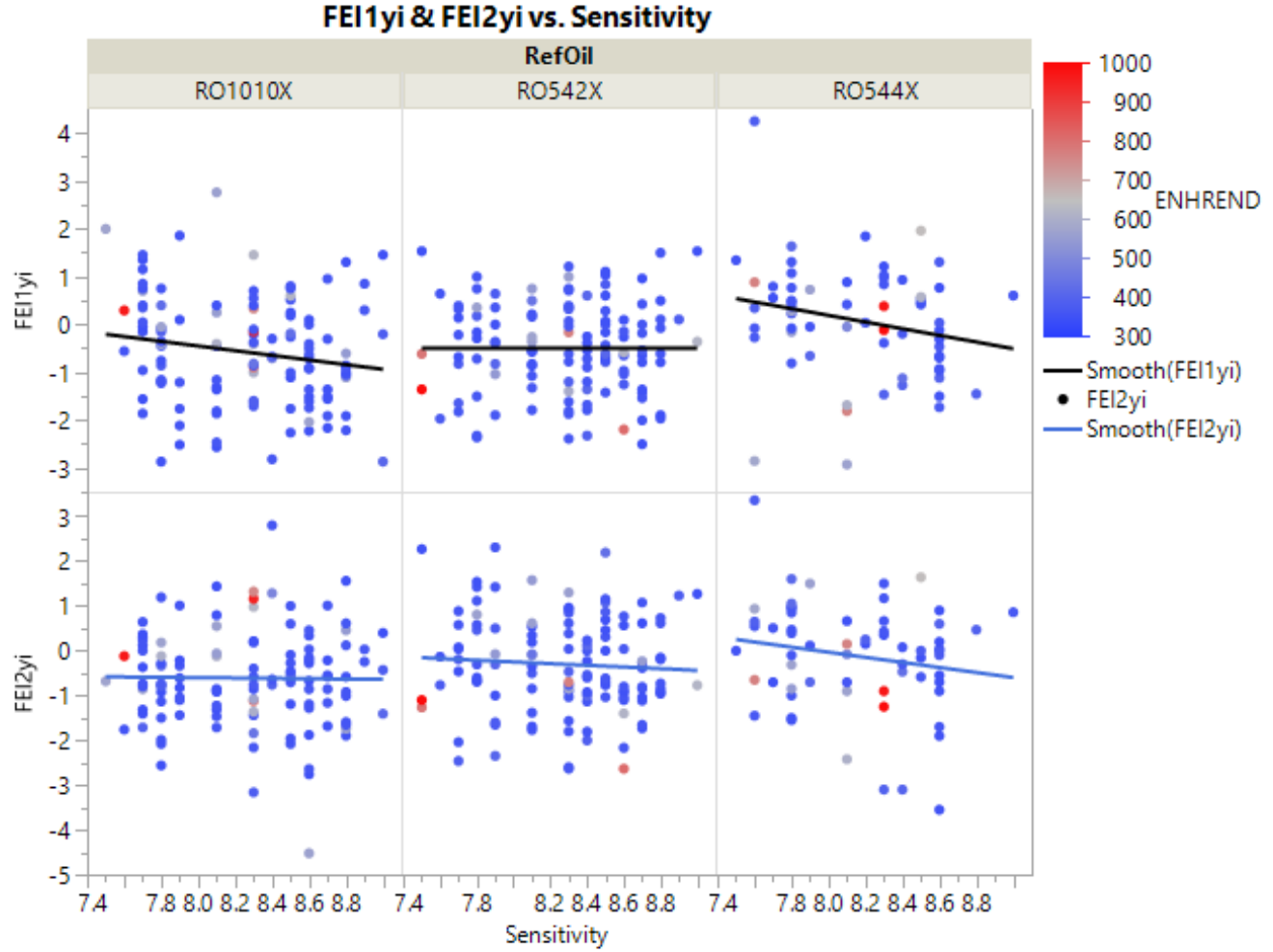
Afton CHEMICAL Passion for Solutions

Graph Builder



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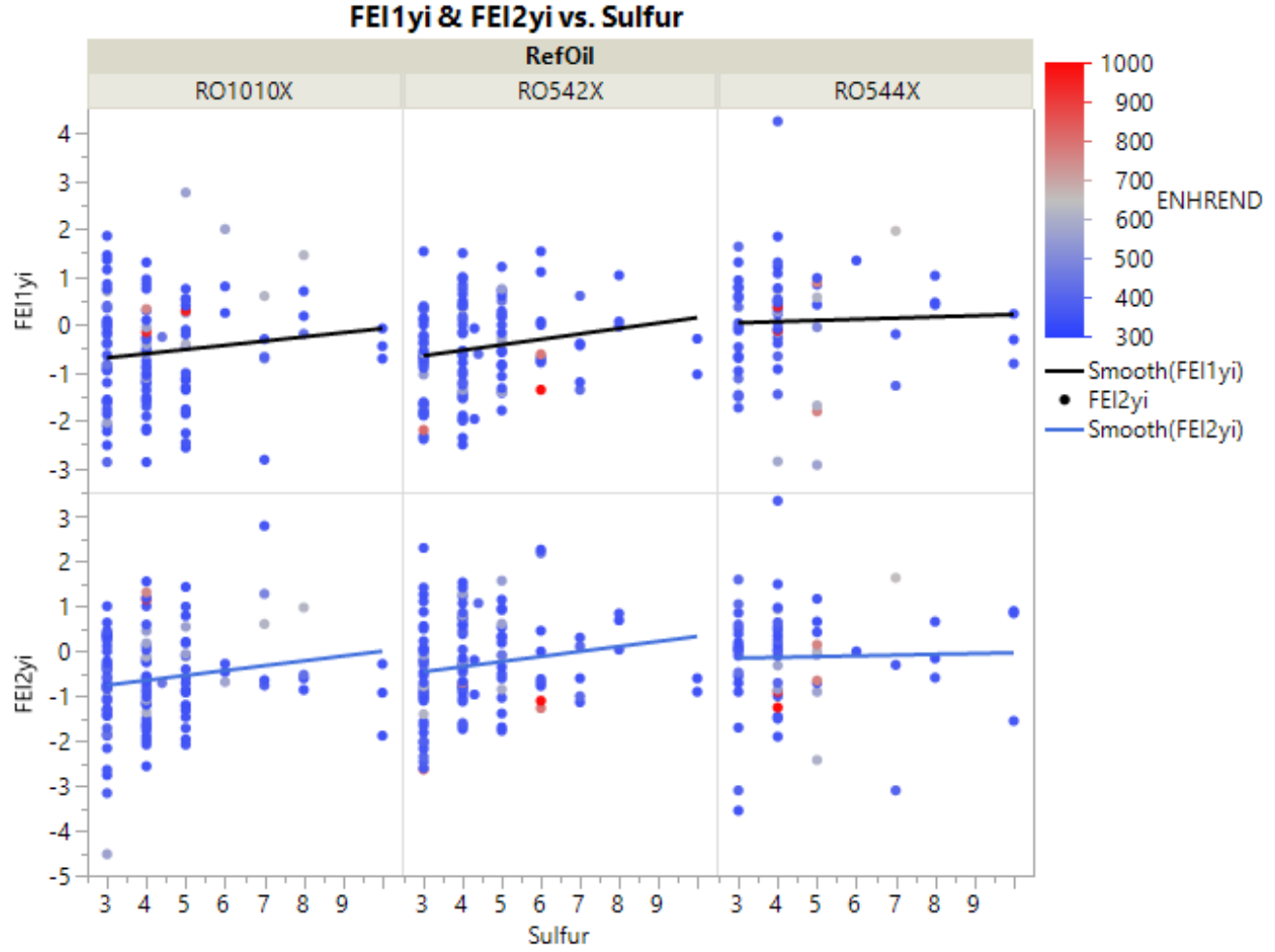
Afton CHEMICAL Passion for Solutions

Graph Builder



Where(1 rows excluded)

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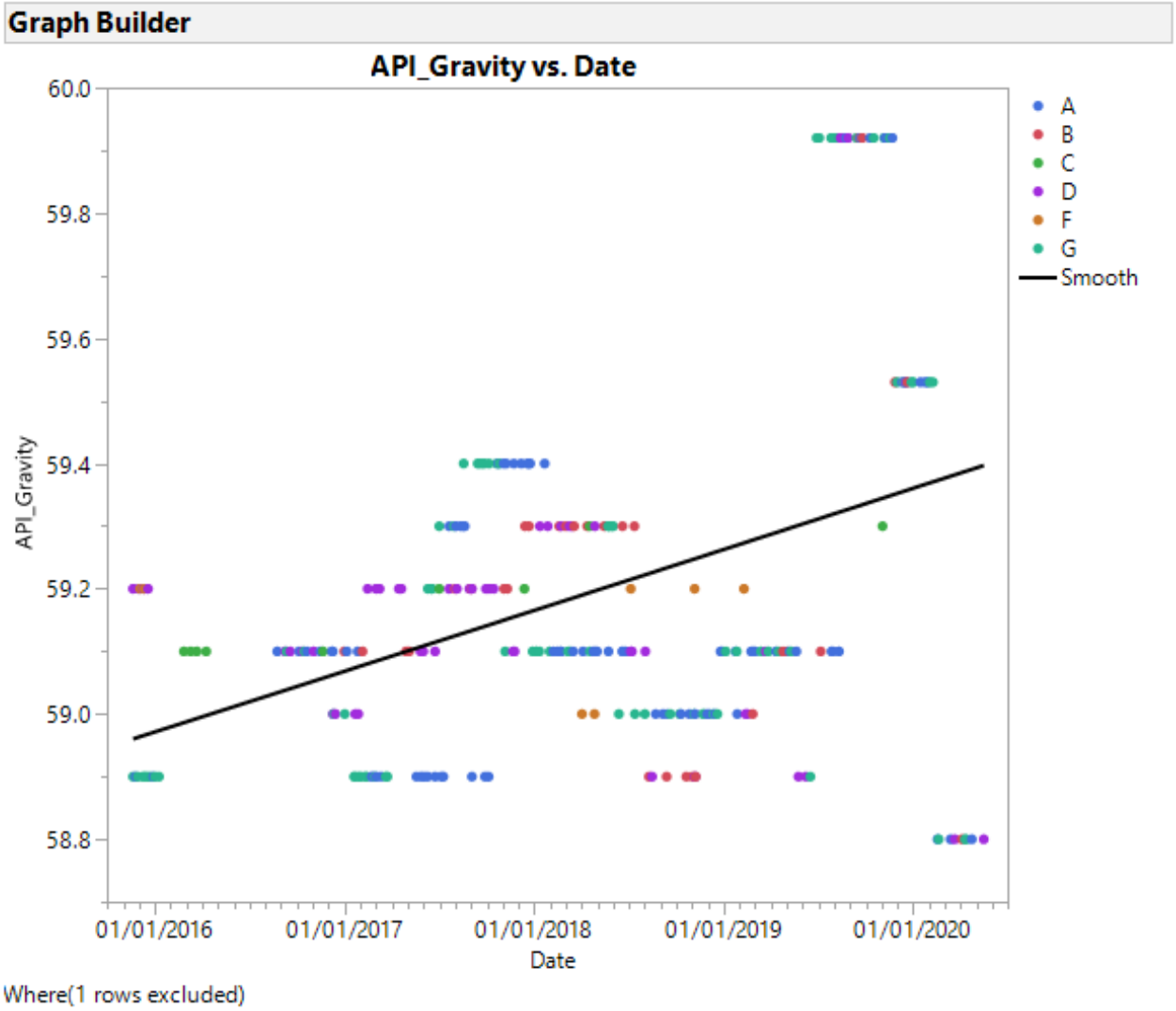
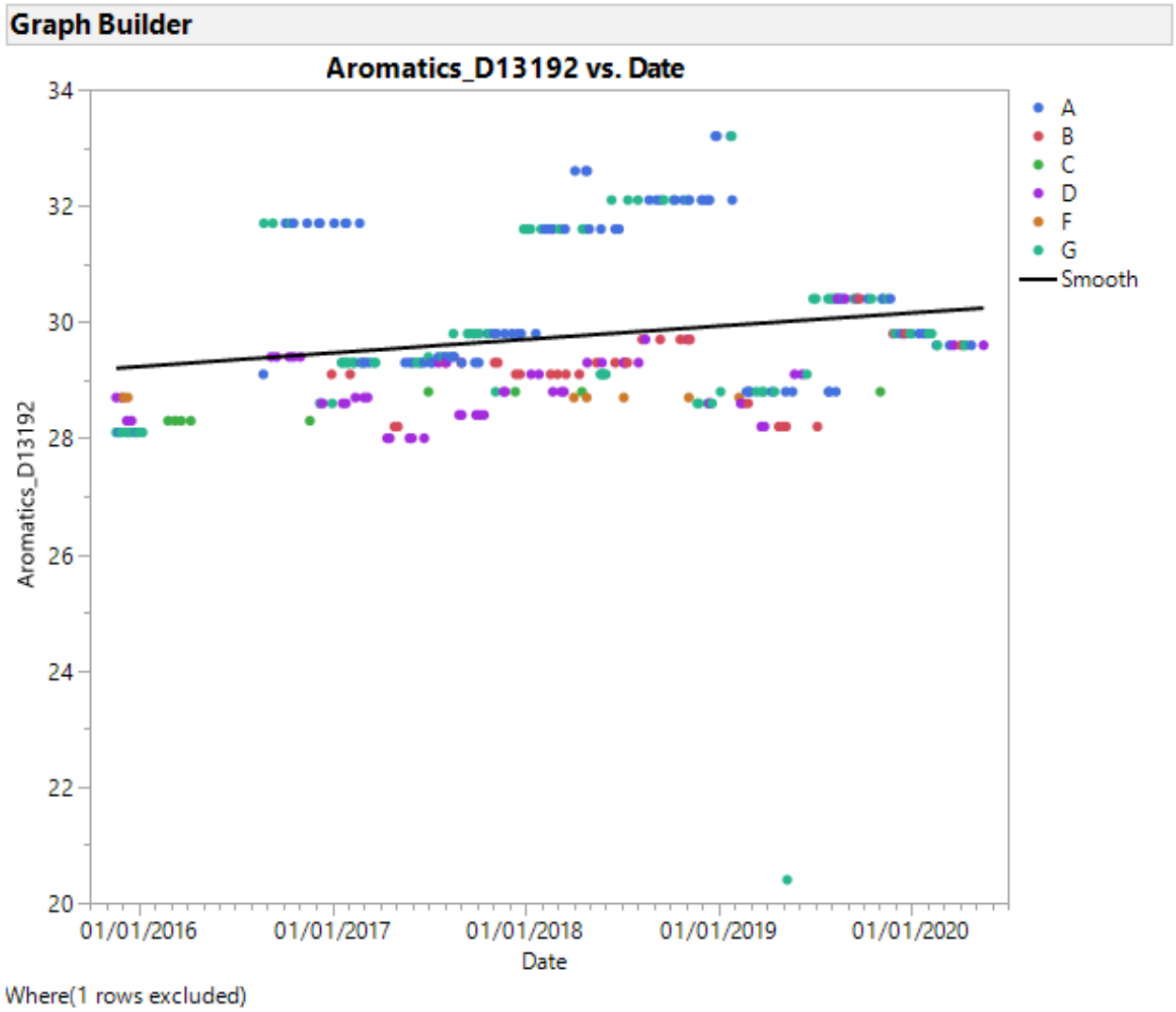
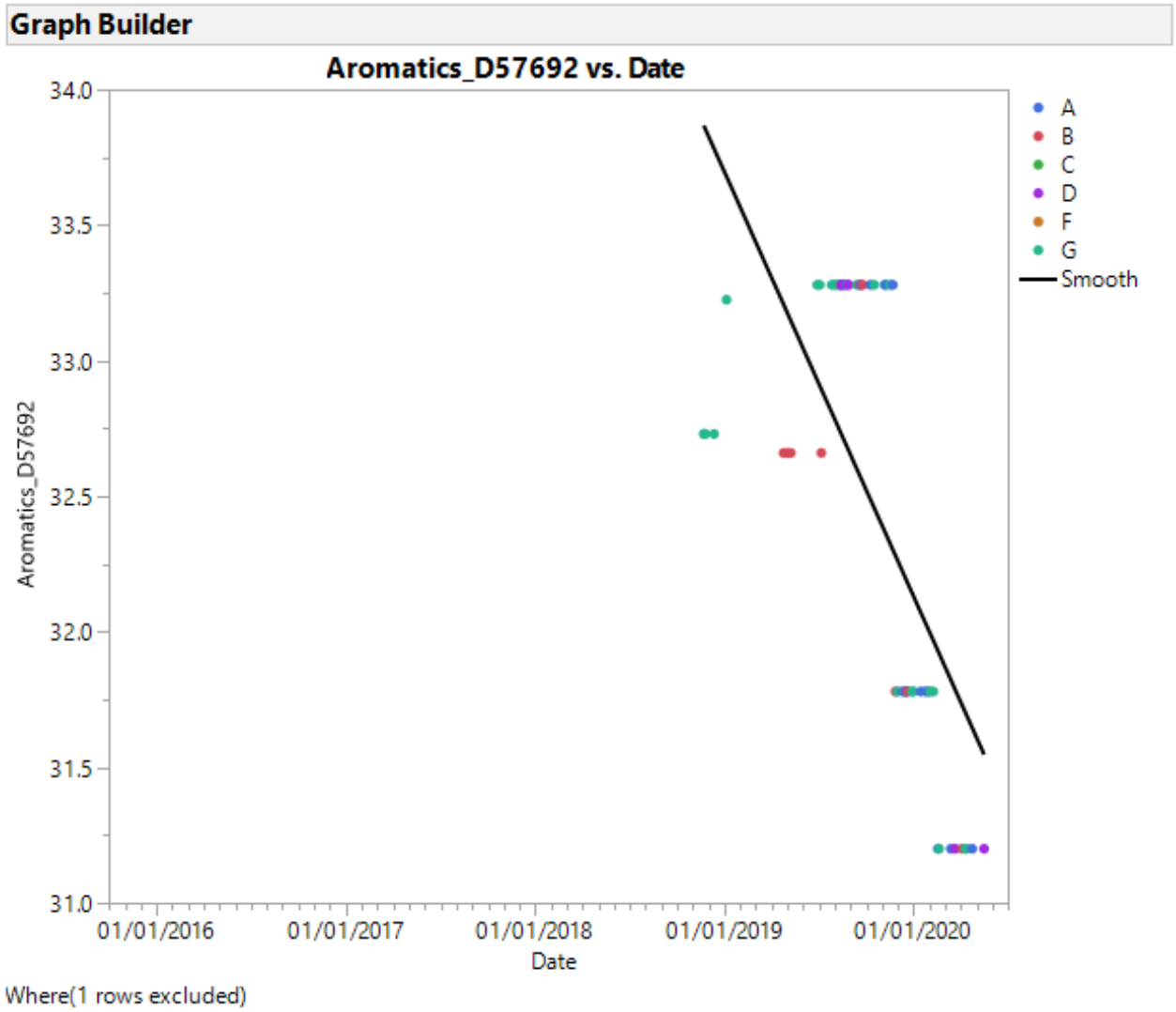
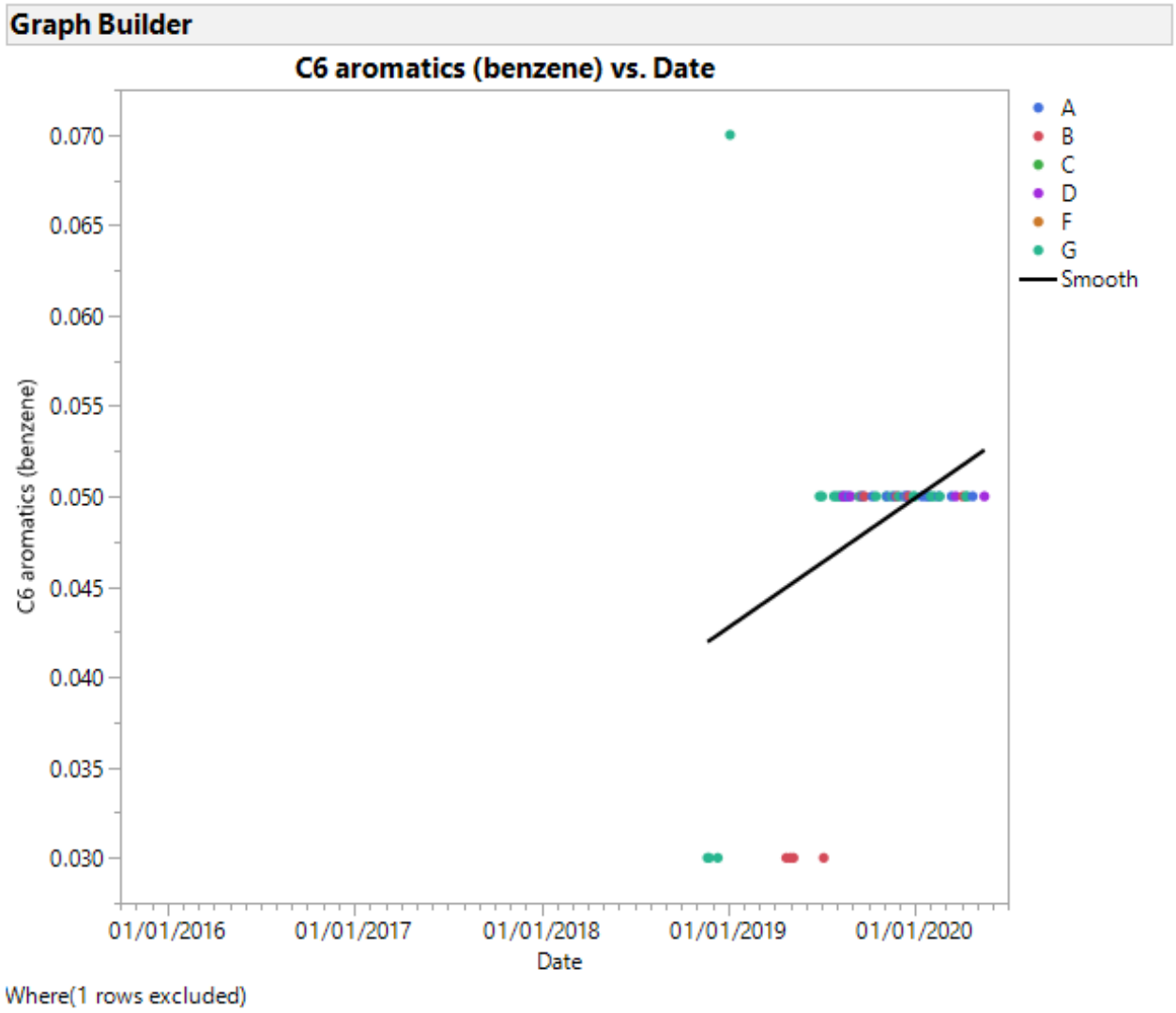
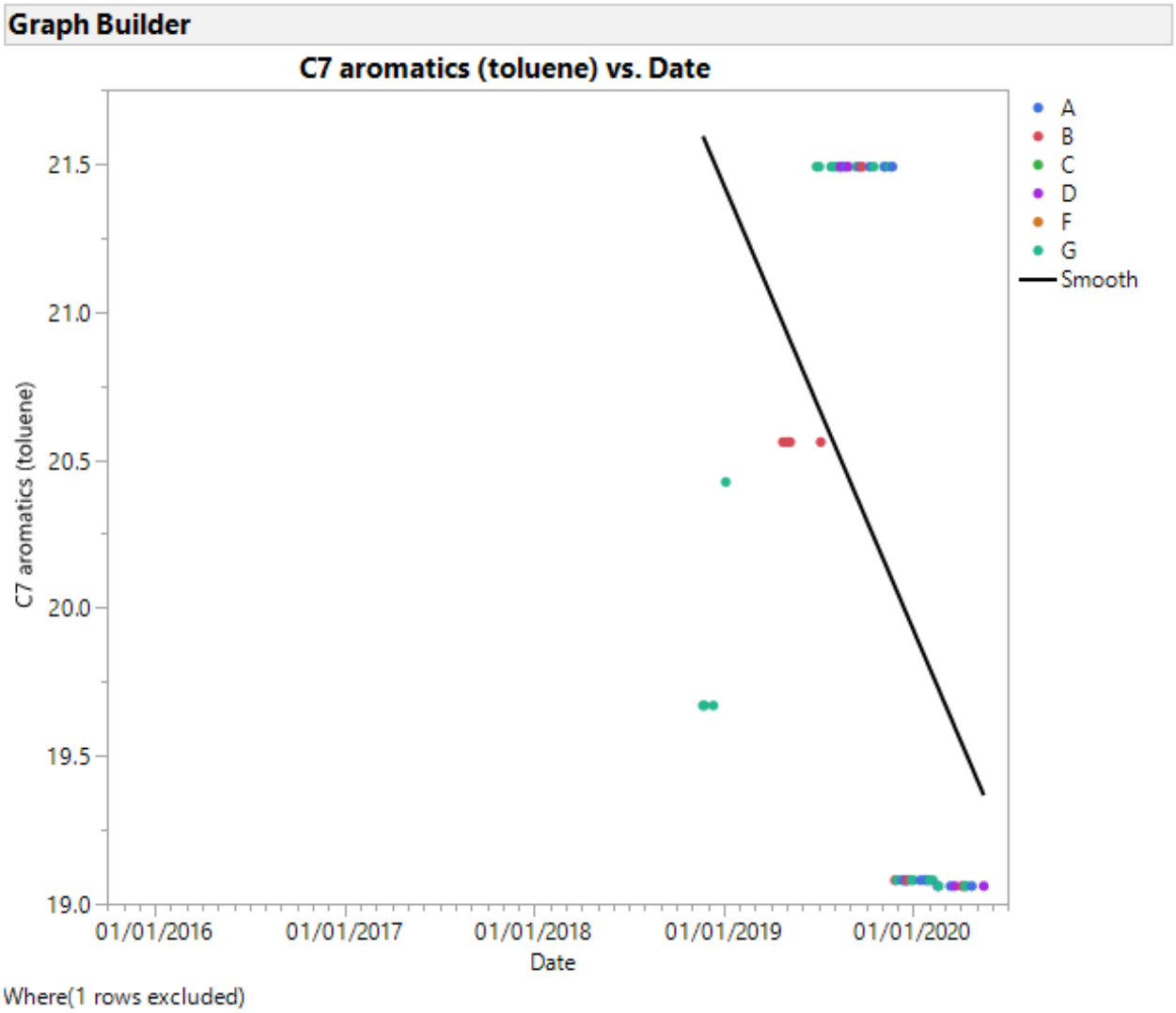
Appendix B - Plots of Fuel Properties vs. Date



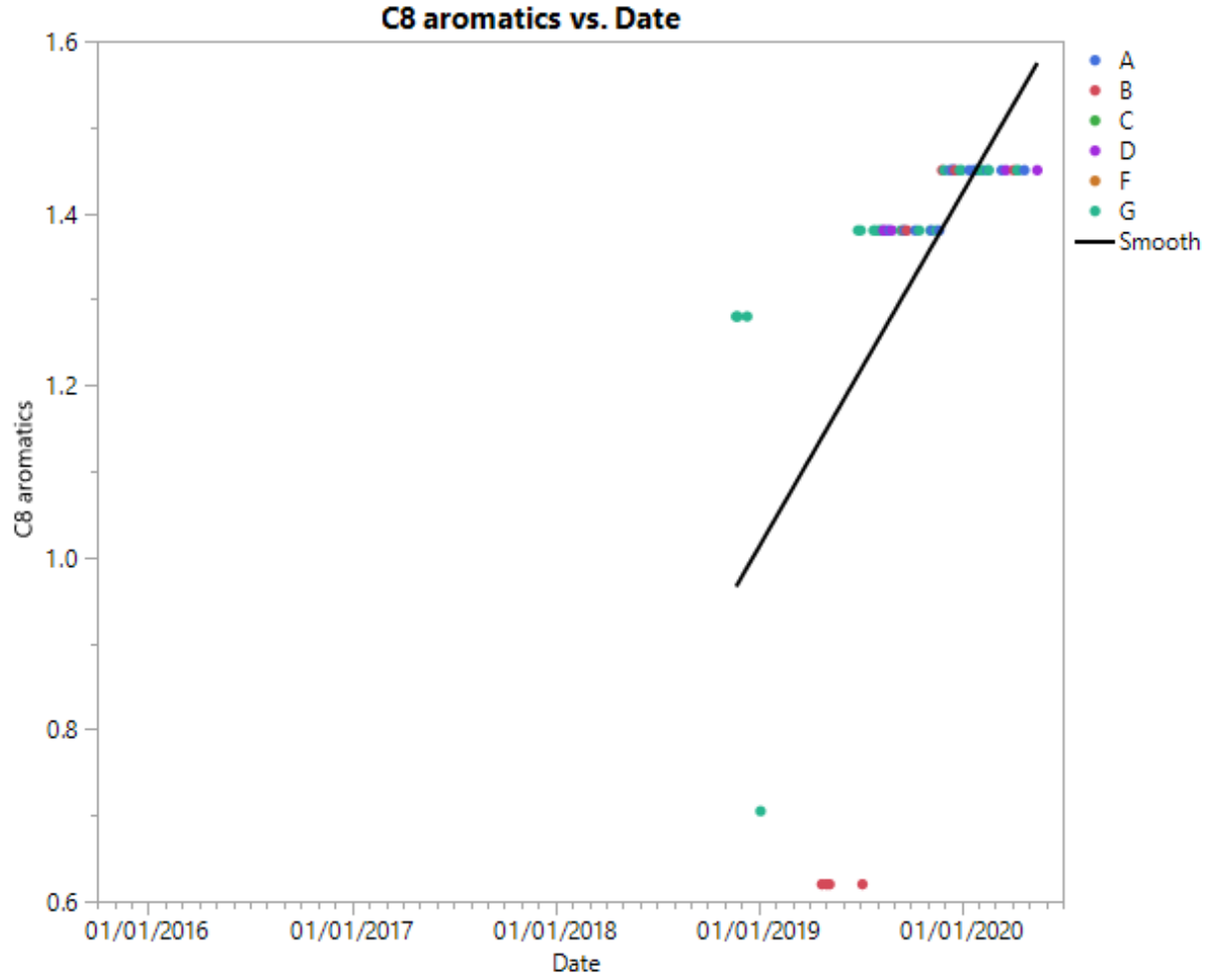




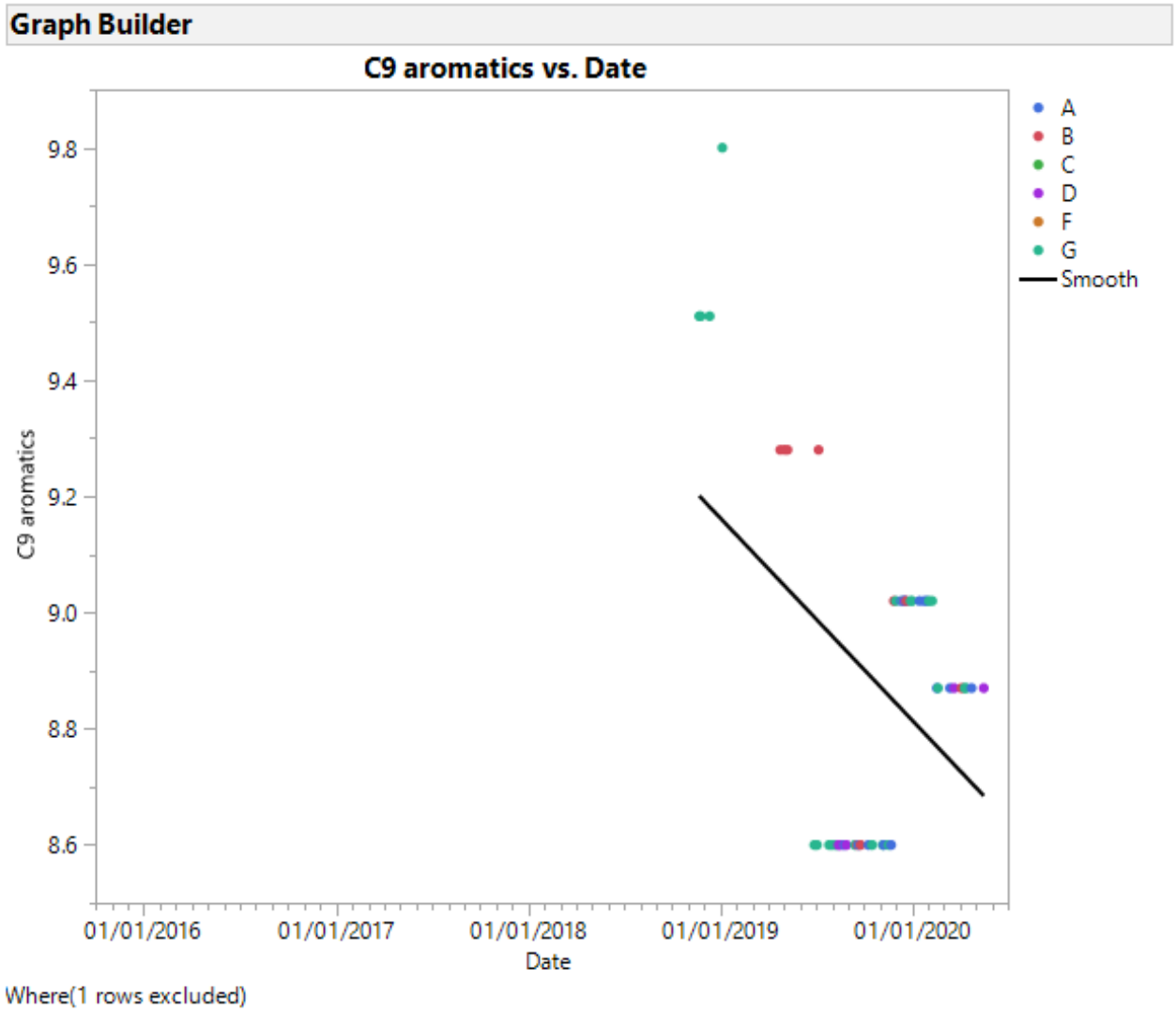

Graph Builder
C6 aromatics (benzene) vs. Date
C6 aromatics (benzene)
0.070
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Date
A
B
C
D
F
G
Smooth
Where(1 rows excluded)

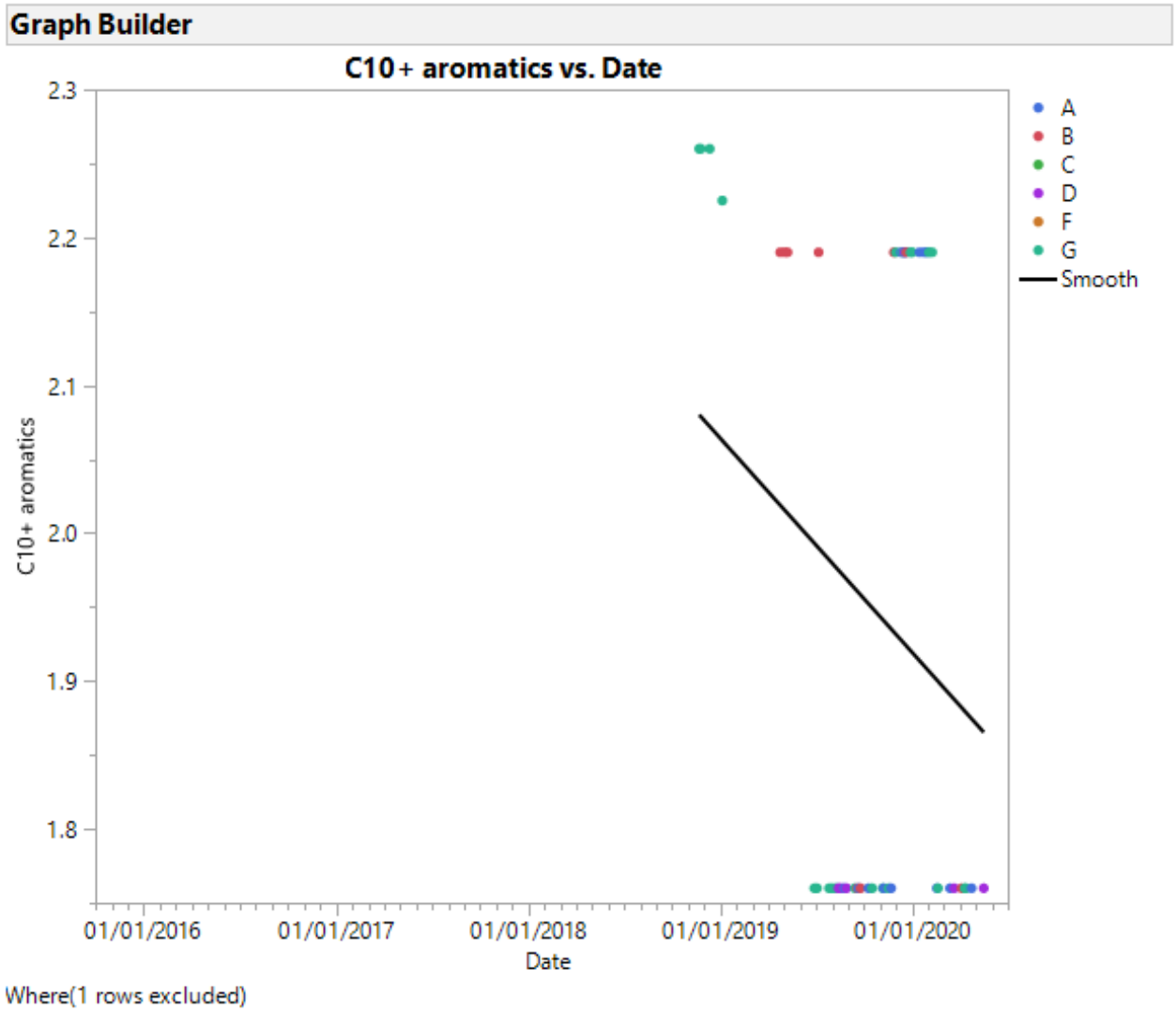

Graph Builder
C7 aromatics (toluene) vs. Date
A
B
C
D
F
G
Smooth
21.5
21.0
20.5
20.0
19.5
19.0
C7 aromatics (toluene)
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Date
Where(1 rows excluded)

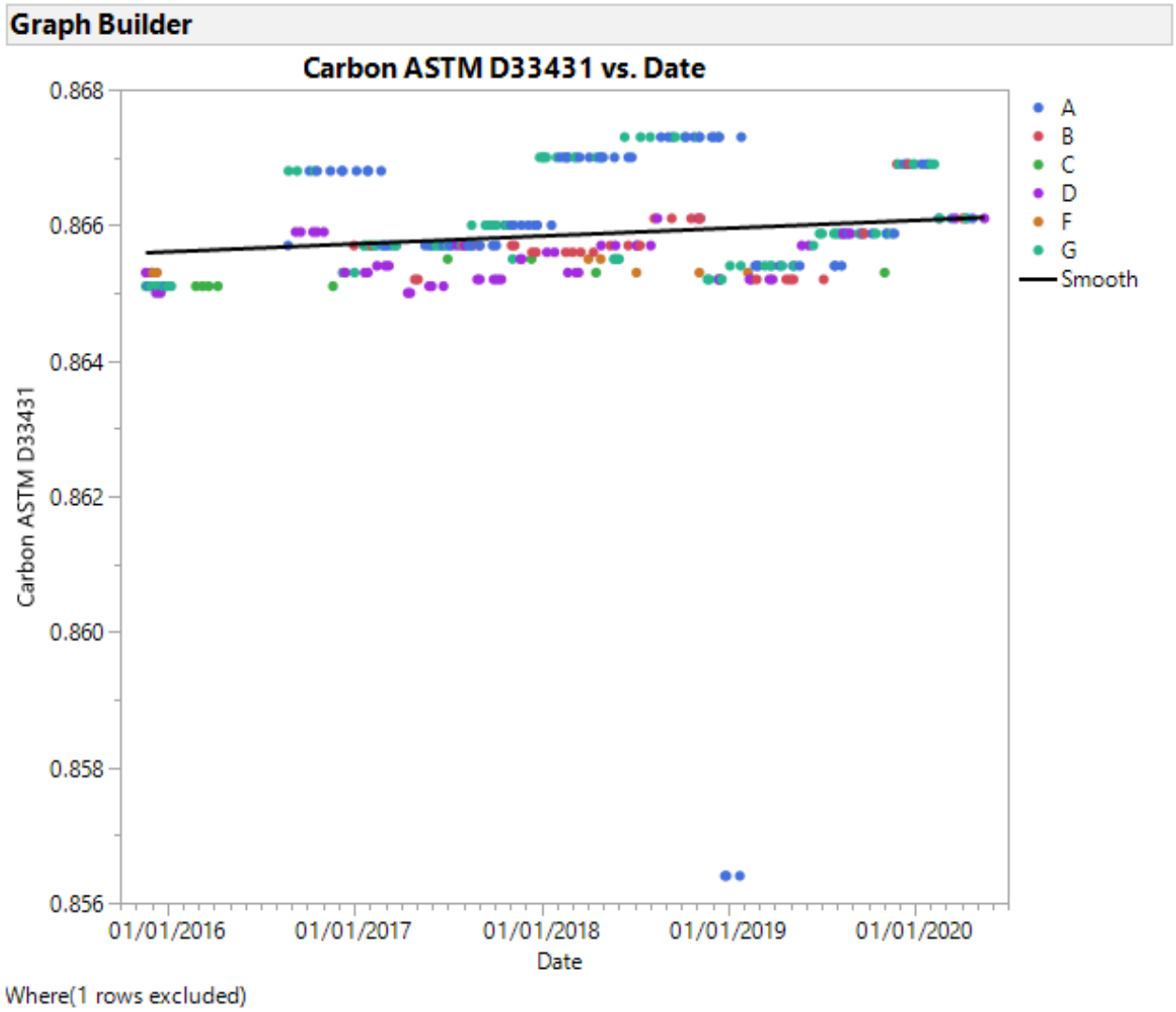
Graph Builder

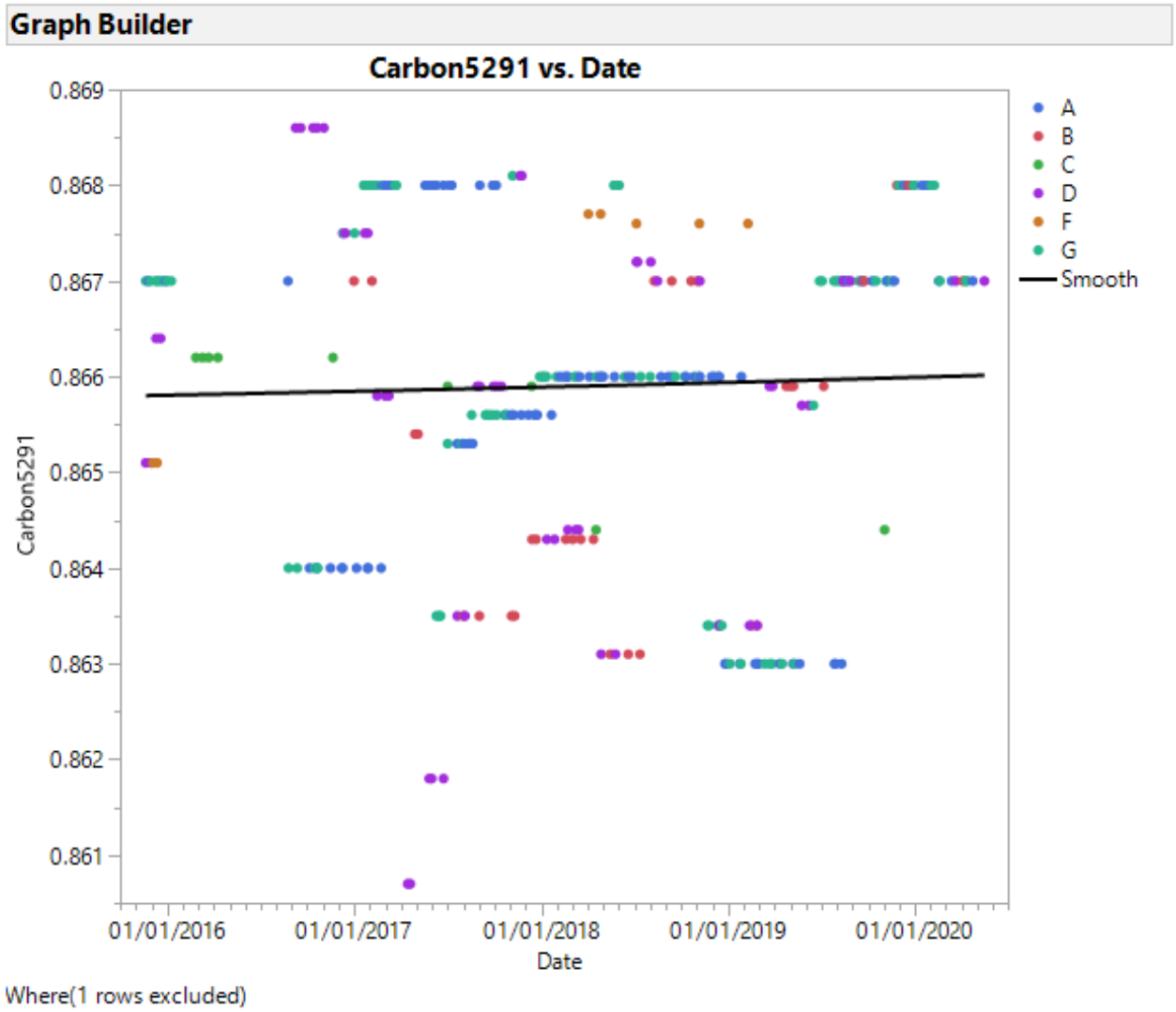


Where(1 rows excluded)

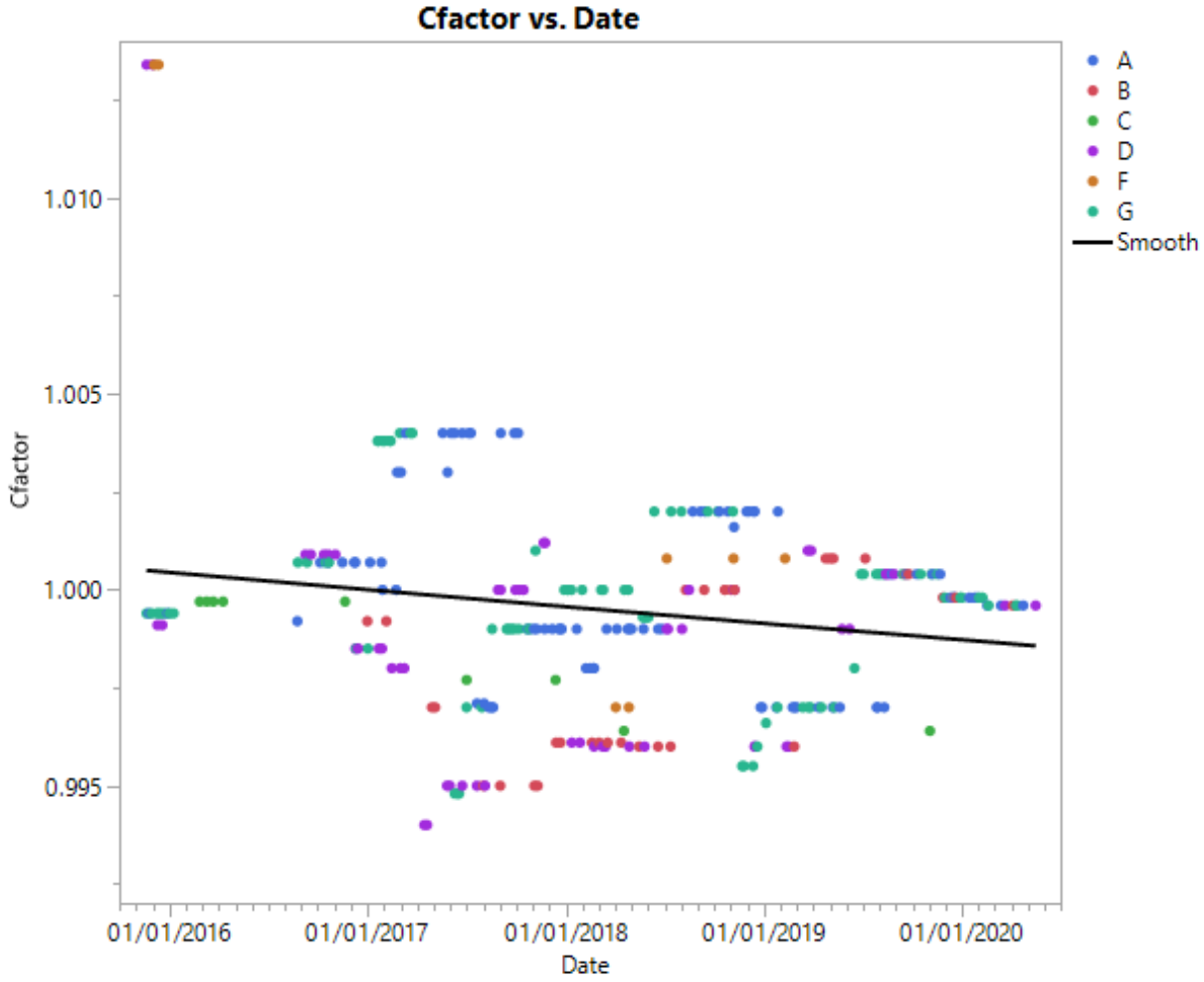

Graph Builder
C9 aromatics vs. Date
C9 aromatics
9.8
9.6
9.4
9.2
9.0
8.8
8.6
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Date
A
B
C
D
F
G
Smooth
Where(1 rows excluded)



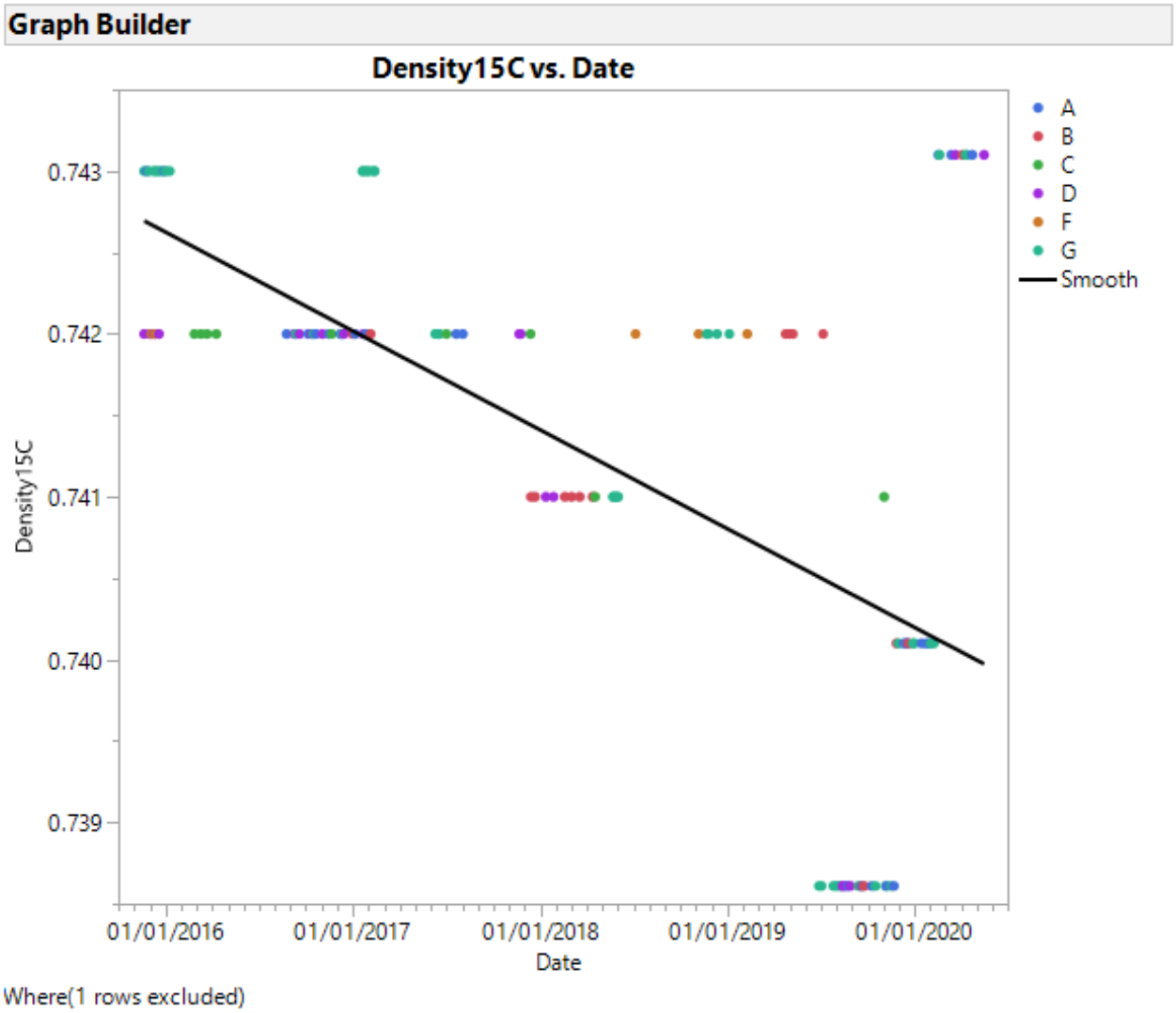

Graph Builder
Carbon ASTM D33431 vs. Date
0.868
0.866
0.864
0.862
0.860
0.858
0.856
Carbon ASTM D33431
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Date
A
B
C
D
F
G
Smooth
Where(1 rows excluded)



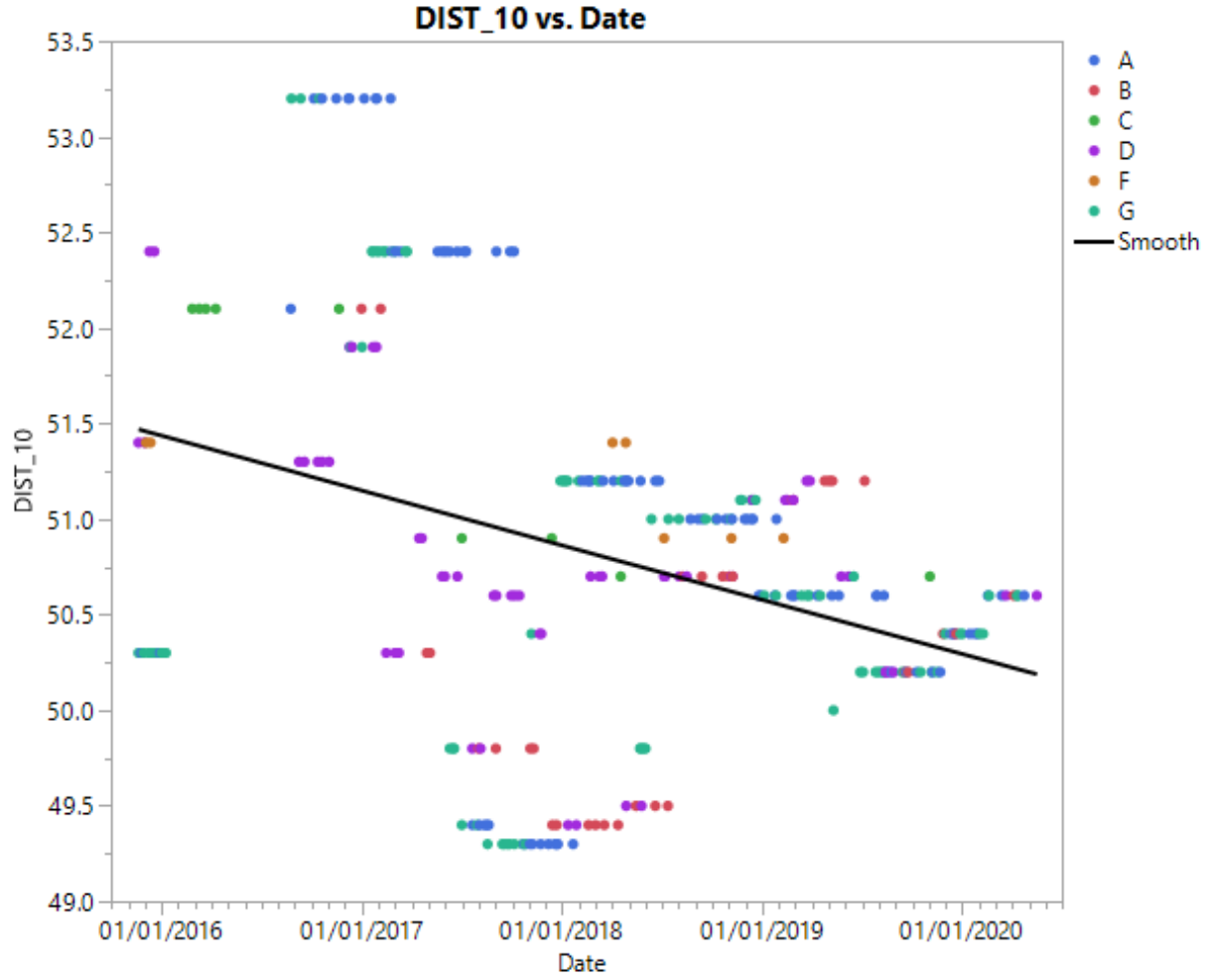
Graph Builder



Where(1 rows excluded)

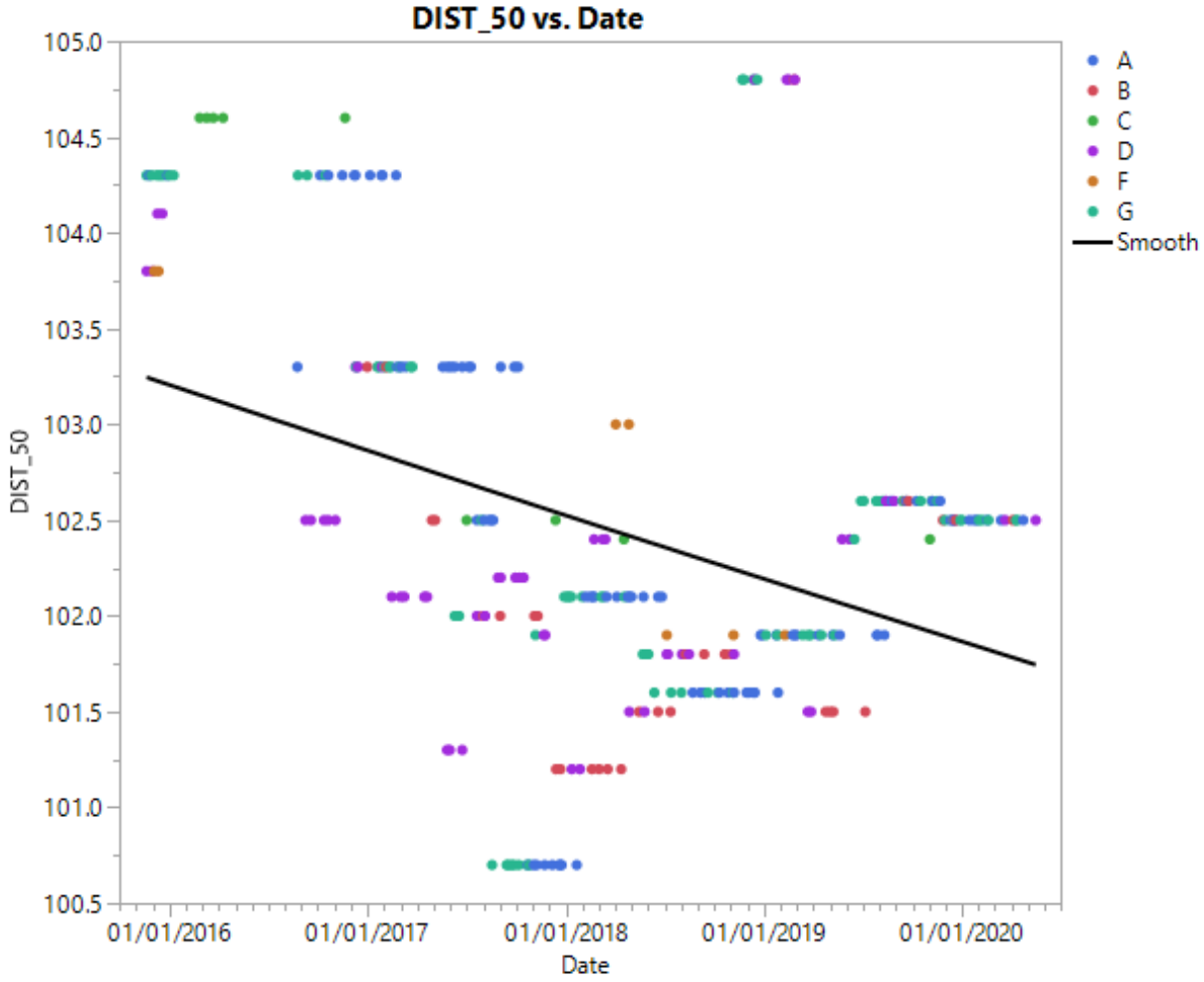


Graph Builder



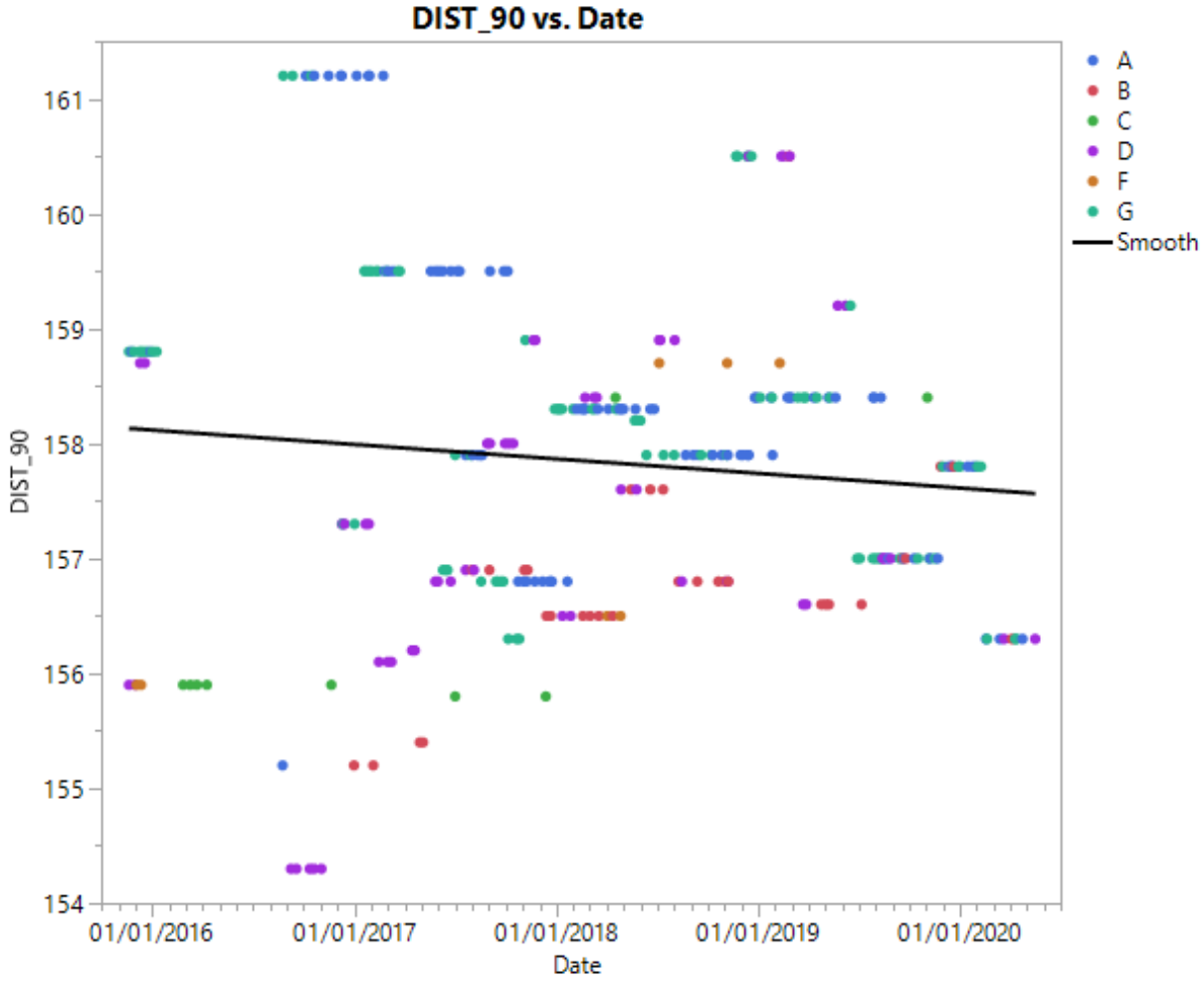
Where(1 rows excluded)

Graph Builder



Where(1 rows excluded)

Graph Builder



Where(1 rows excluded)

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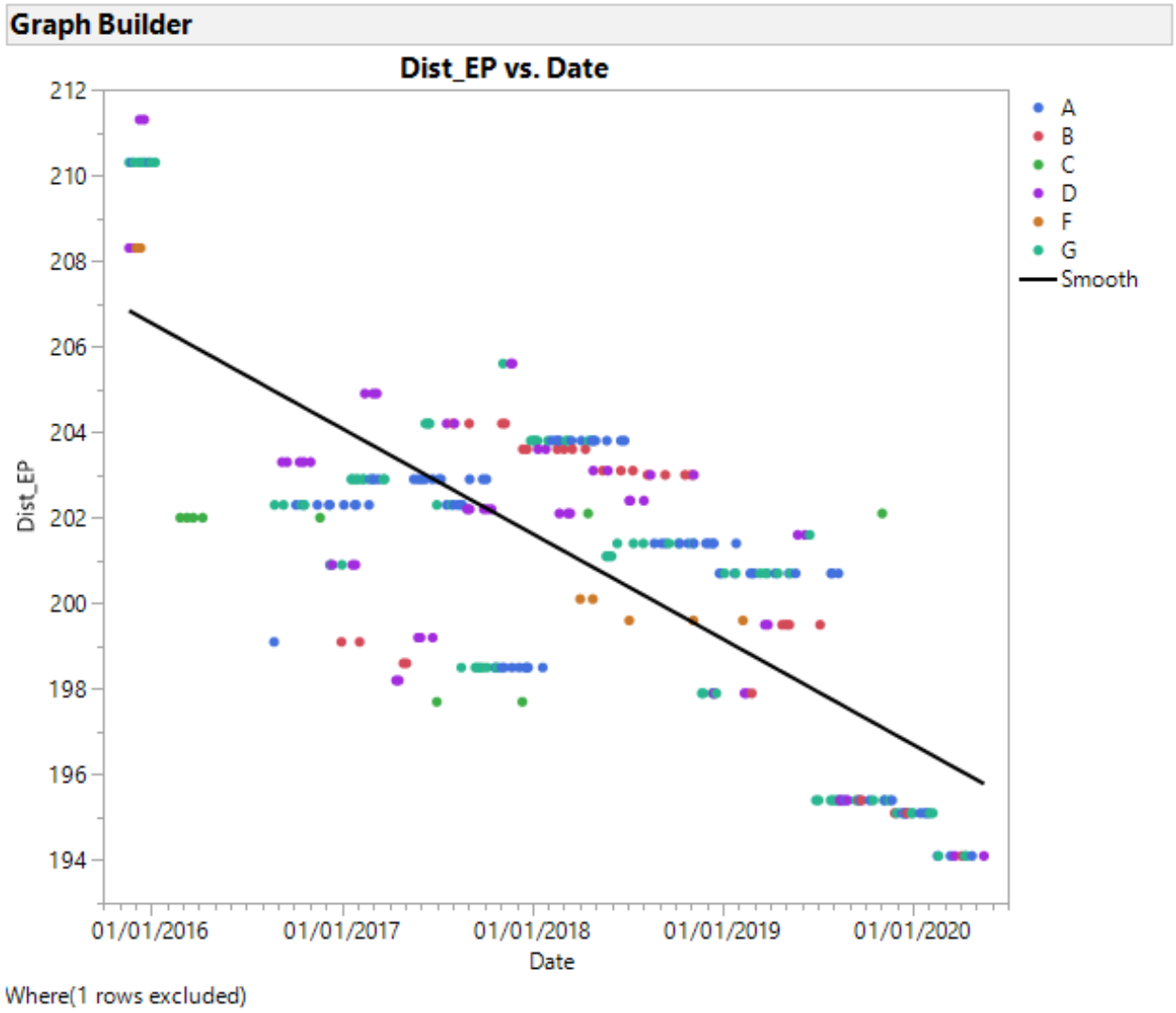
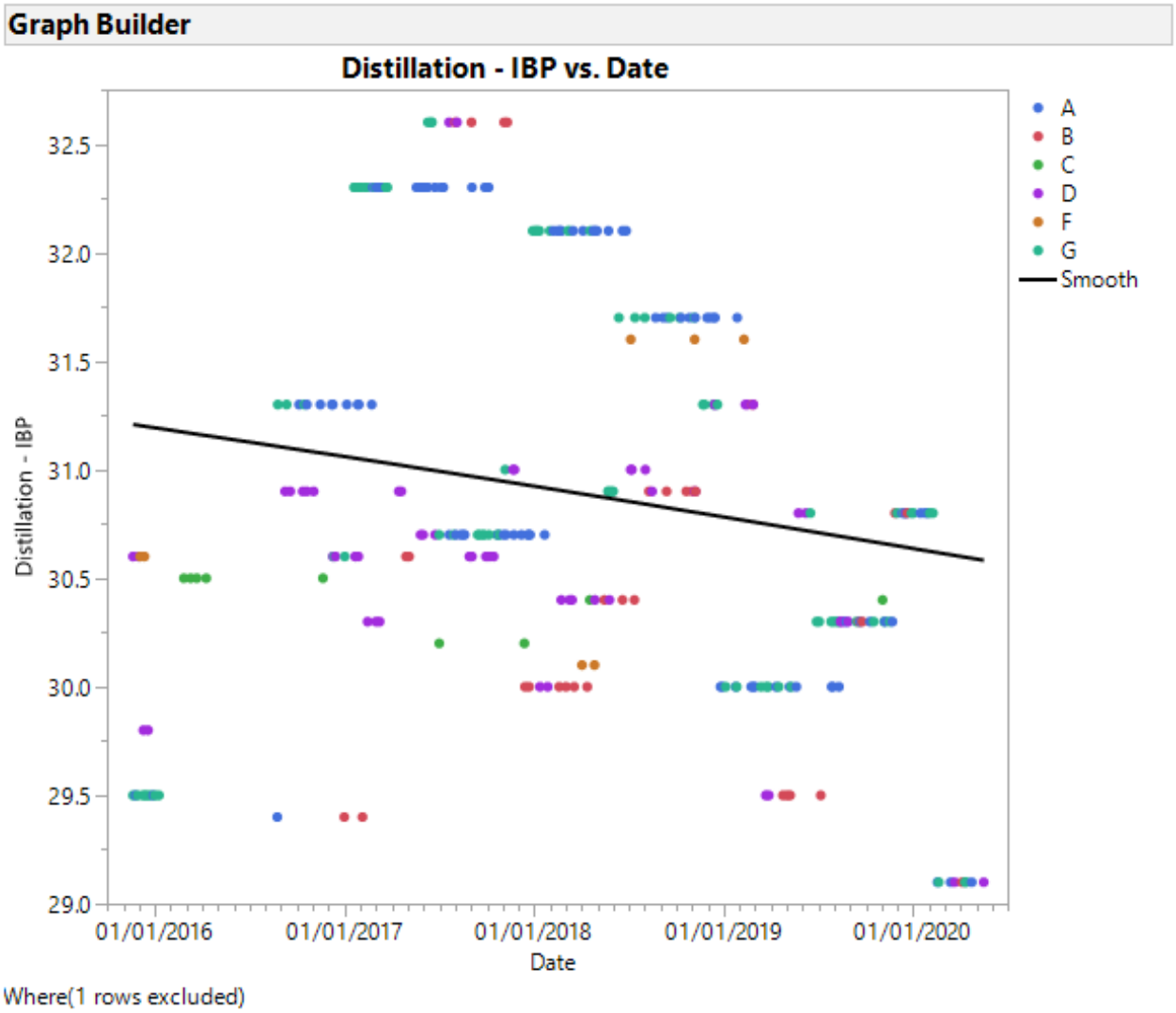
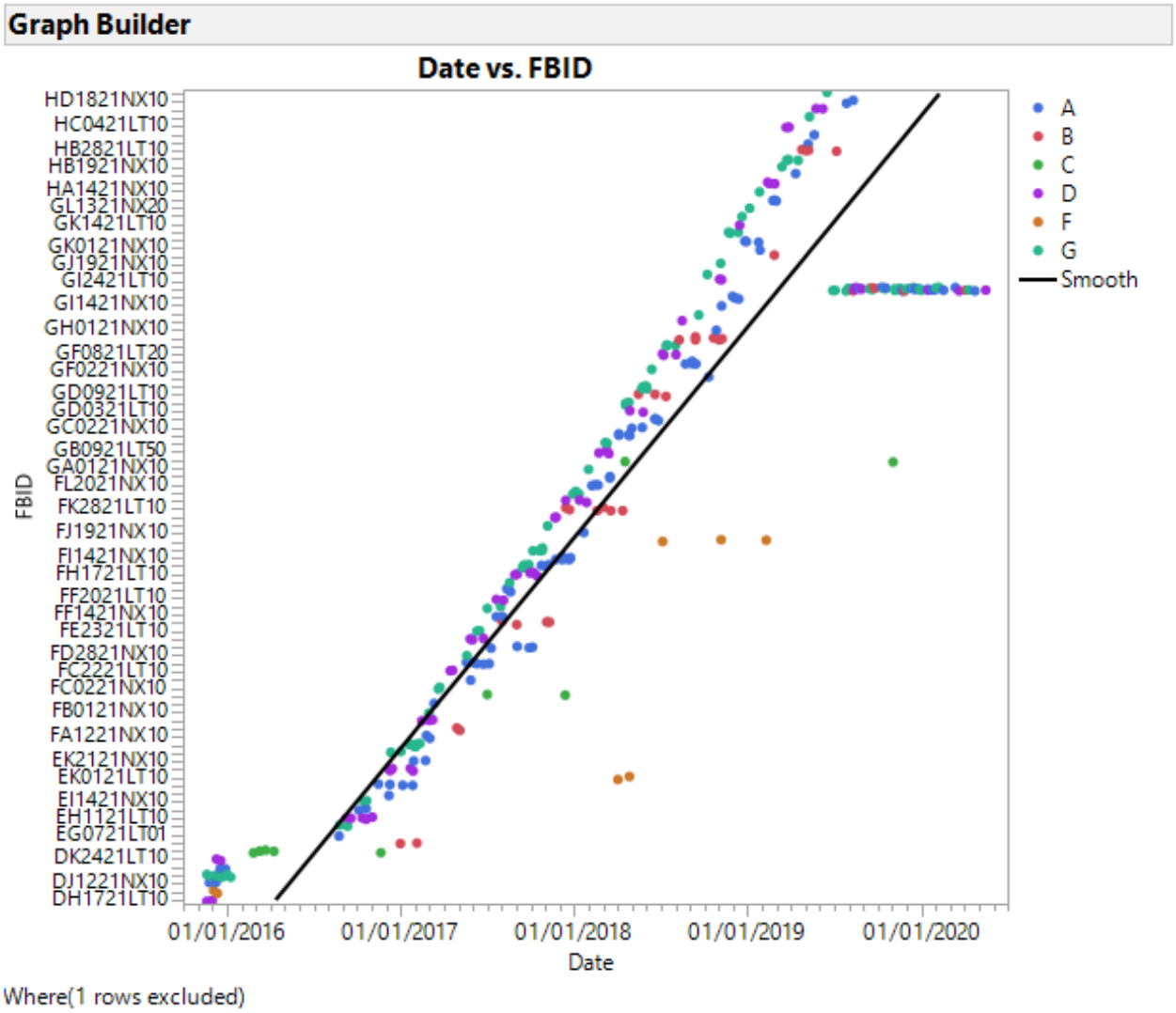
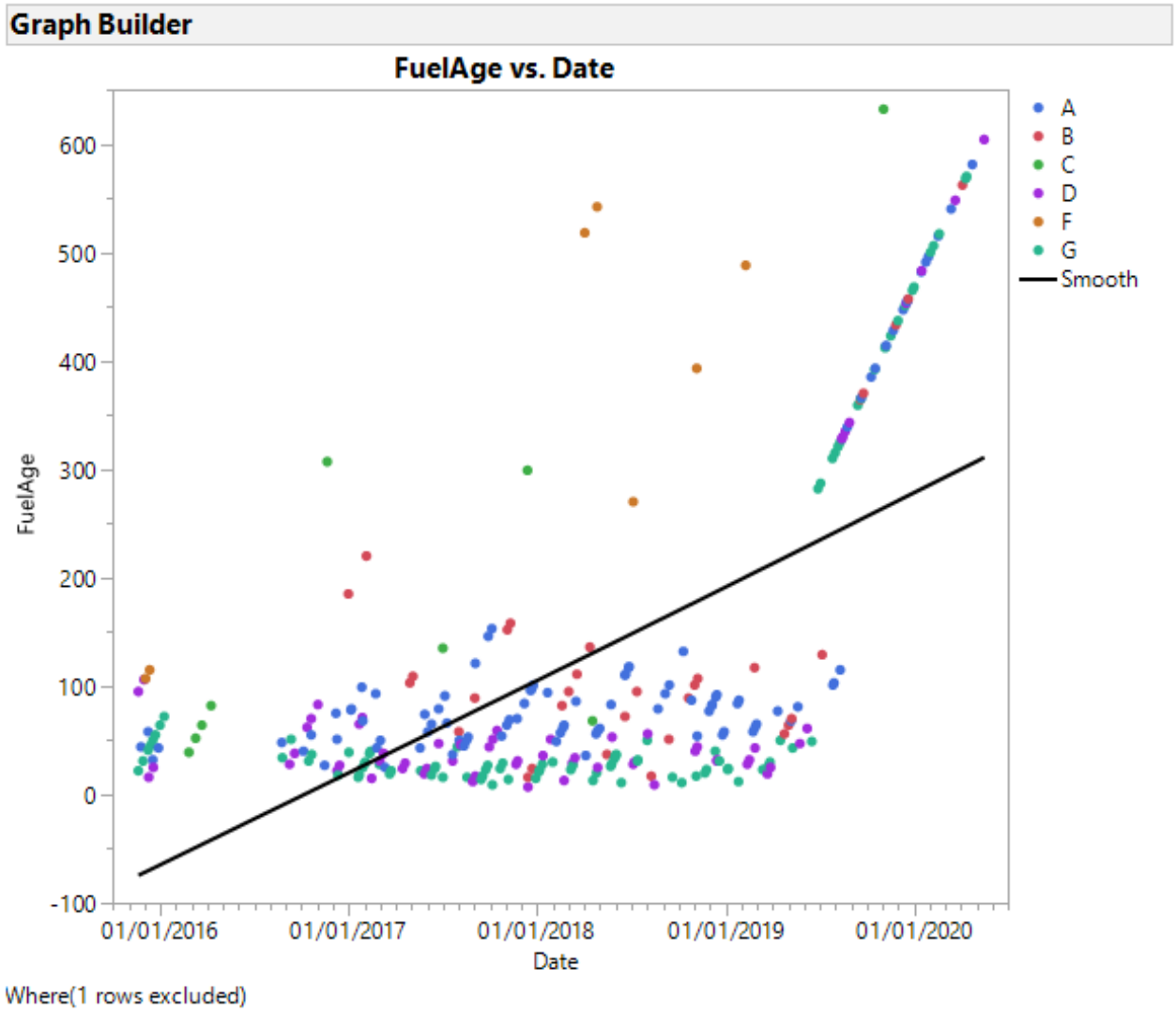
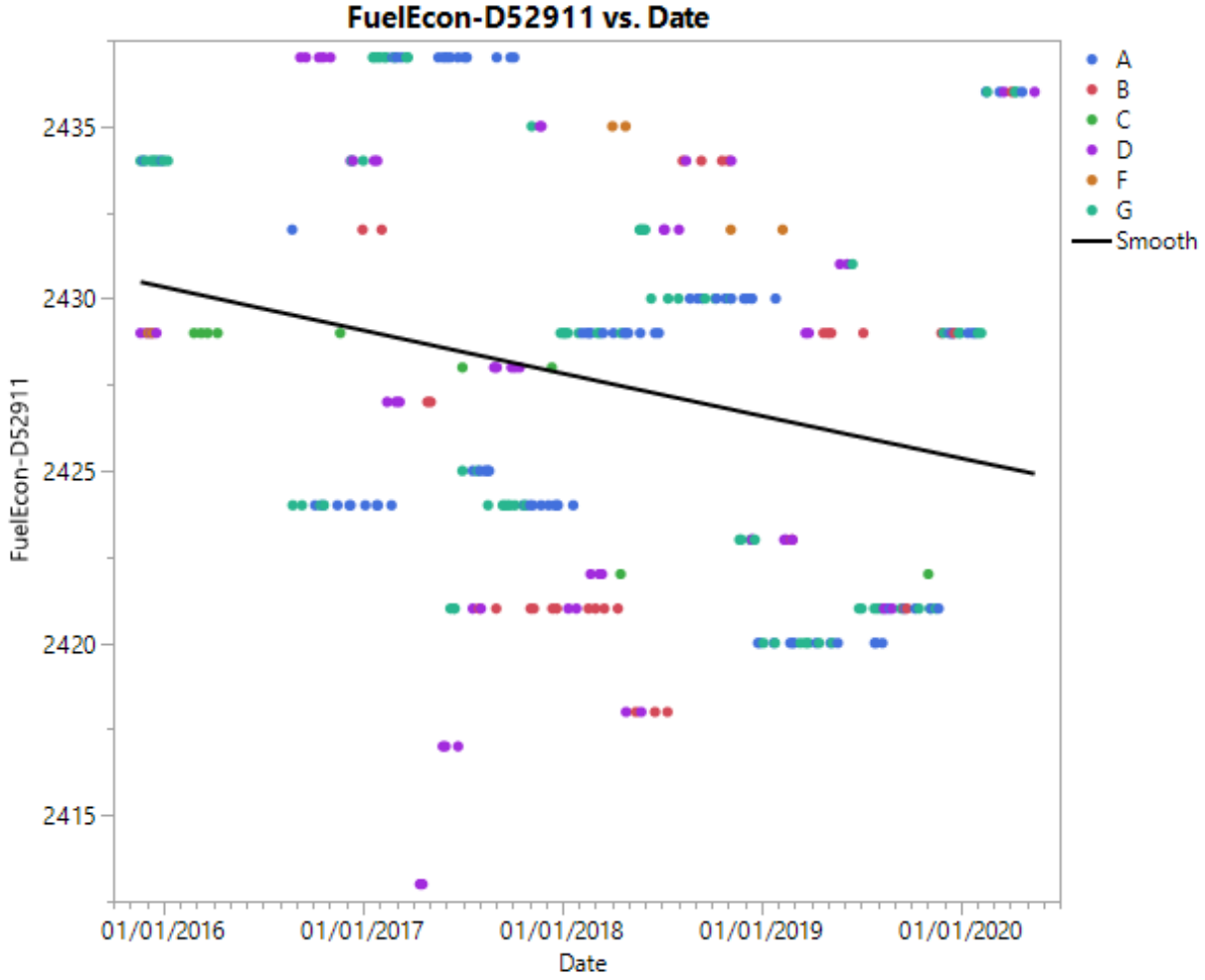




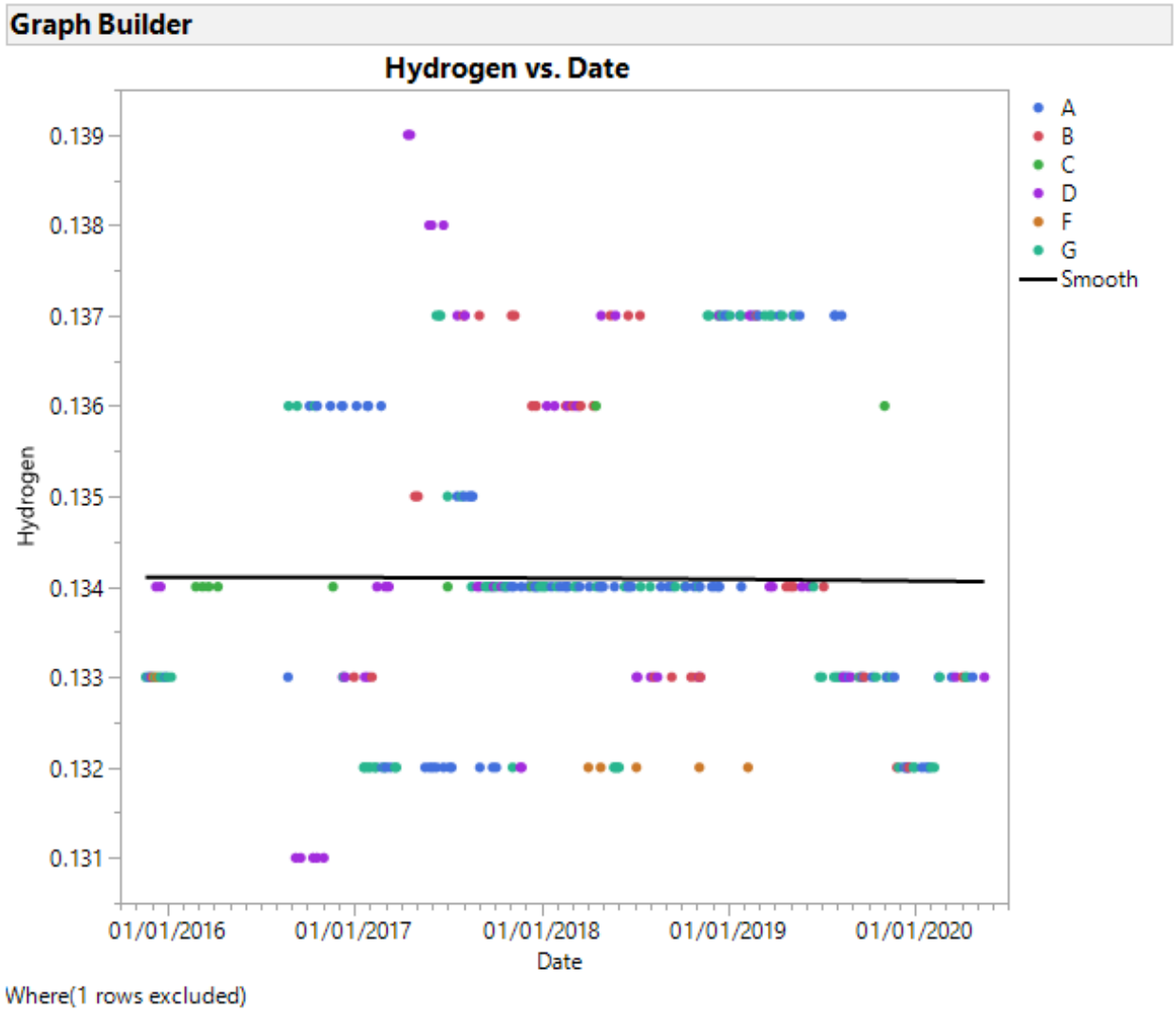


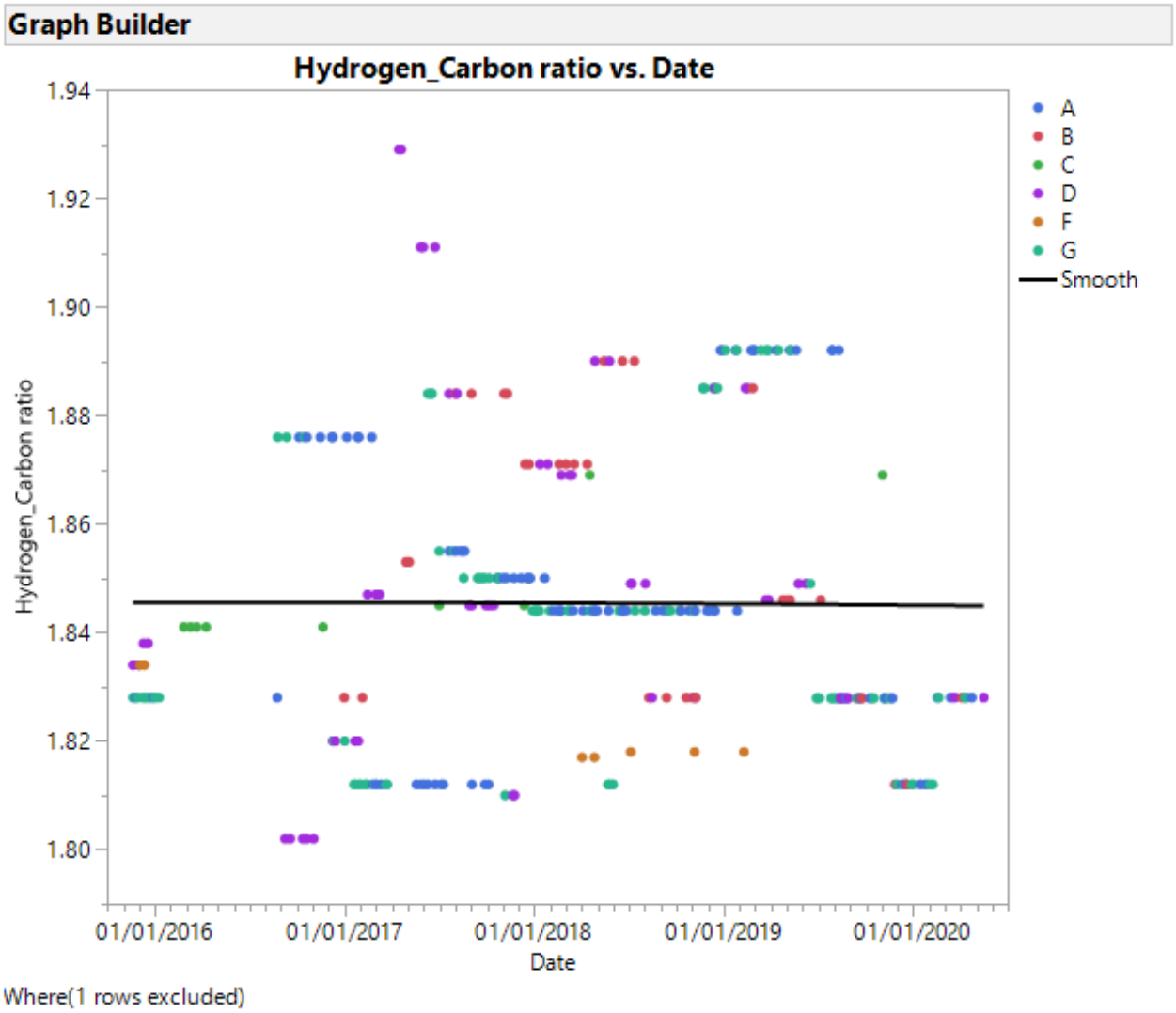


Graph Builder



Where(1 rows excluded)

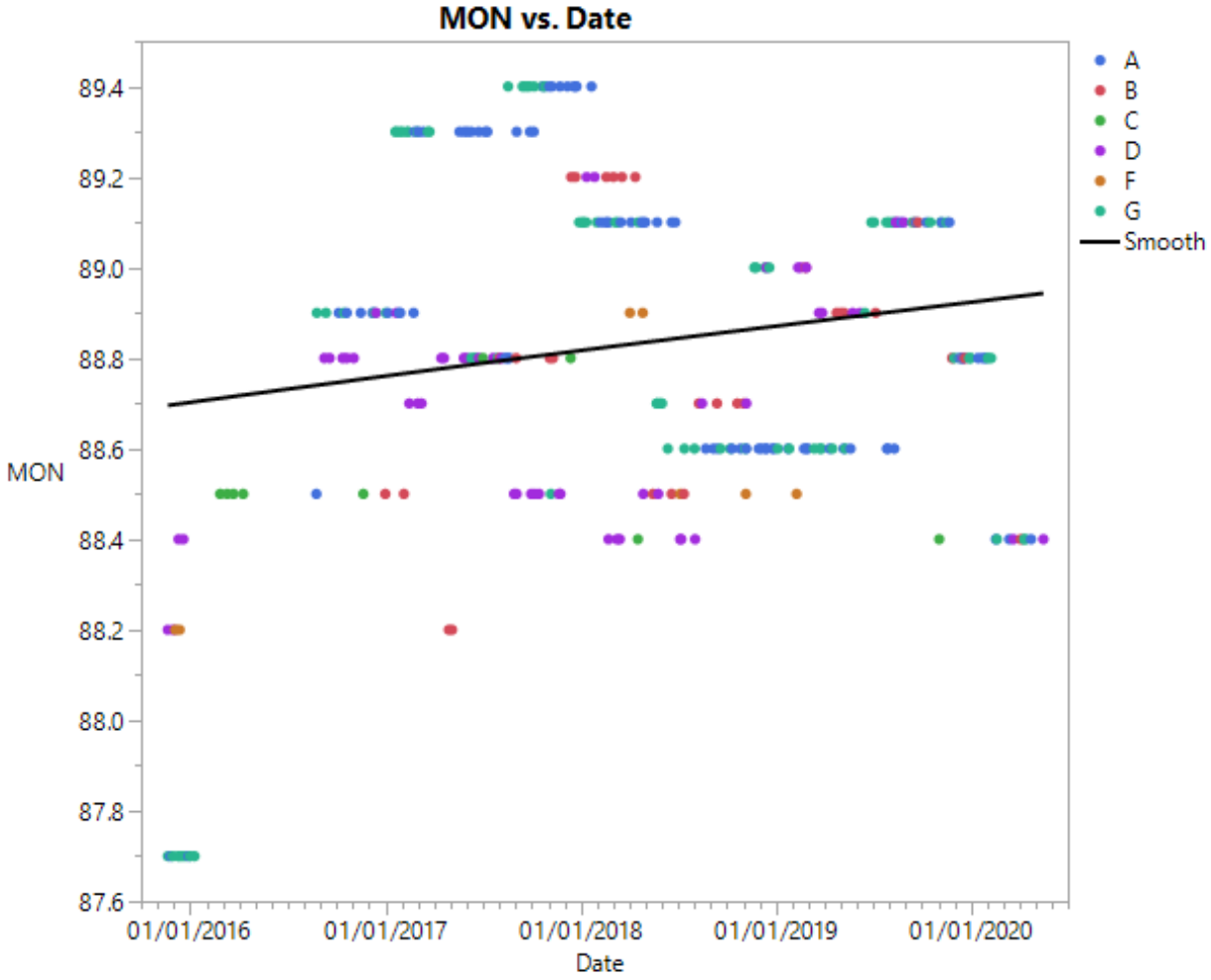

Graph Builder
Hydrogen vs. Date
Hydrogen
0.139
0.138
0.137
0.136
0.135
0.134
0.133
0.132
0.131
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Date
A
B
C
D
F
G
Smooth
Where(1 rows excluded)



Graph Builder

Where(1 rows excluded)

Graph Builder



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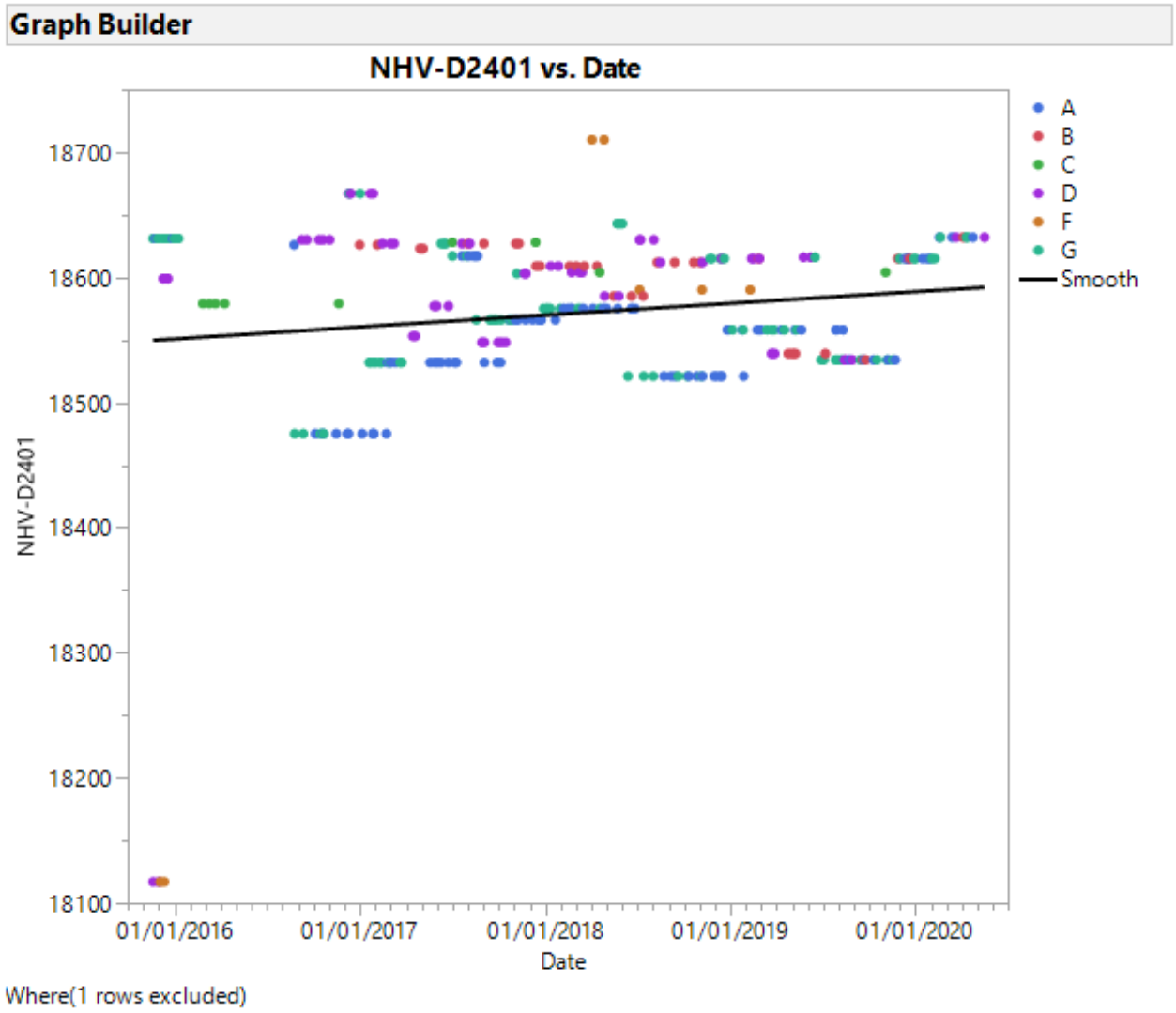
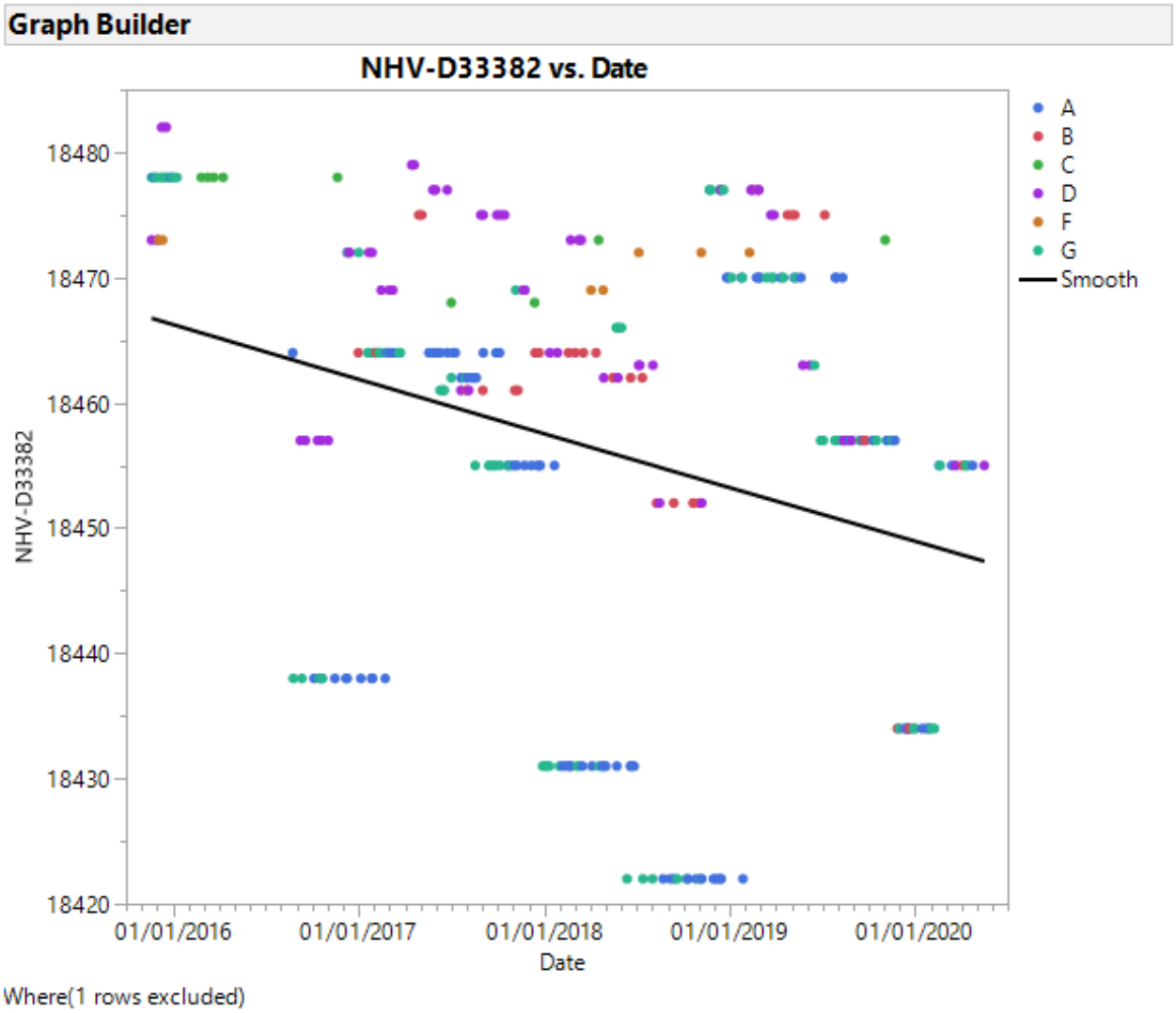
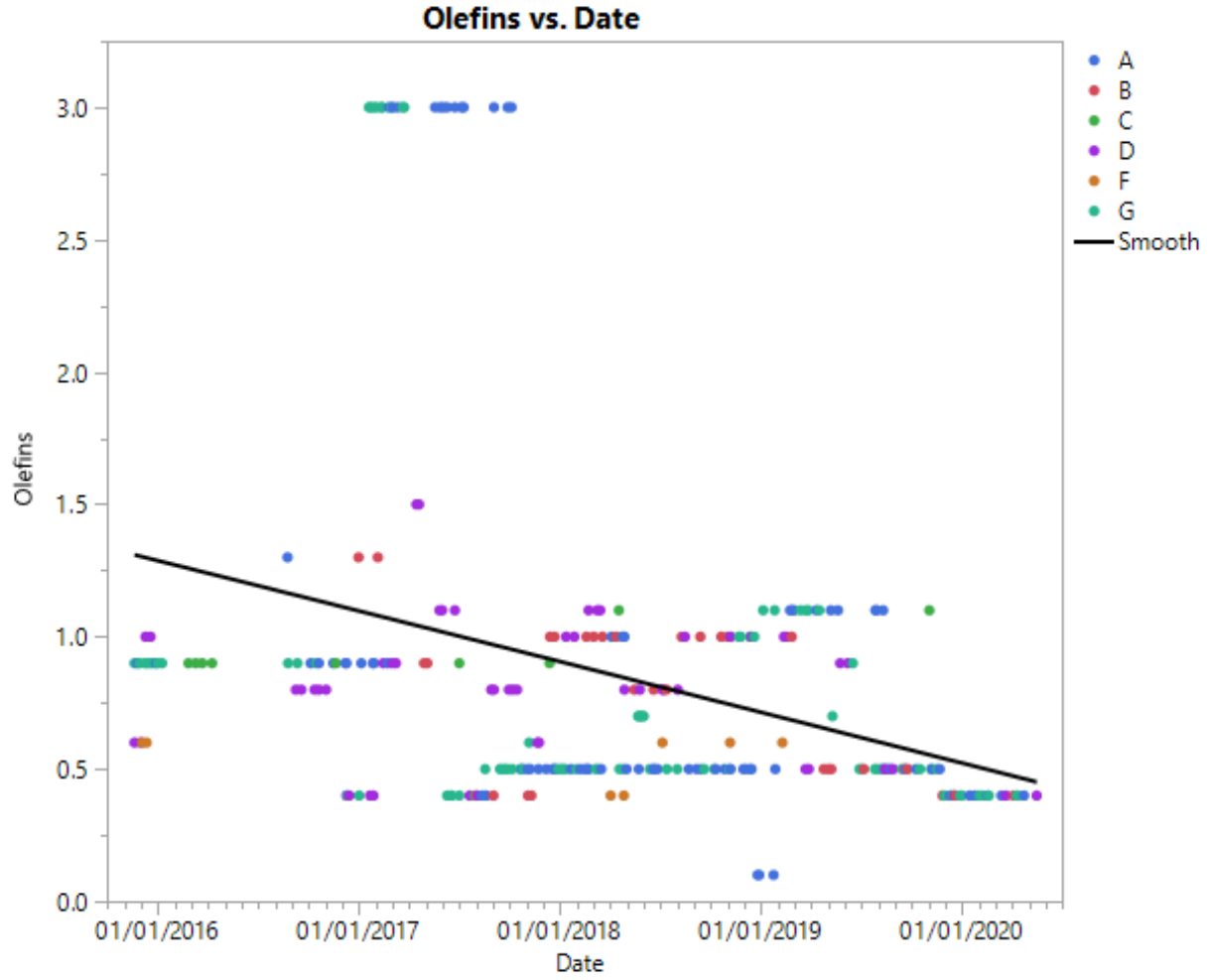
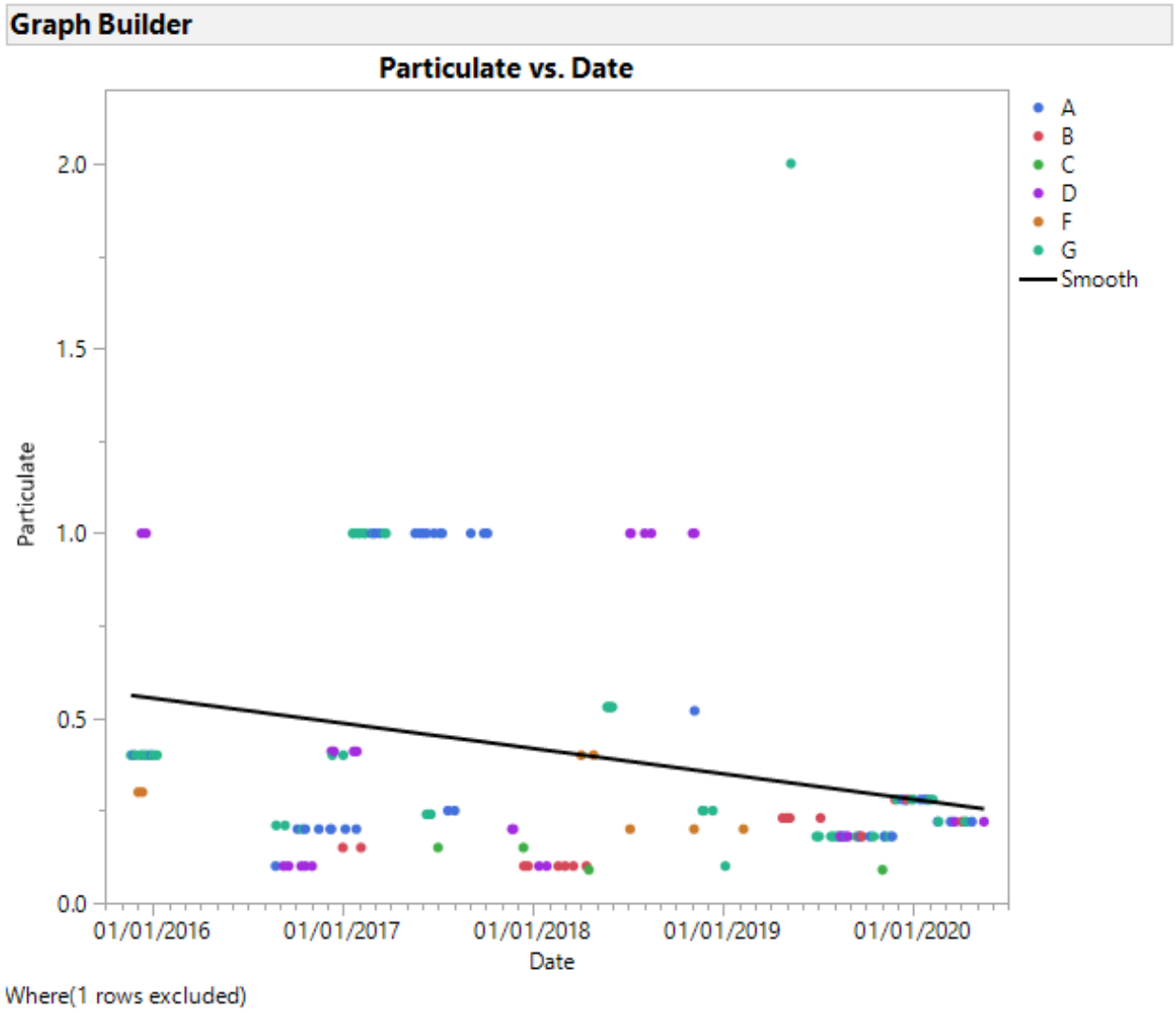

Graph Builder
NHV-D2401 vs. Date
NHV-D2401
18700
18600
18500
18400
18300
18200
18100
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Date
A
B
C
D
F
G
Smooth
Where(1 rows excluded)


Graph Builder
NHV-D33382 vs. Date
NHV-D33382
18480
18470
18460
18450
18440
18430
18420
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Date
A
B
C
D
F
G
Smooth
Where(1 rows excluded)

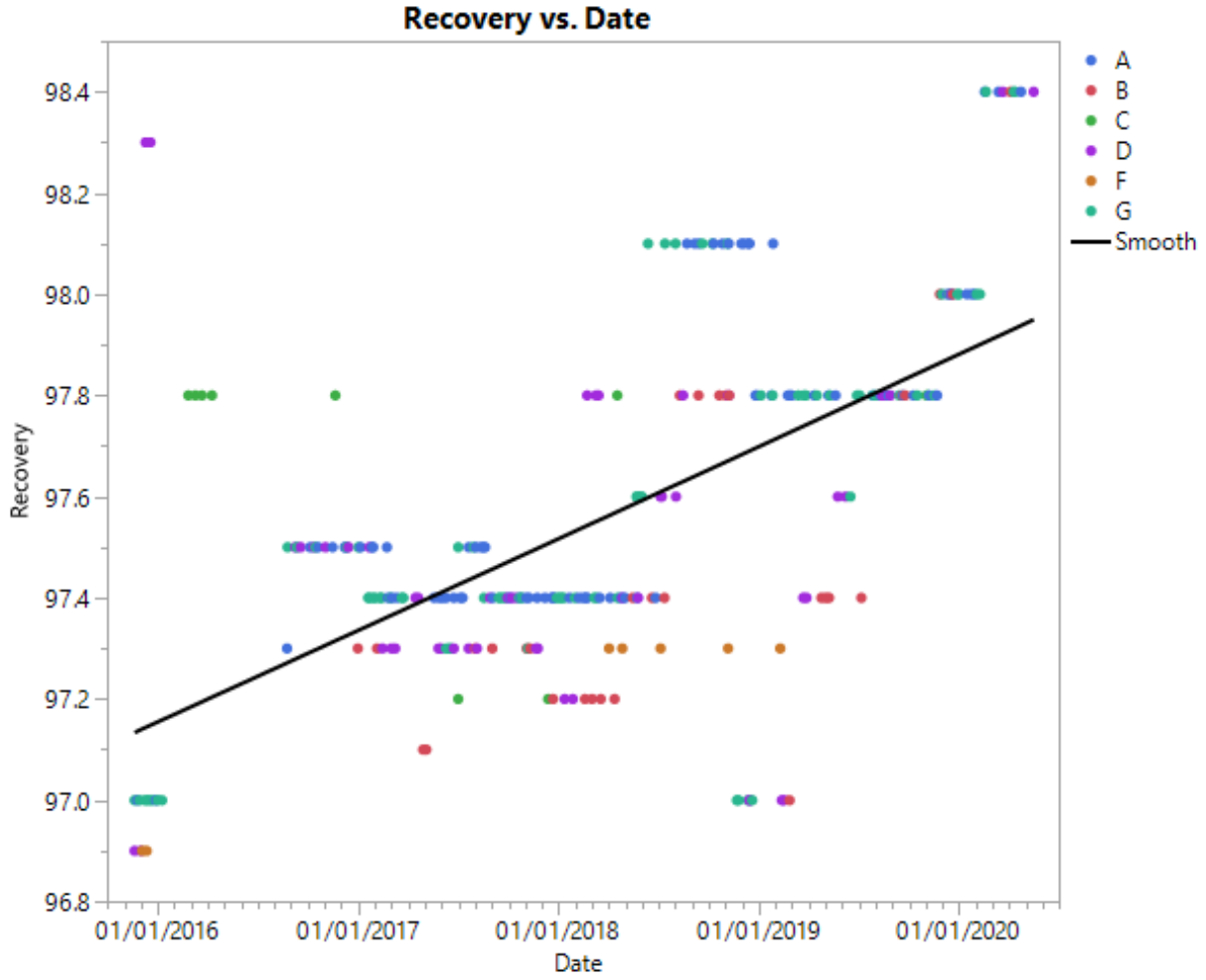
Graph Builder



Where(1 rows excluded)

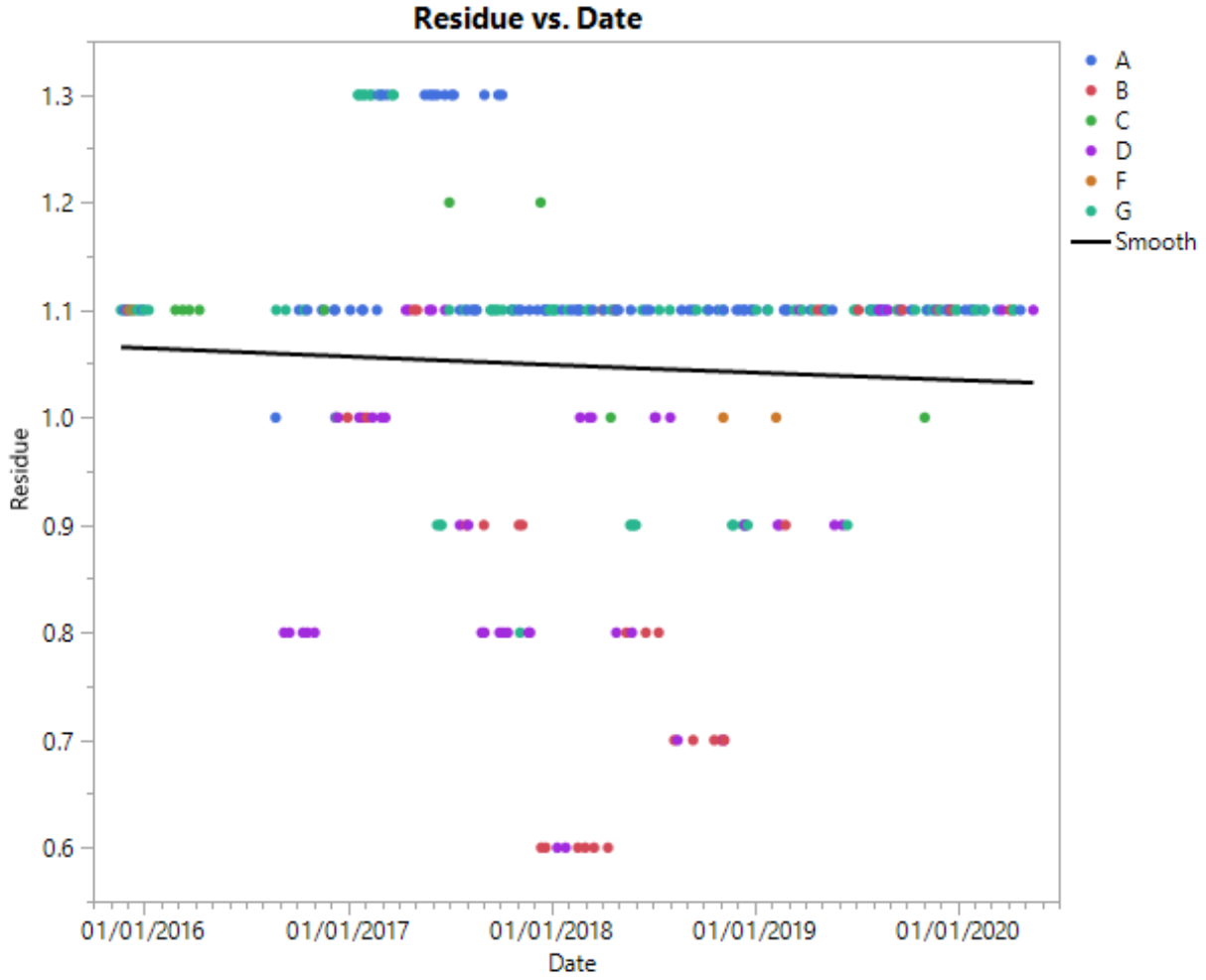

Graph Builder
Particulate vs. Date
A
B
C
D
F
G
Smooth
2.0
1.5
1.0
0.5
0.0
Particulate
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Date
Where(1 rows excluded)

Graph Builder

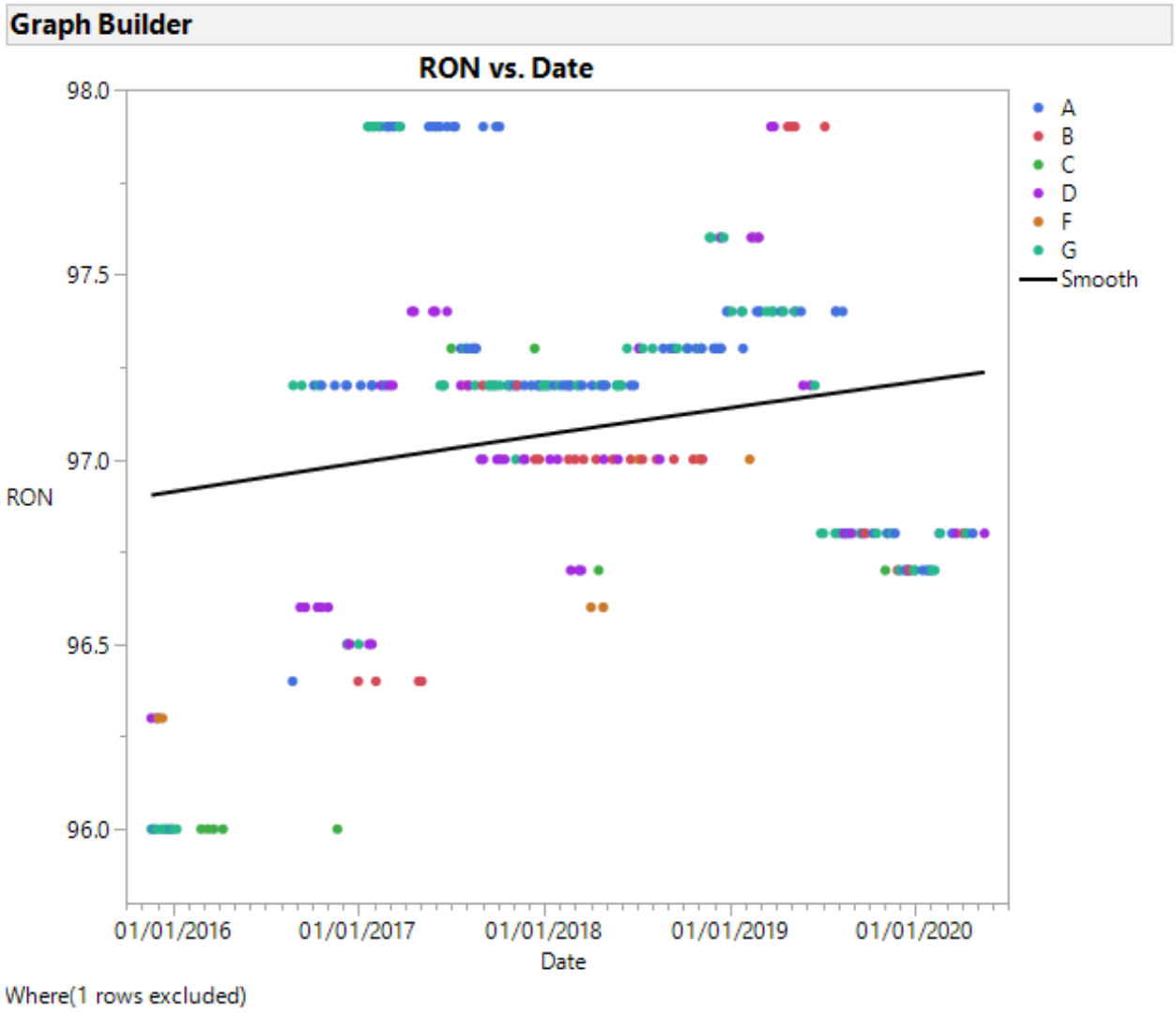


Where(1 rows excluded)

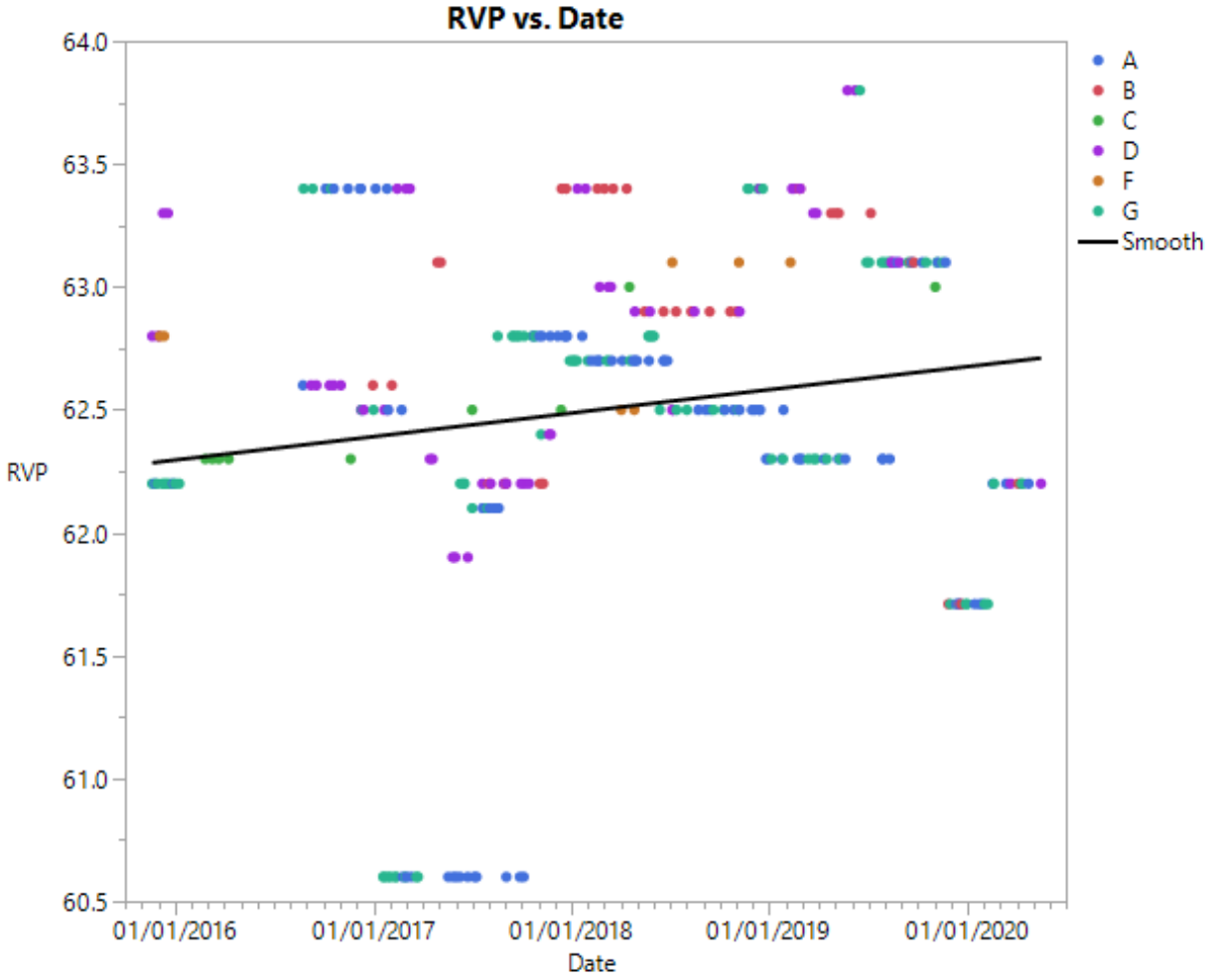
Graph Builder



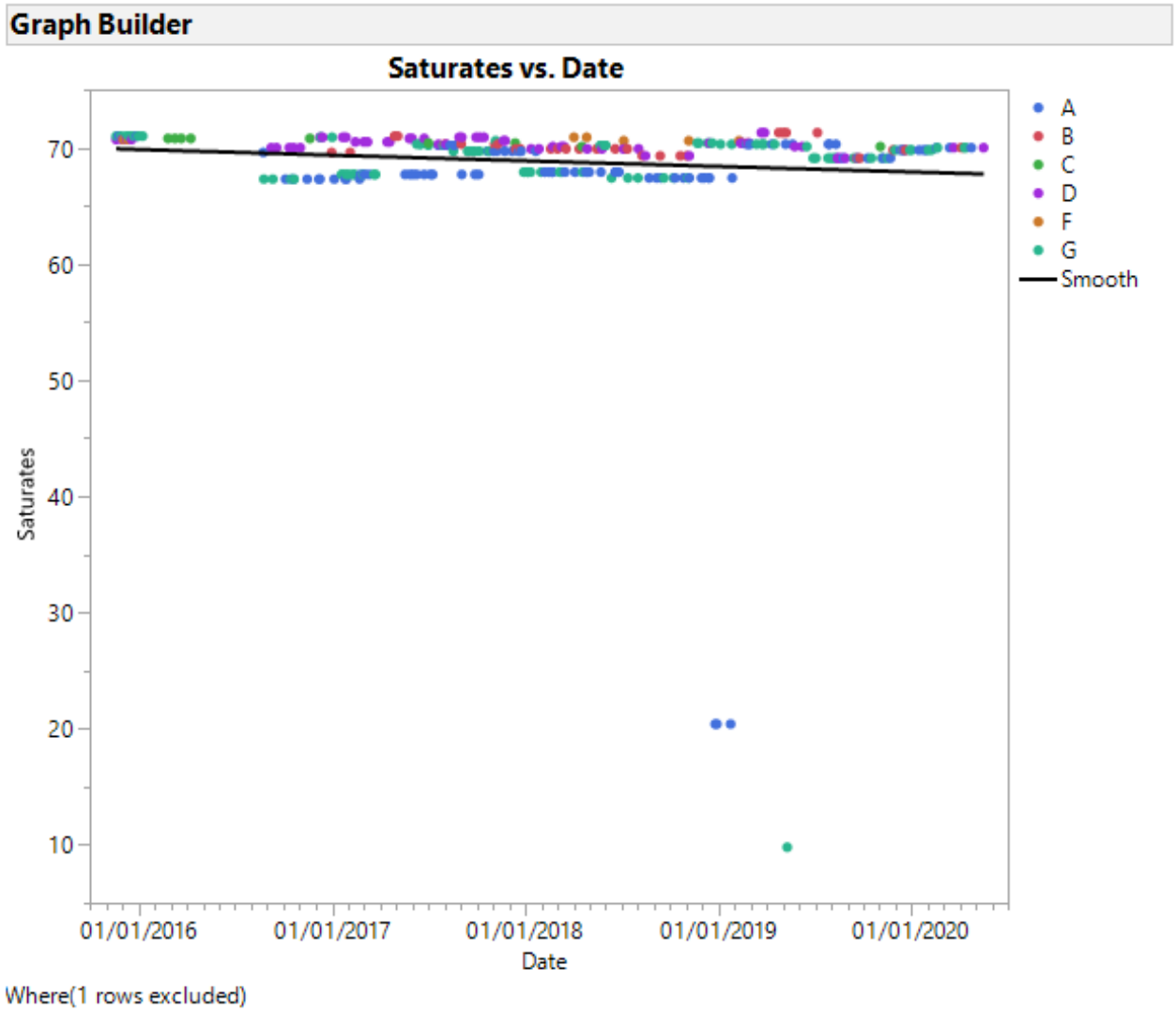
Where(1 rows excluded)

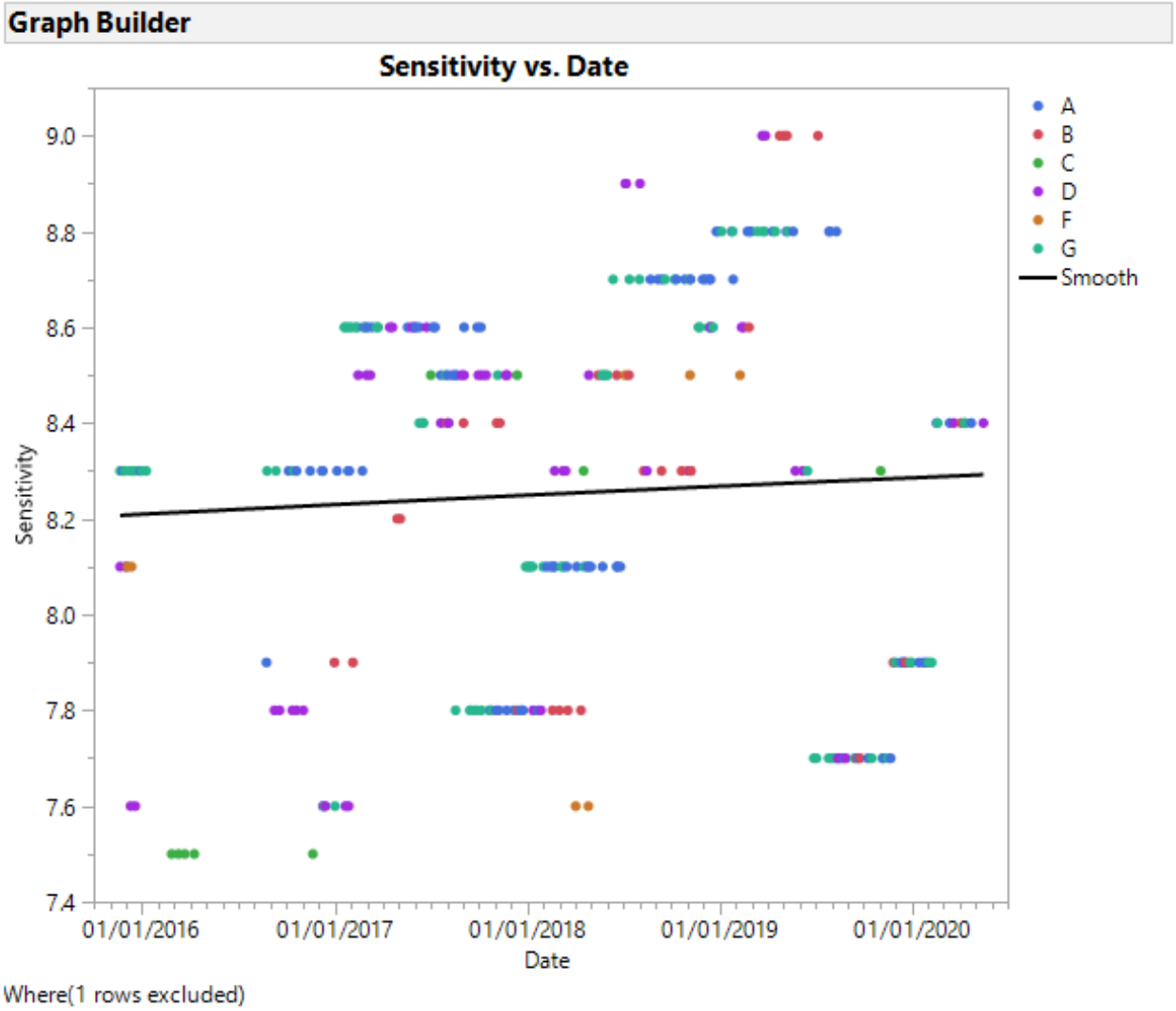


Graph Builder

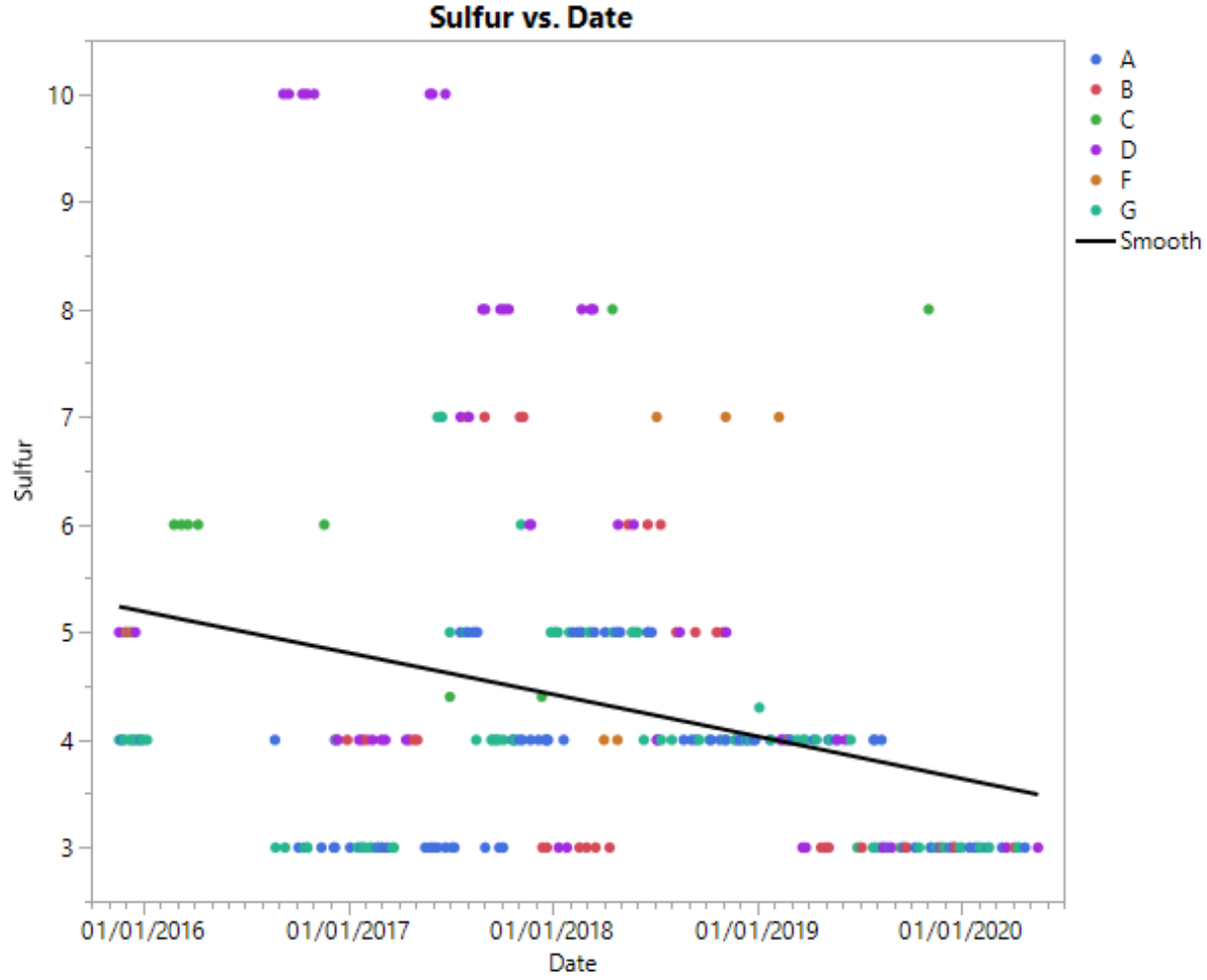


Where(1 rows excluded)




Graph Builder
Sensitivity vs. Date
Sensitivity
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
01/01/2016
01/01/2017
01/01/2018
01/01/2019
01/01/2020
Date
A
B
C
D
F
G
Smooth
Where(1 rows excluded)

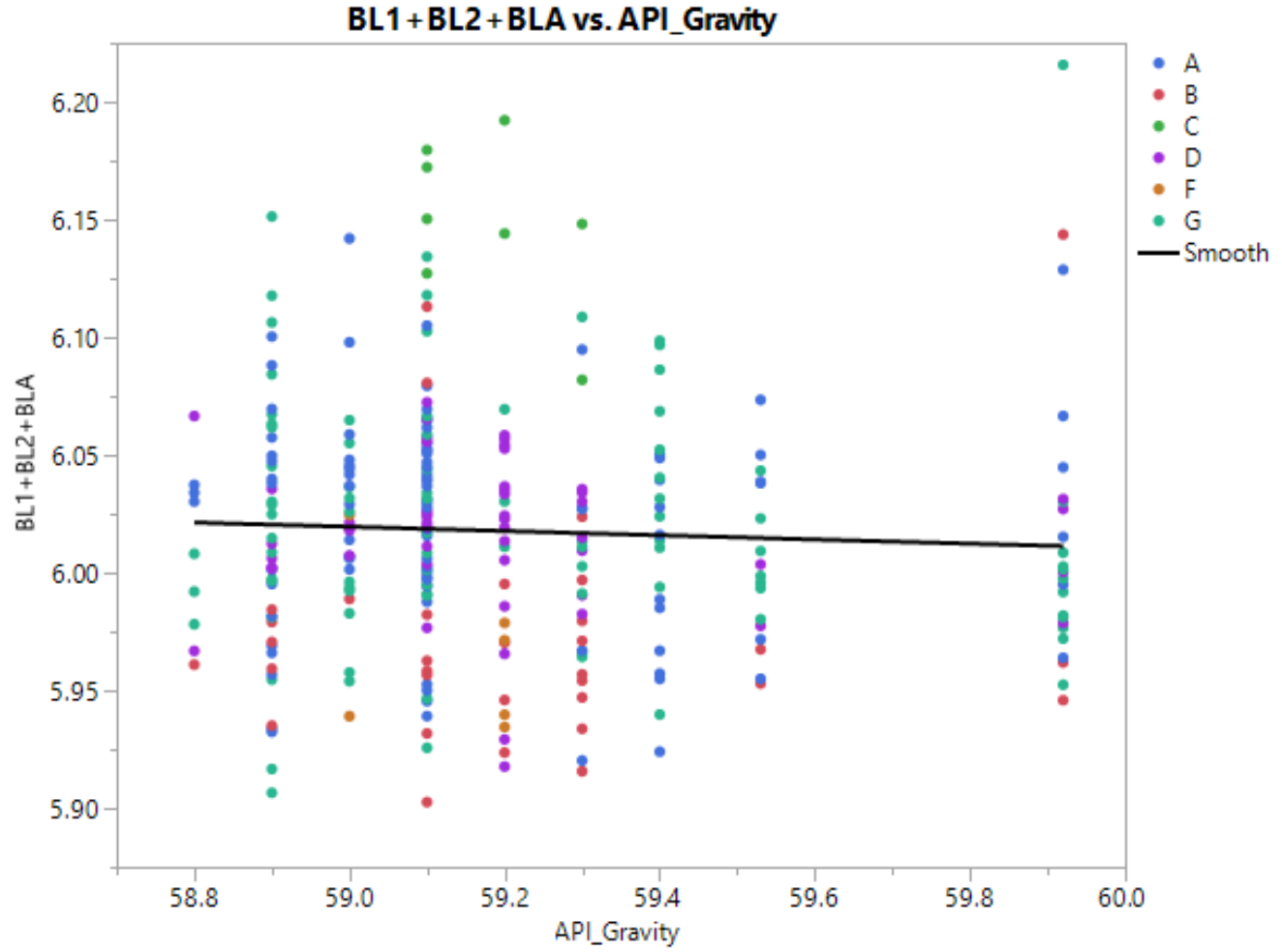
Graph Builder



Where(1 rows excluded)

Appendix C - Plots Fuel Consumed (BLB1+BLB2+BLA) vs. Fuel Properties

Graph Builder



Where(1 rows excluded)

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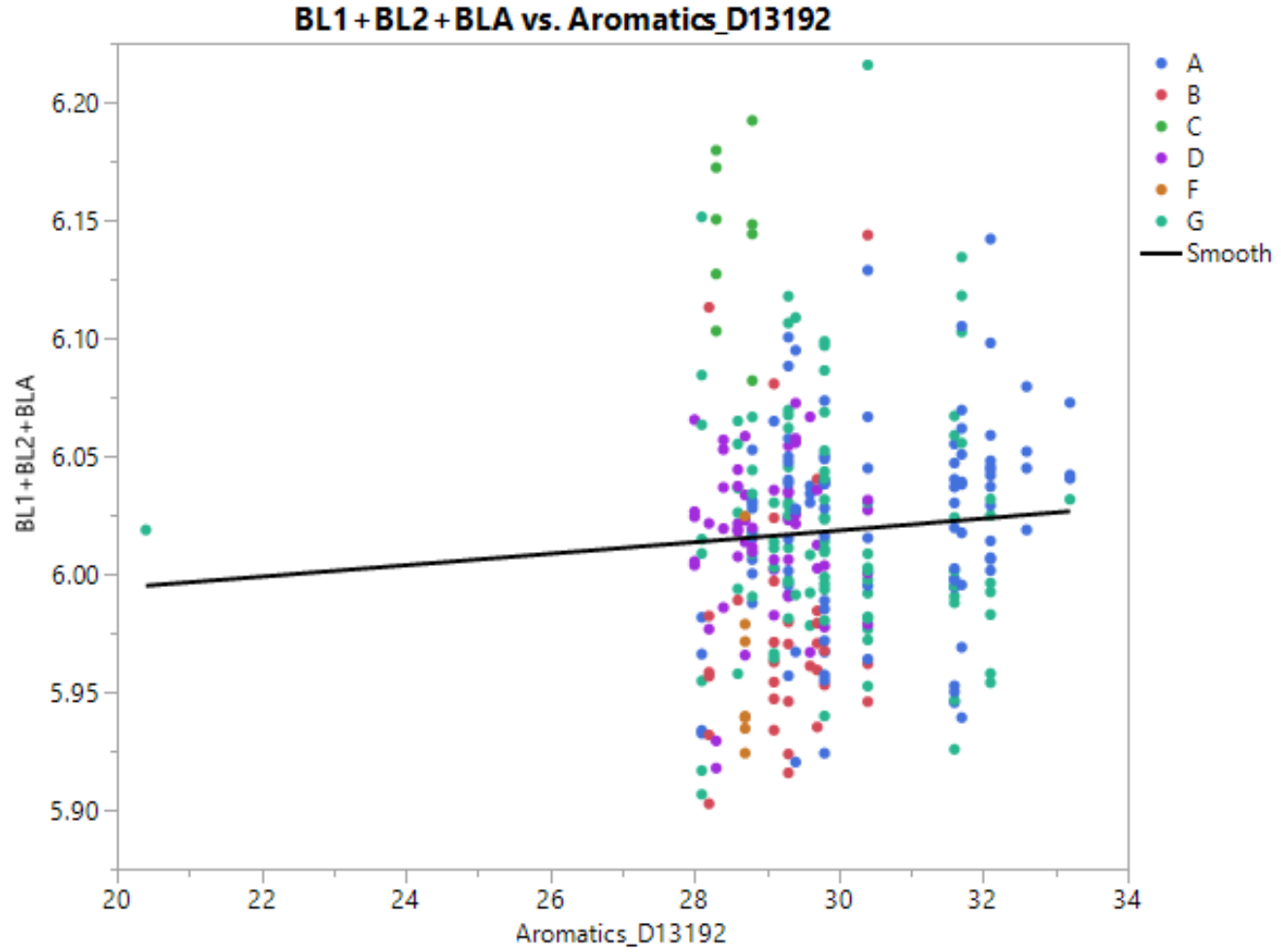
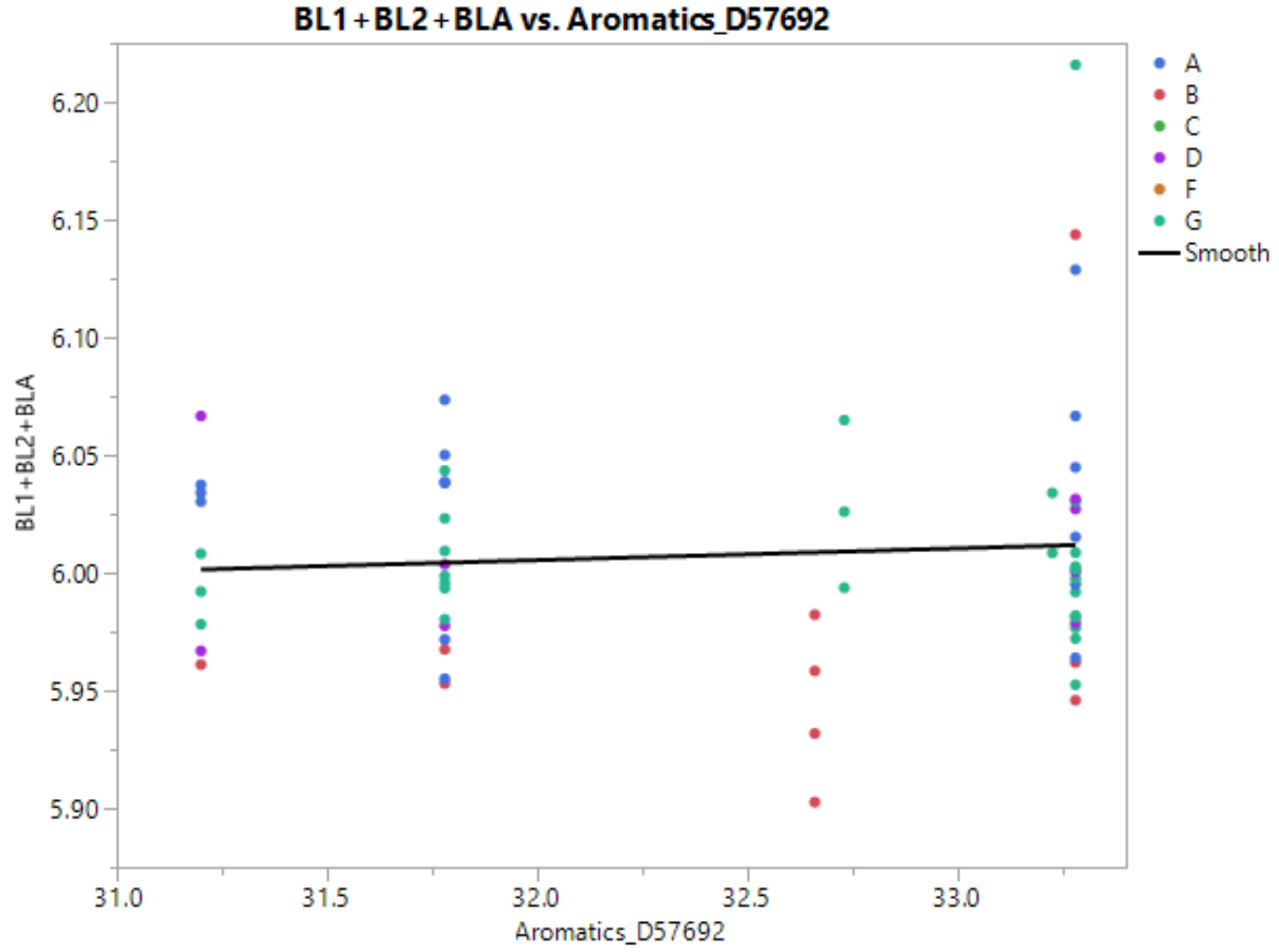
Graph Builder



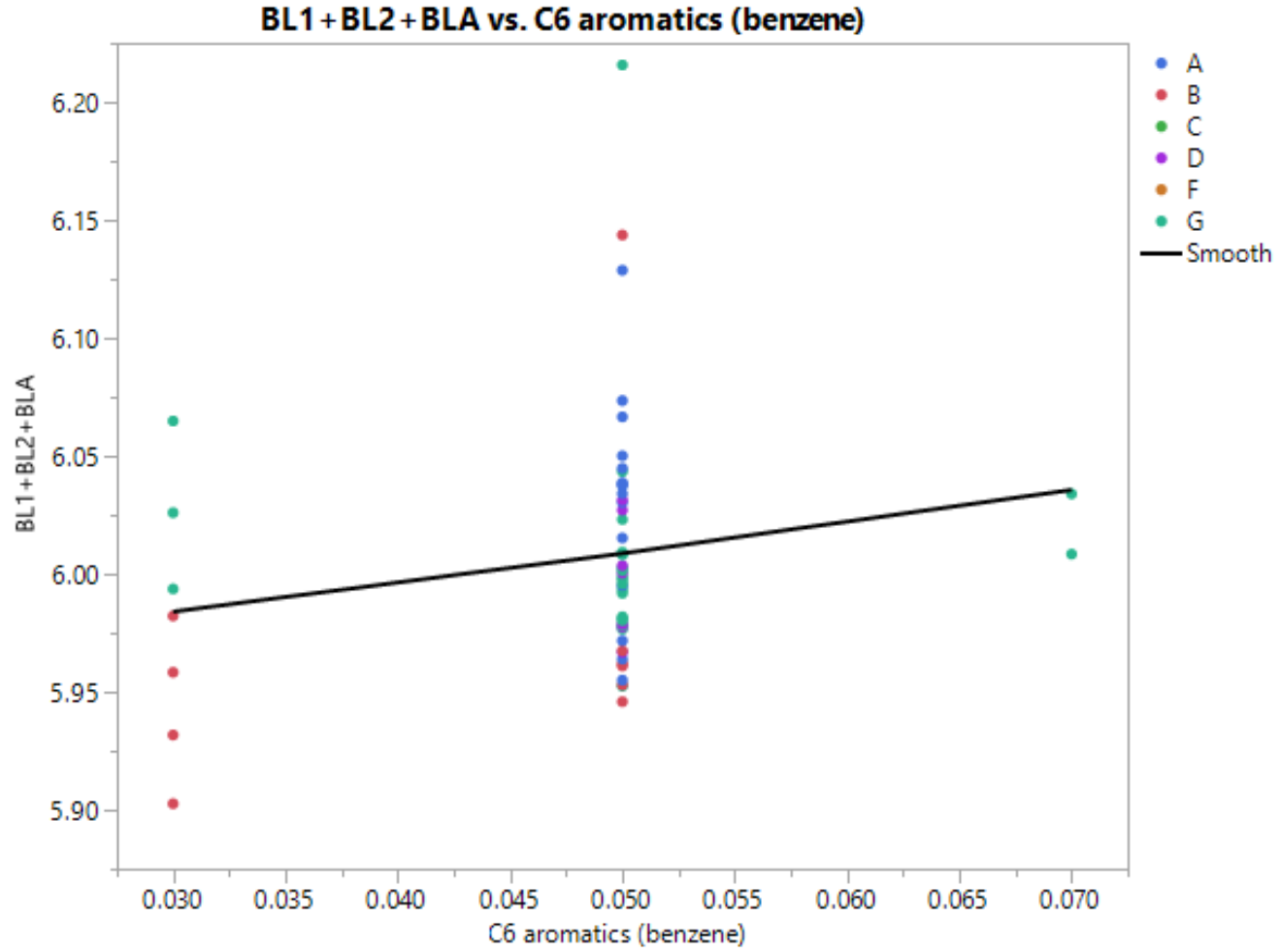
Where(1 rows excluded)

Graph Builder

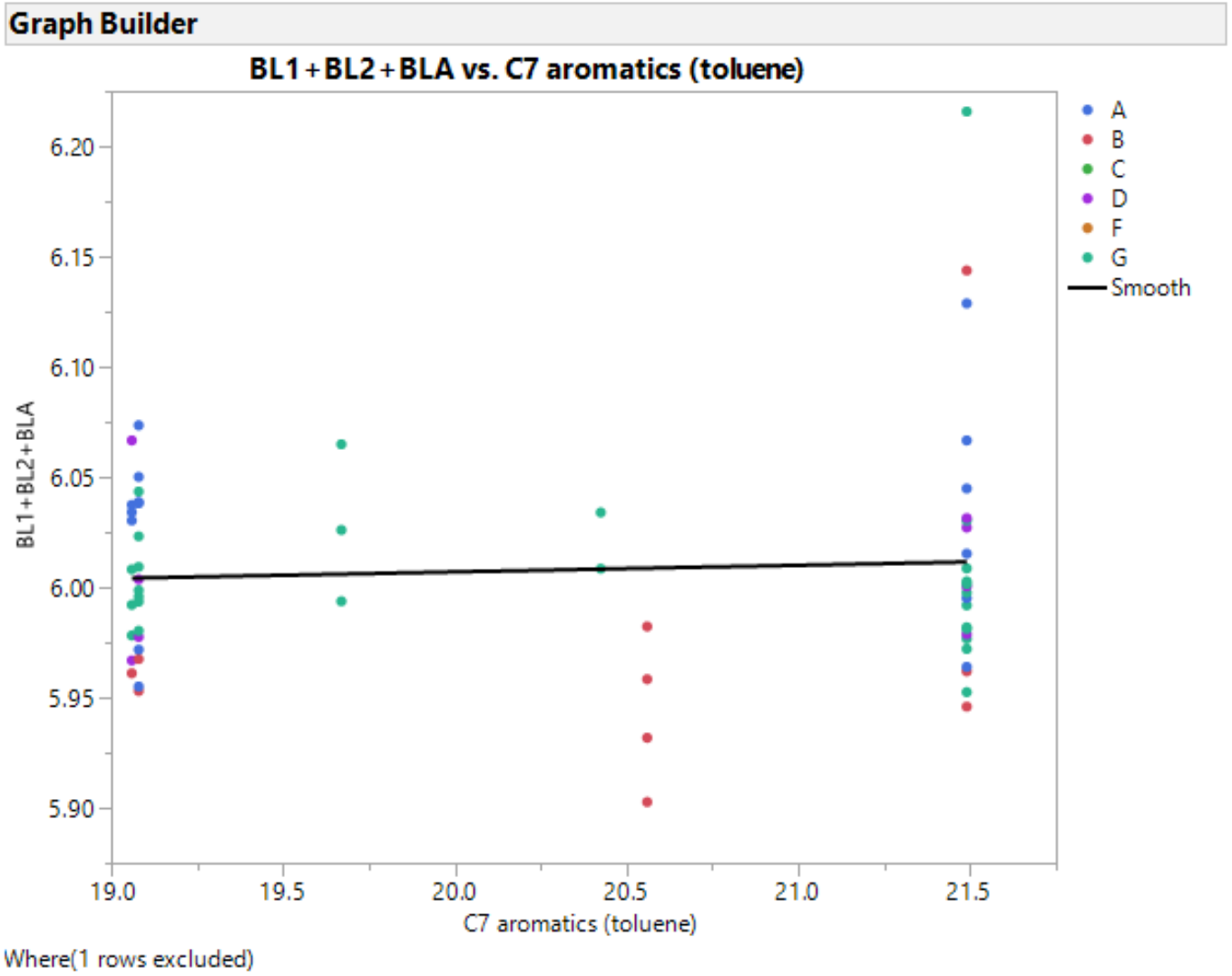


Where(1 rows excluded)

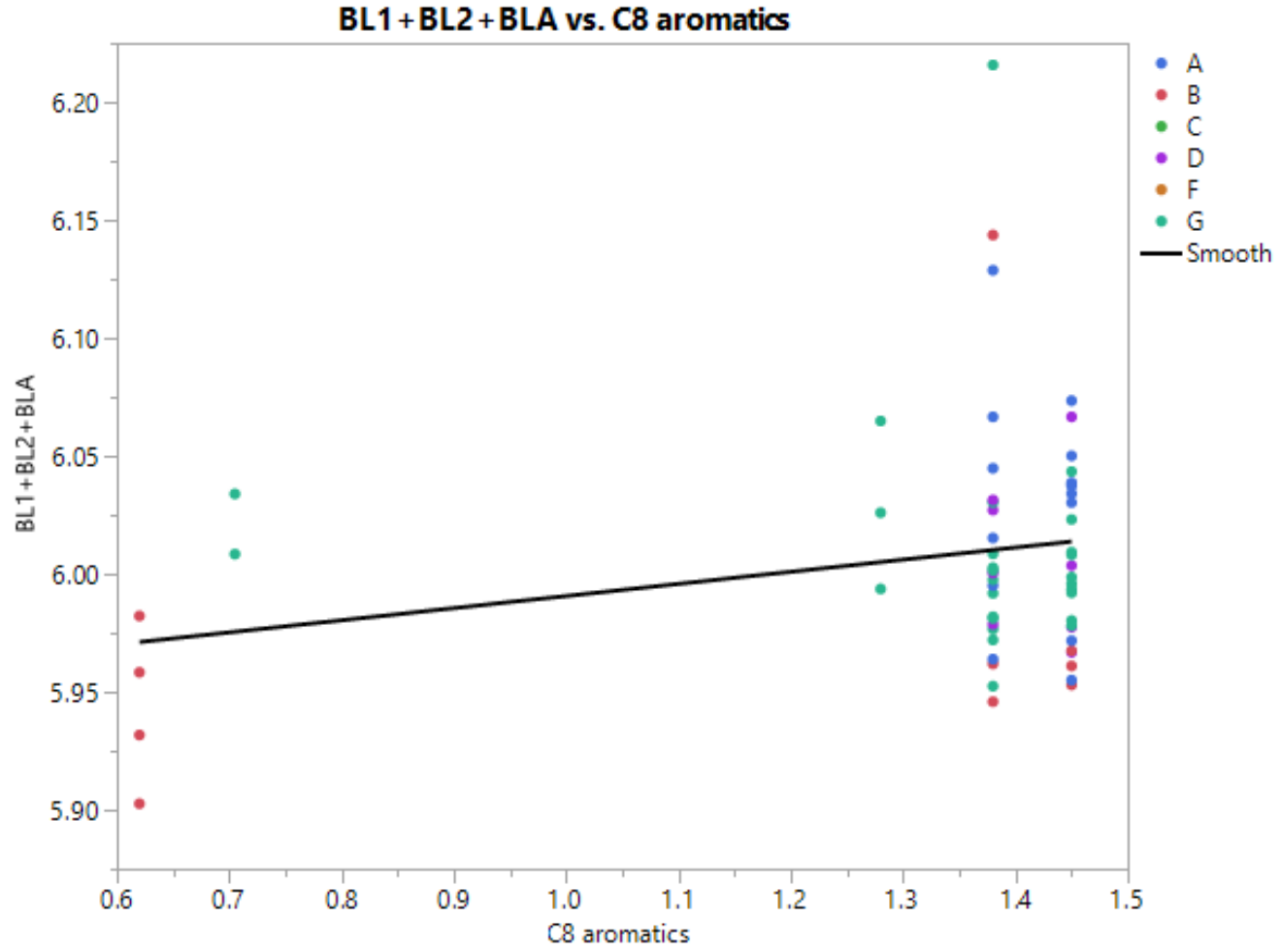
Graph Builder



Where(1 rows excluded)

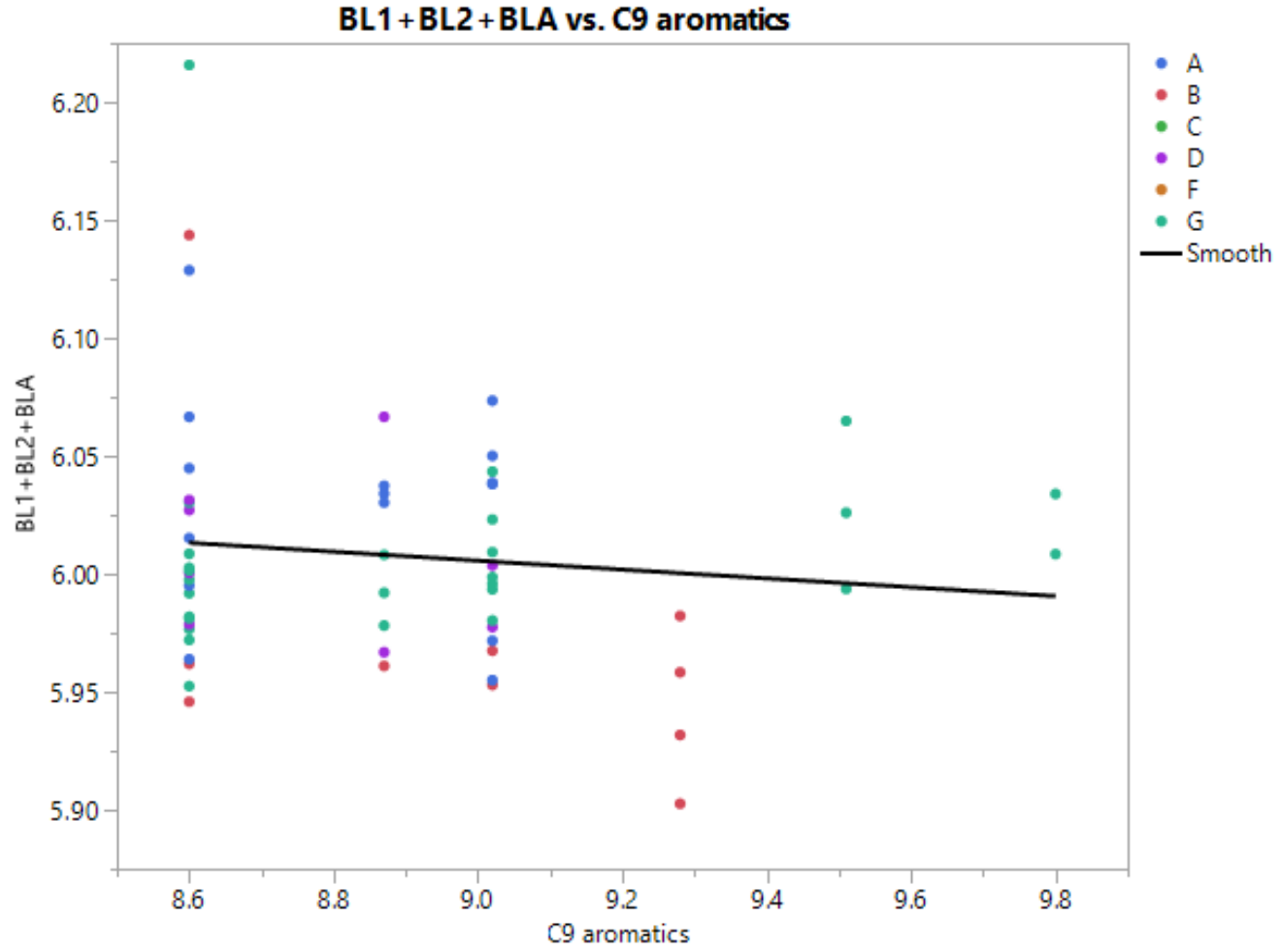


Graph Builder

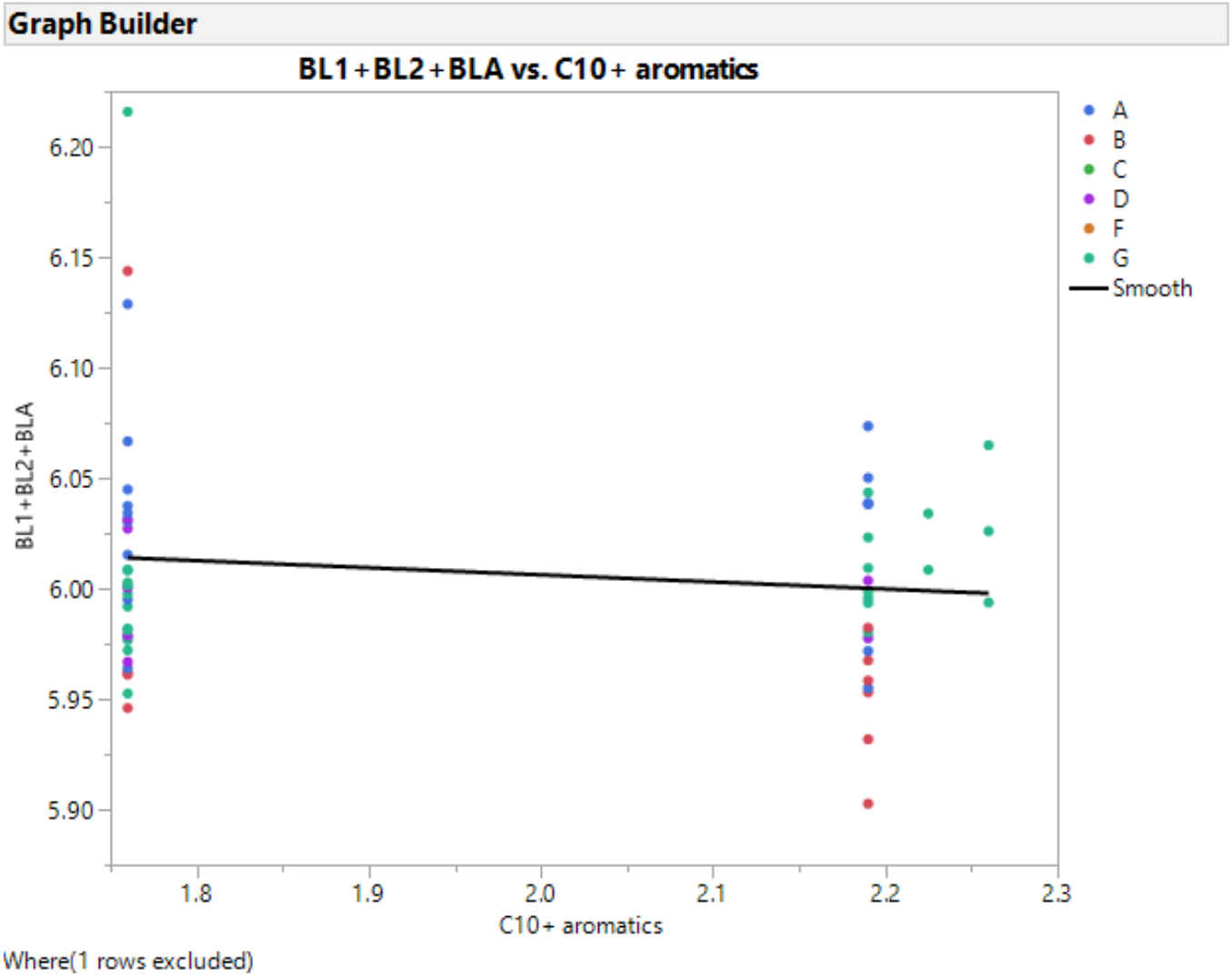


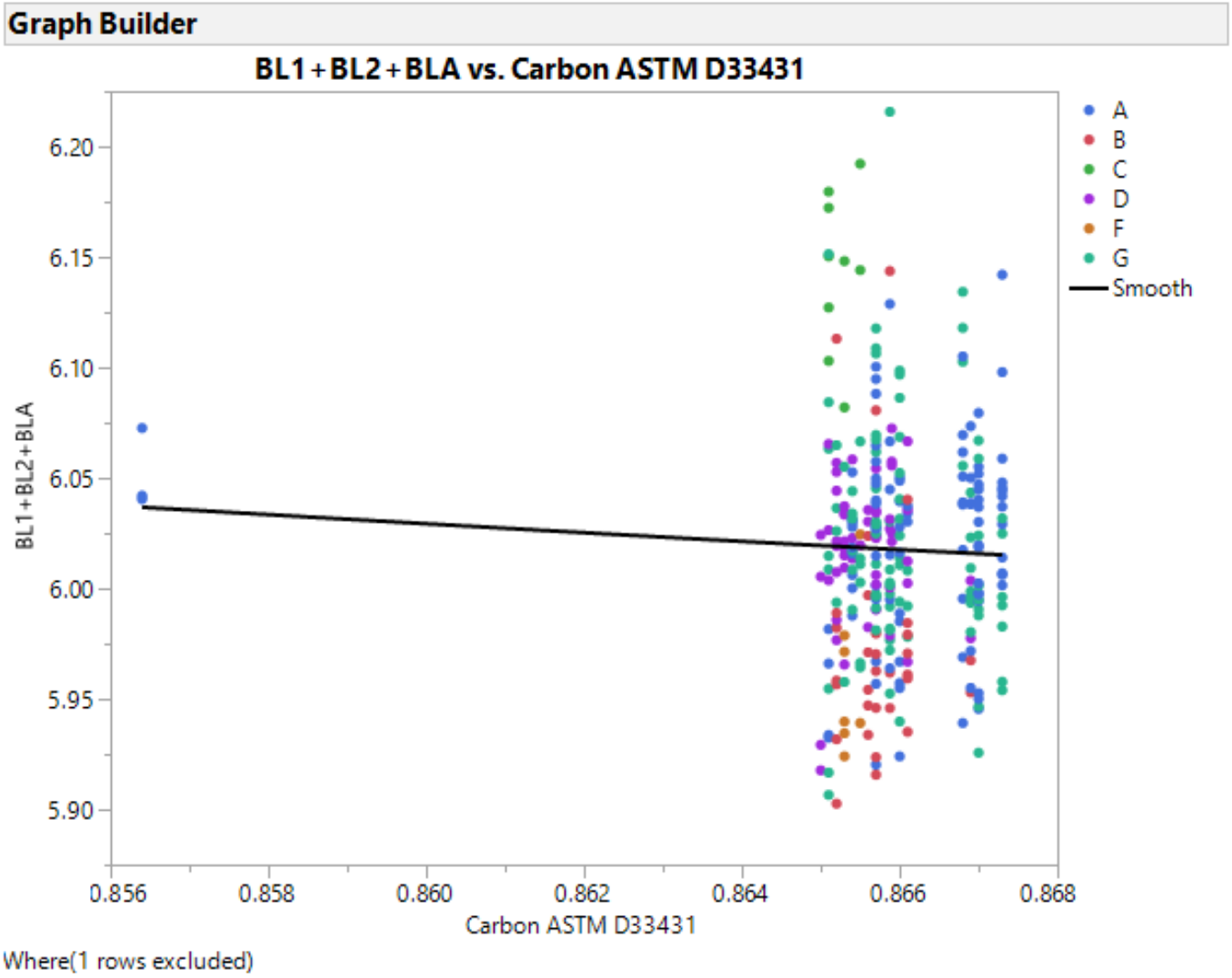
Where(1 rows excluded)

Graph Builder

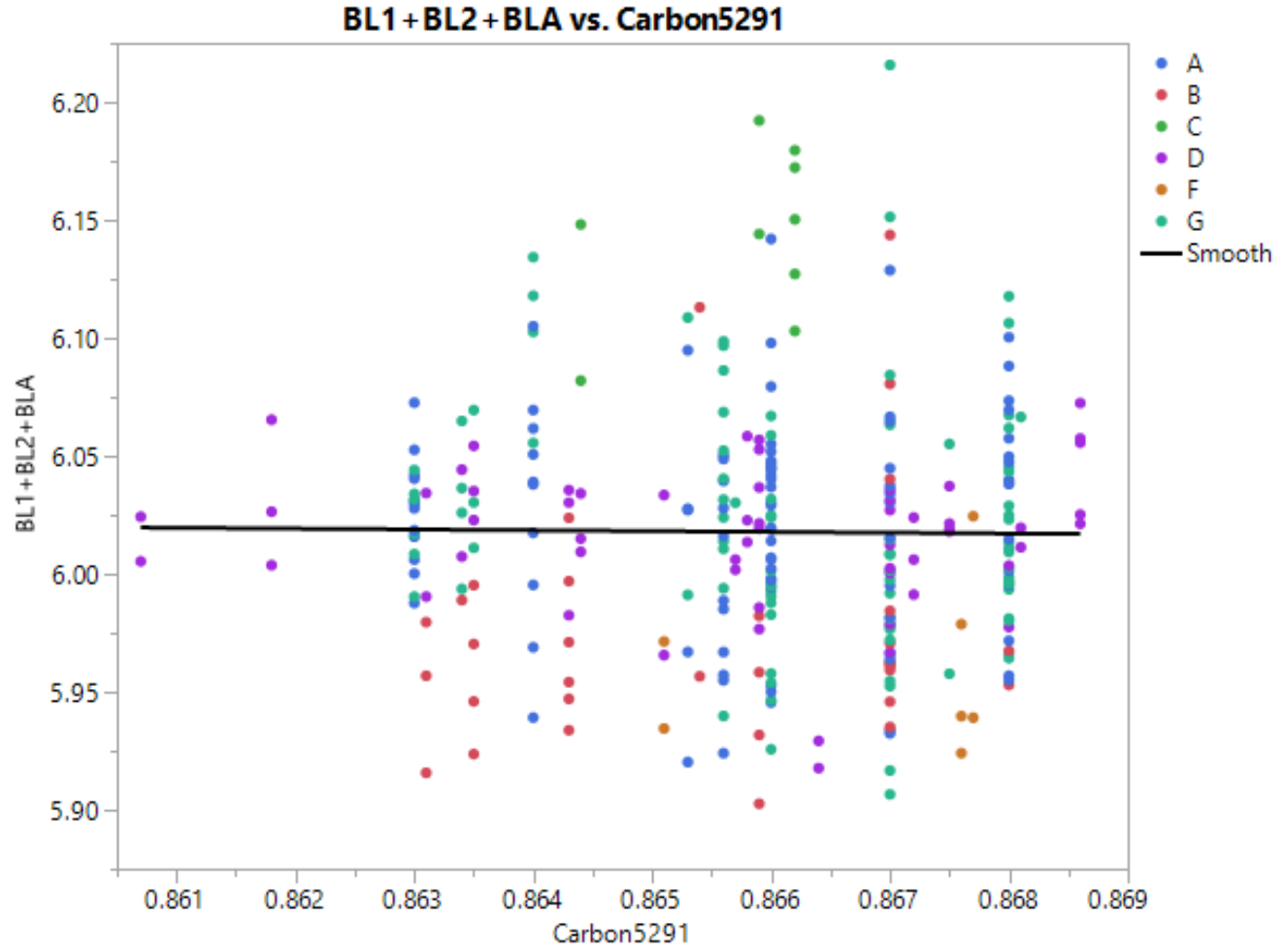


Where(1 rows excluded)


Graph Builder
BL1+BL2+BLA vs. C10+ aromatics
BL1+BL2+BLA
6.20
6.15
6.10
6.05
6.00
5.95
5.90
1.8
1.9
2.0
2.1
2.2
2.3
C10+ aromatics
A
B
C
D
F
G
Smooth
Where(1 rows excluded)

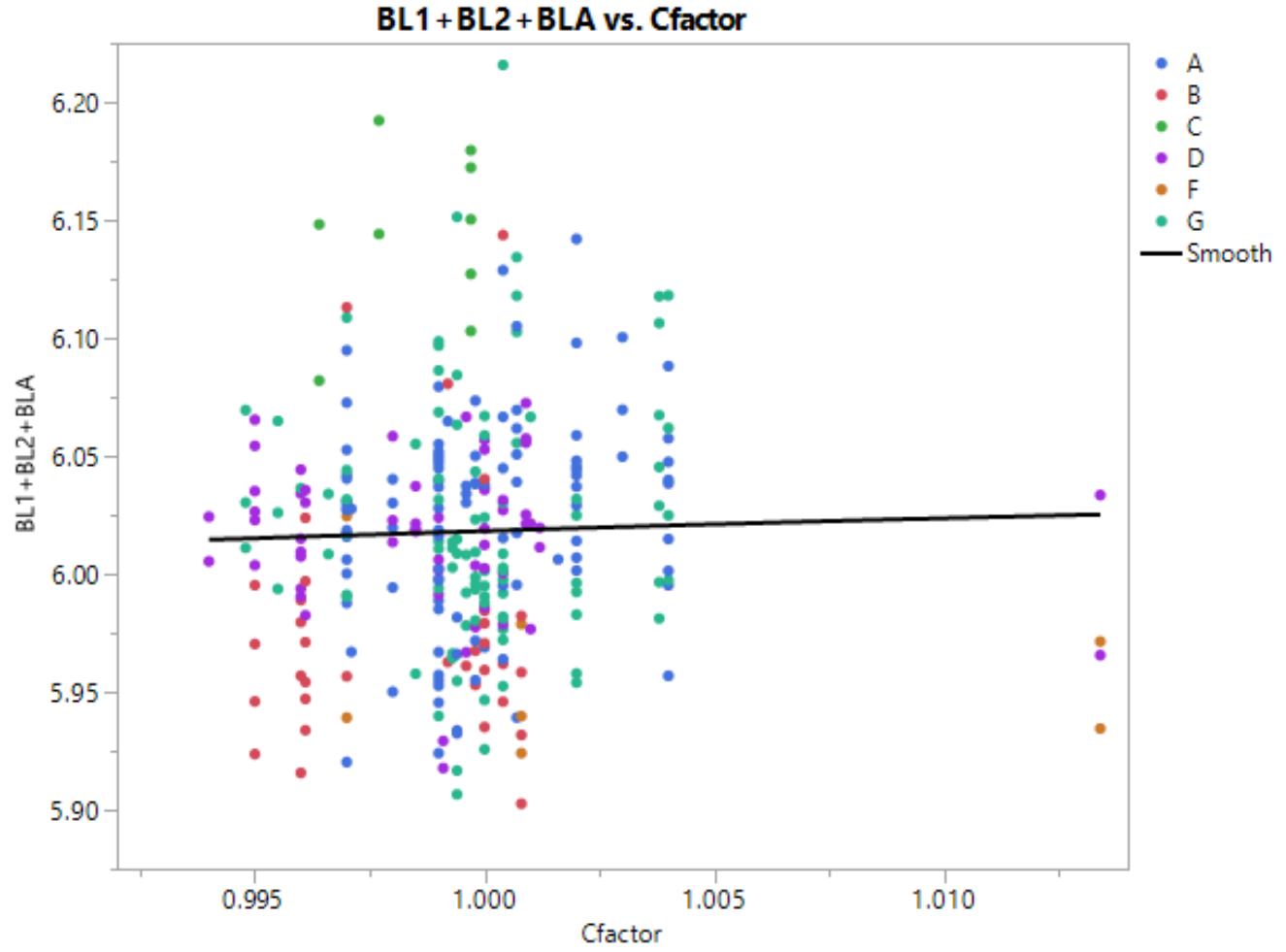


Graph Builder



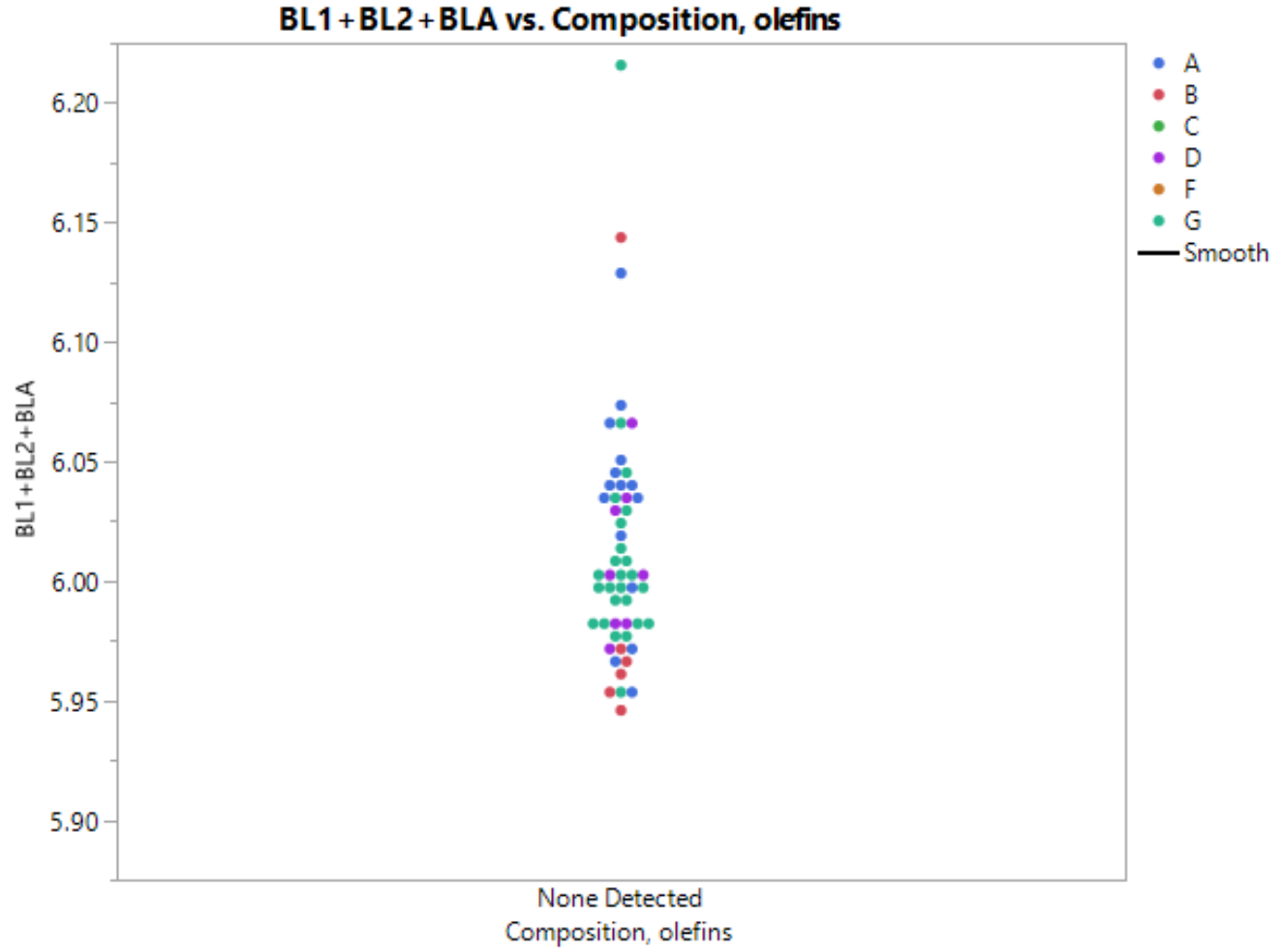
Where(1 rows excluded)

Graph Builder



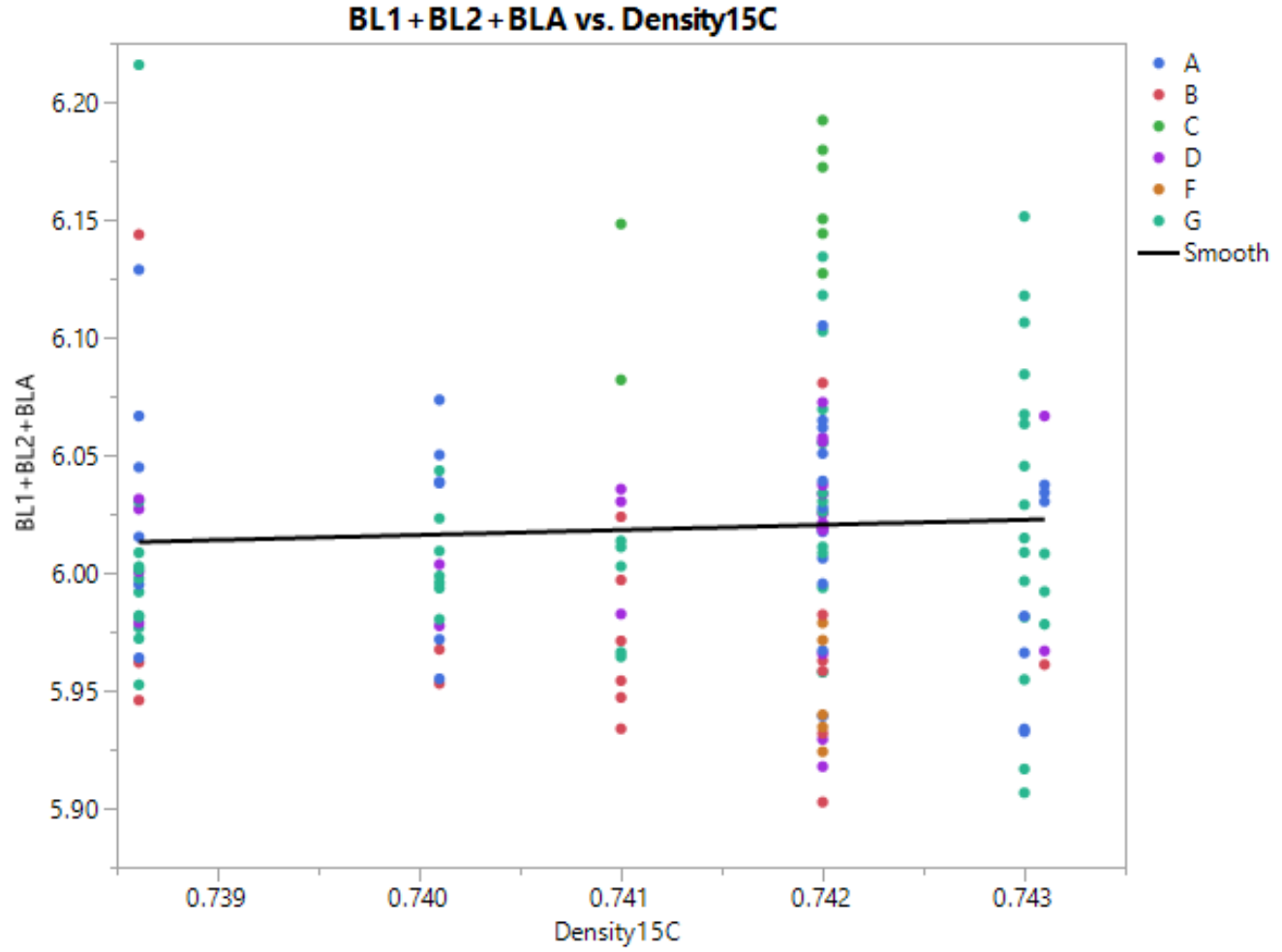
Where(1 rows excluded)

Graph Builder



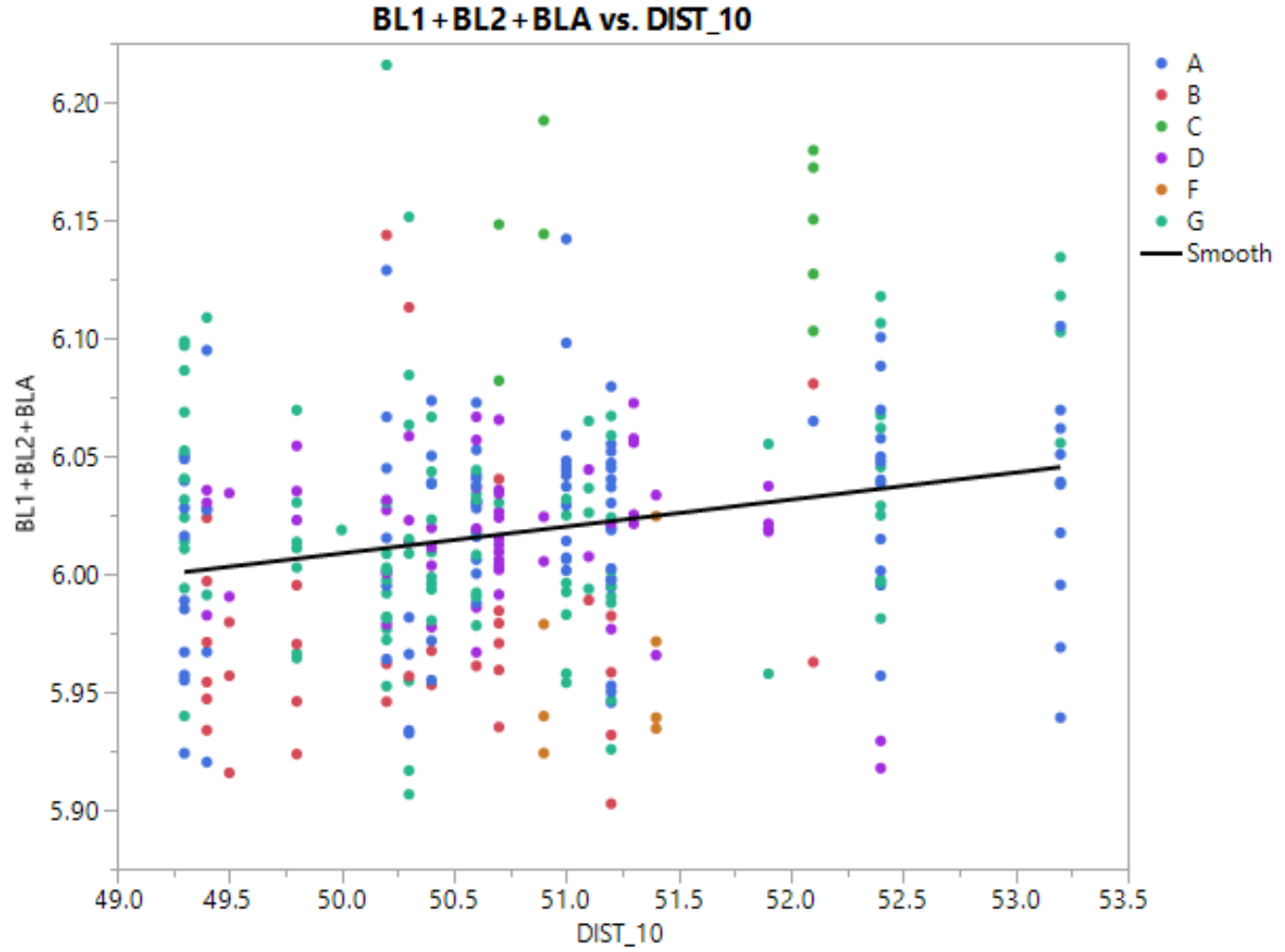
Where(1 rows excluded)

Graph Builder



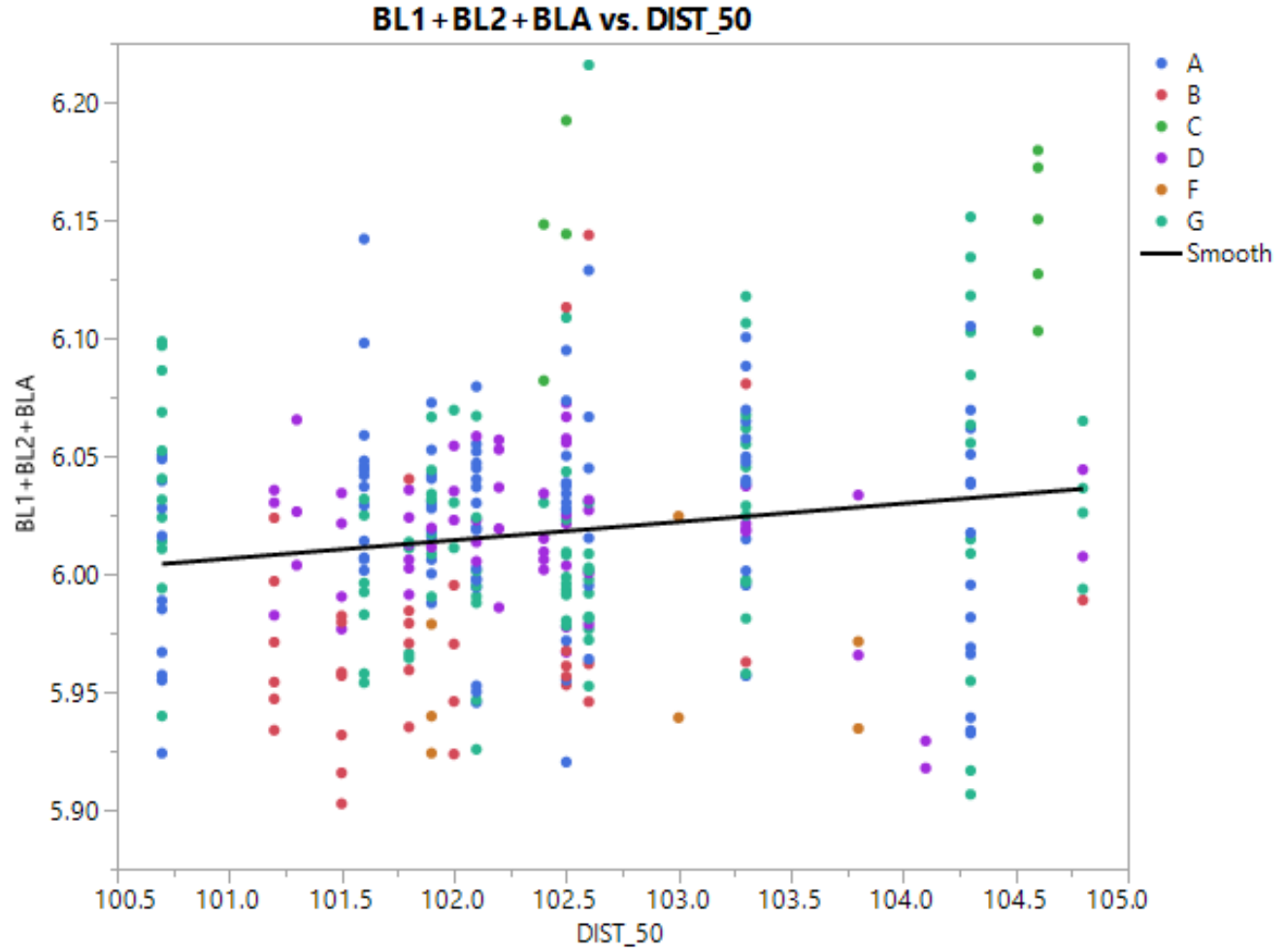
Where(1 rows excluded)

Graph Builder



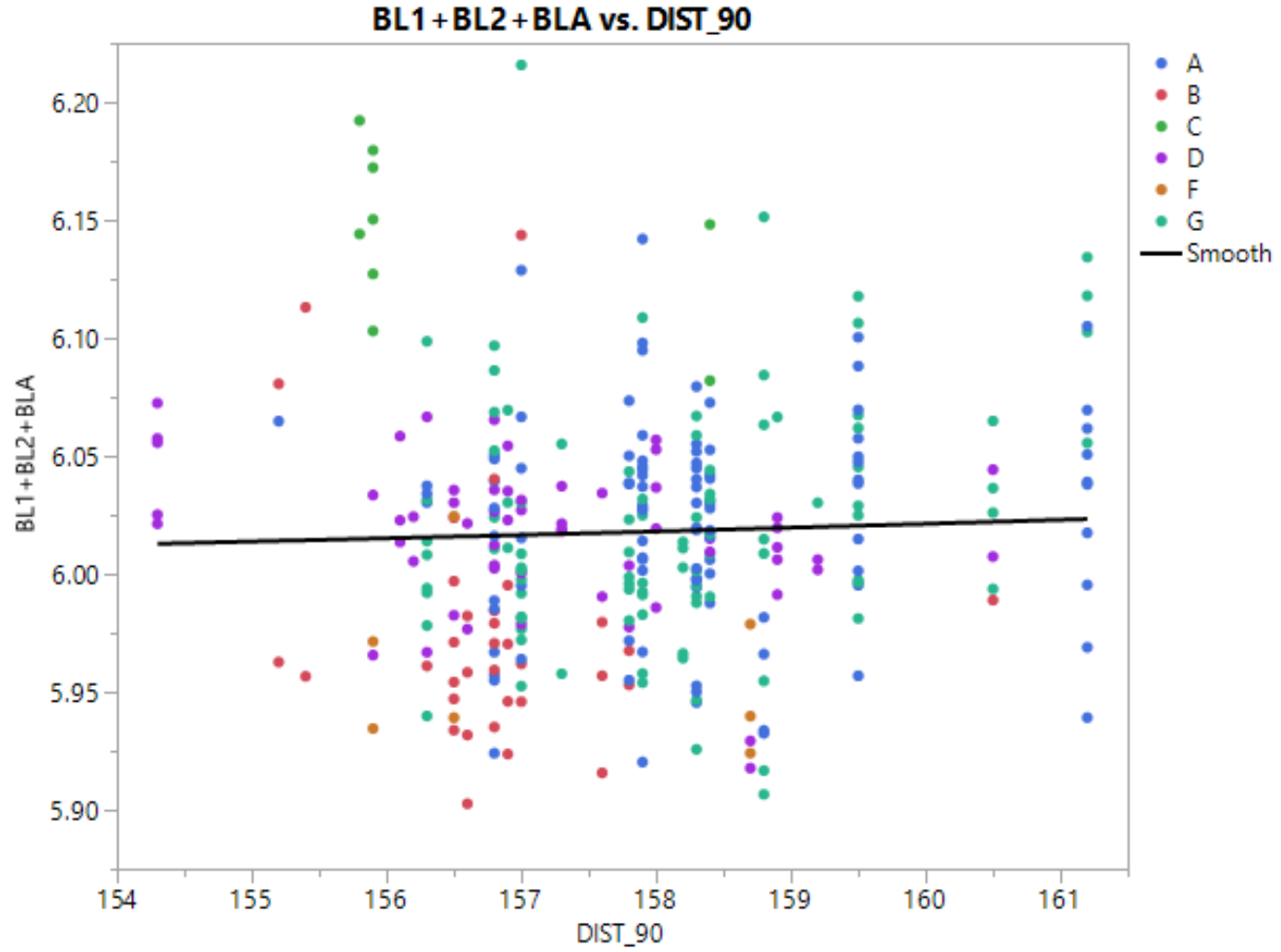
Where(1 rows excluded)

Graph Builder



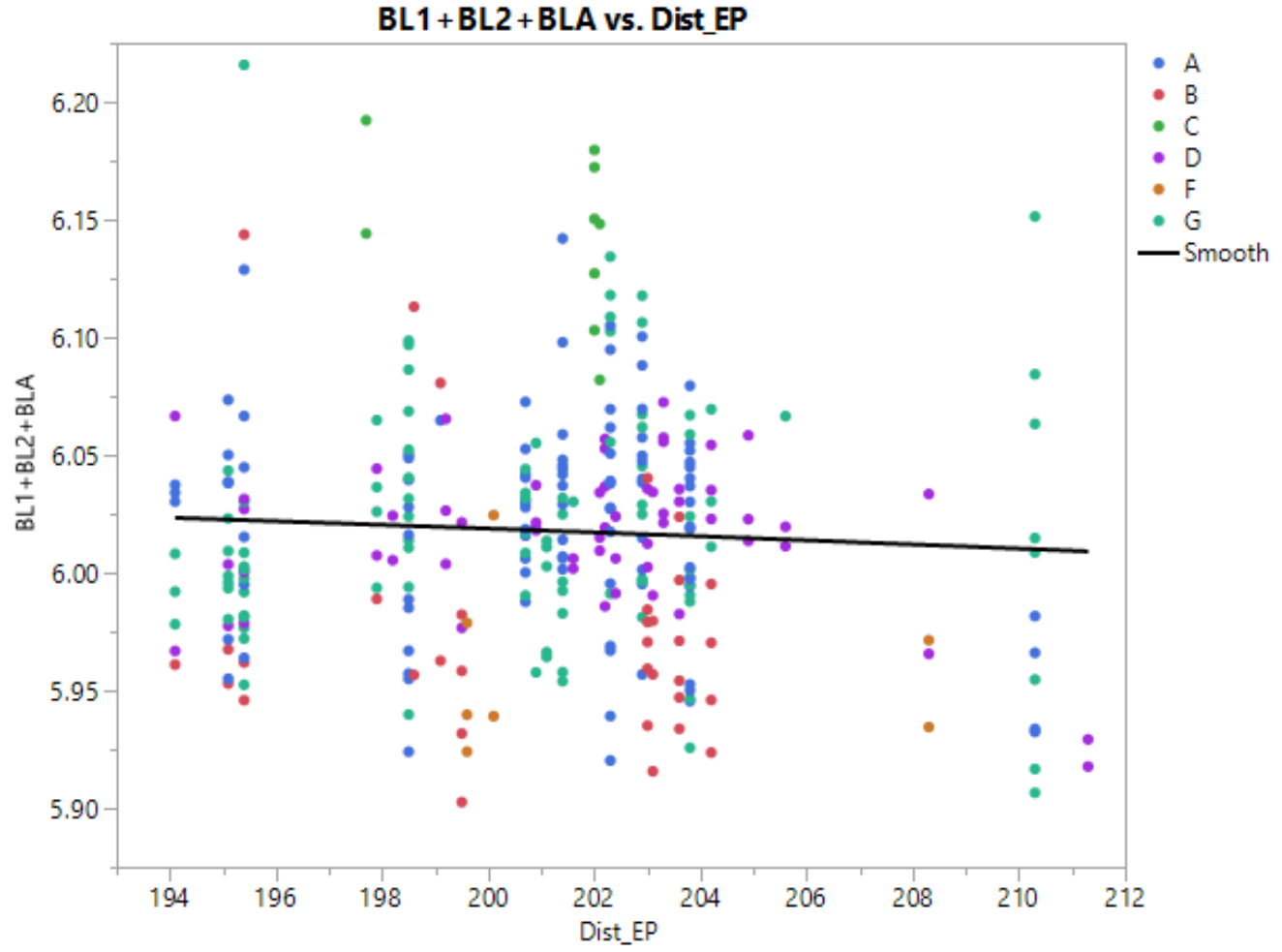
Where(1 rows excluded)

Graph Builder



Where(1 rows excluded)

Graph Builder



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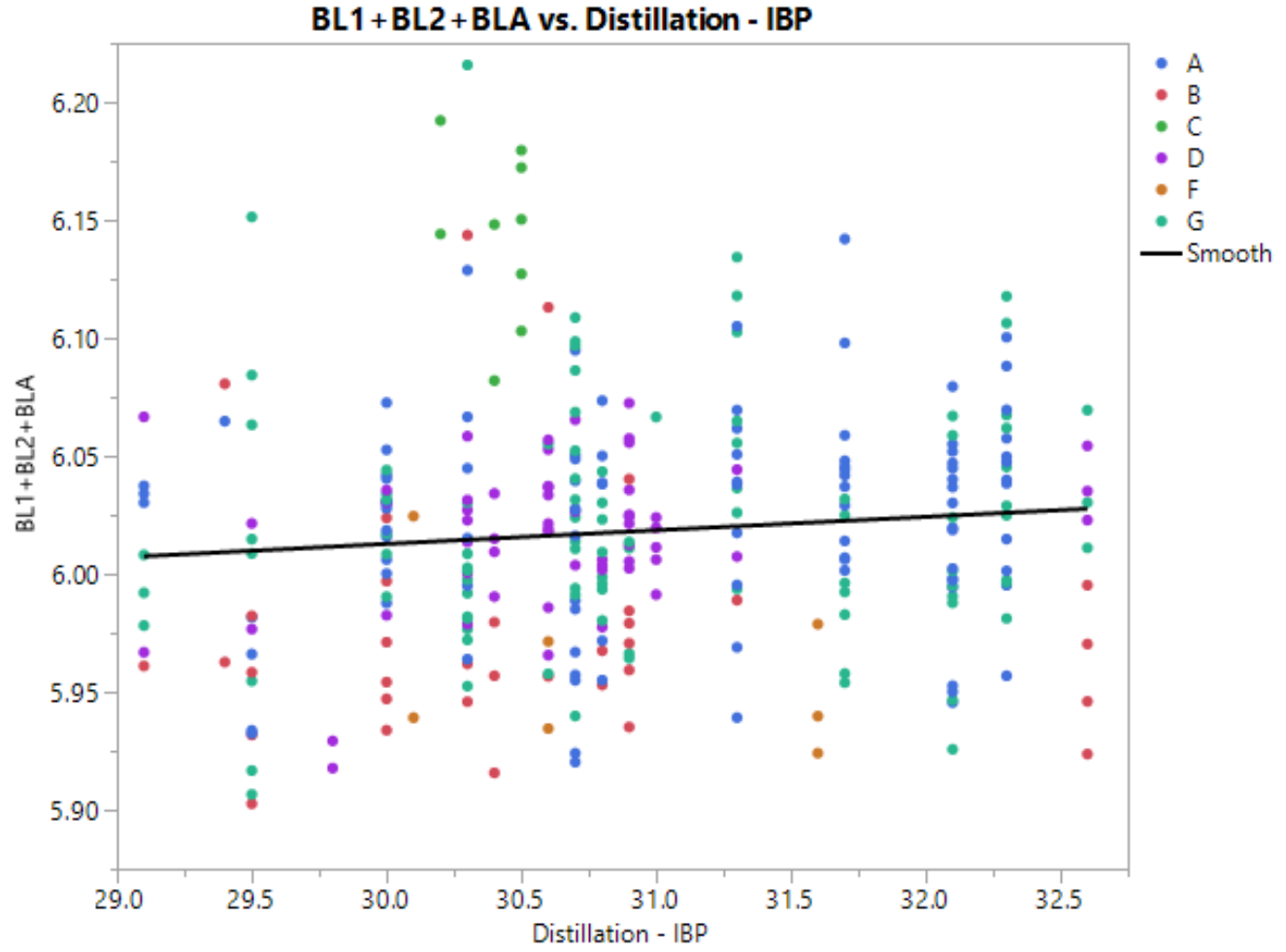

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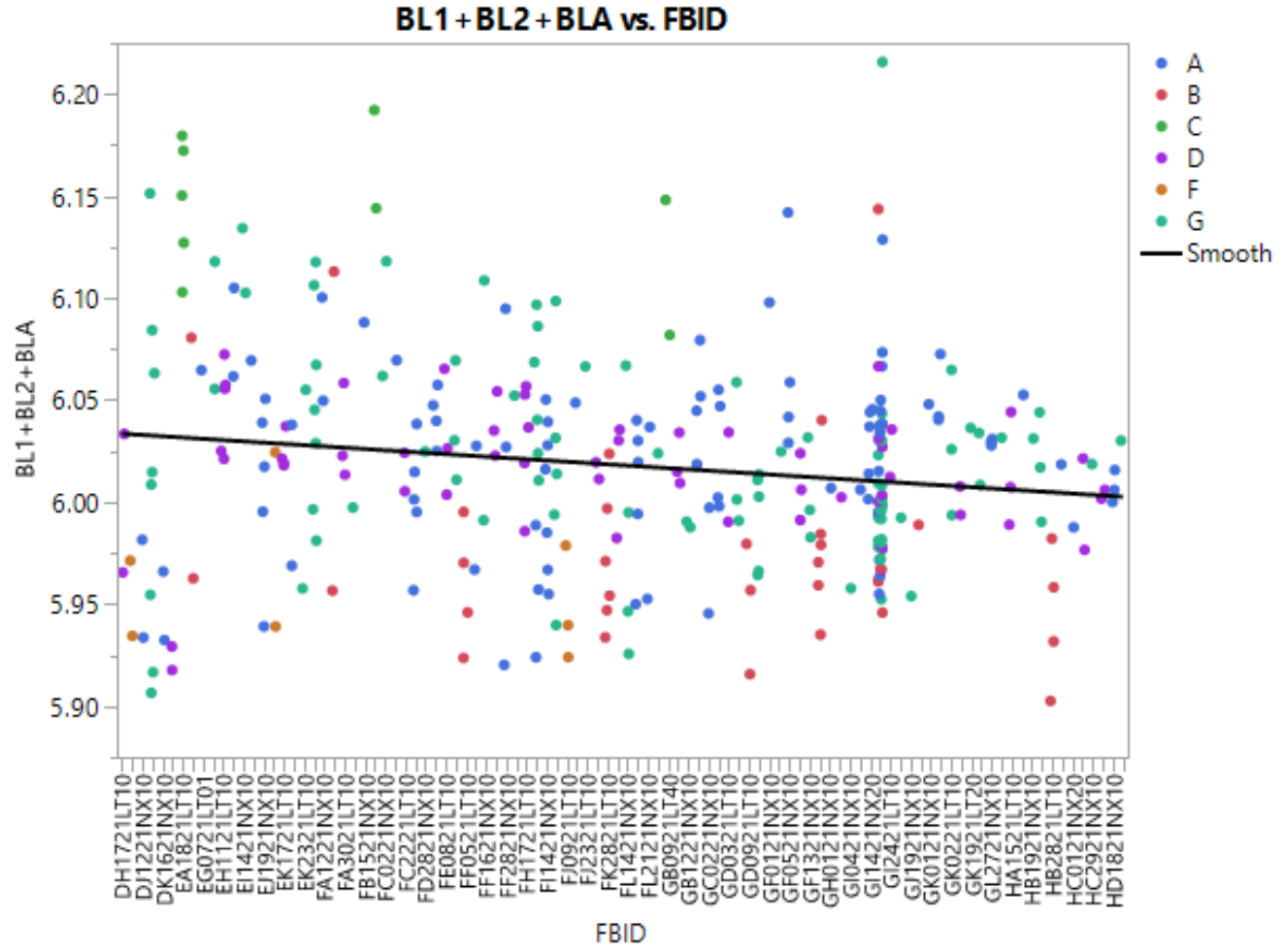

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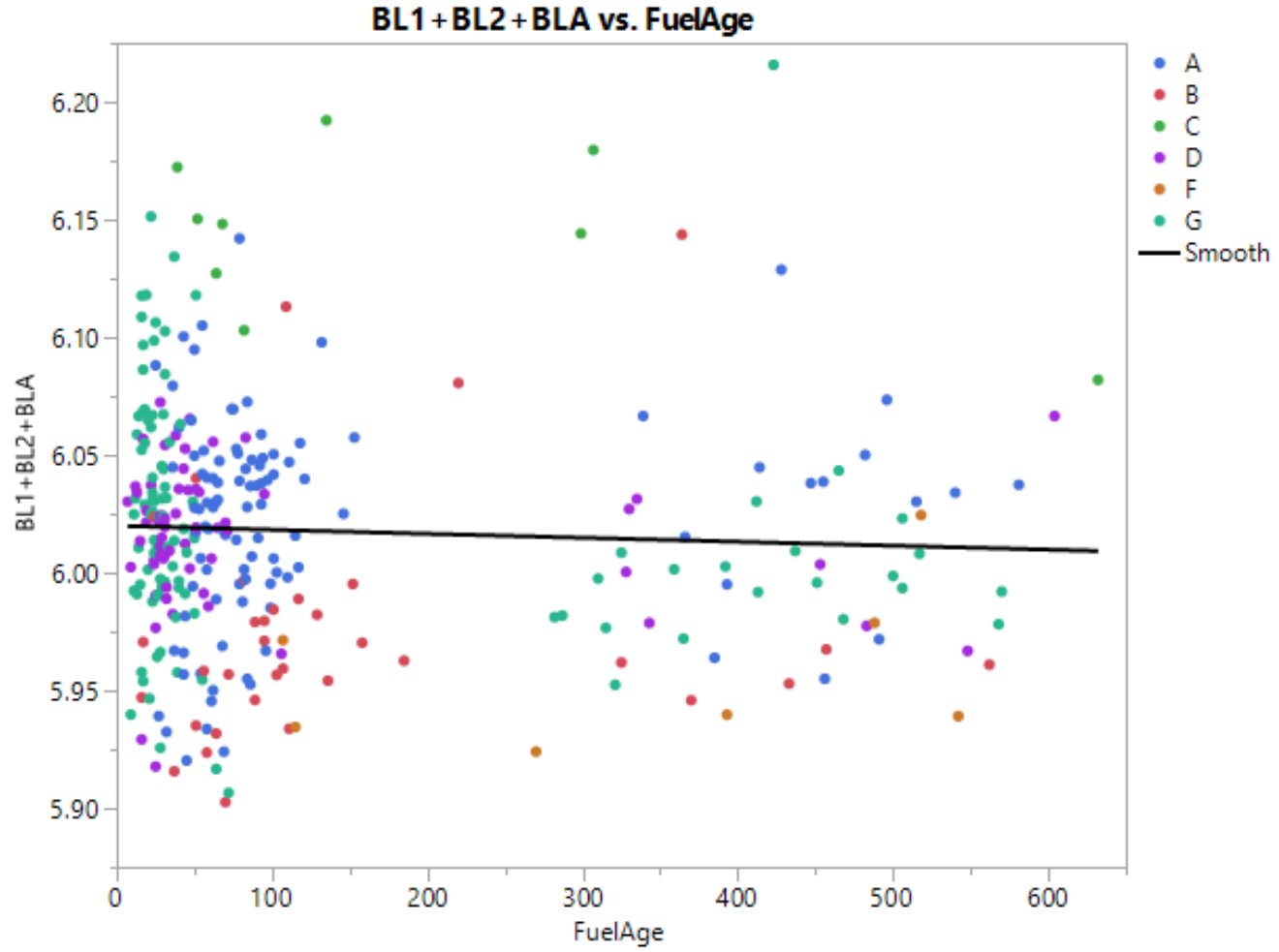
Afton CHEMICAL Passion for Solutions

Graph Builder



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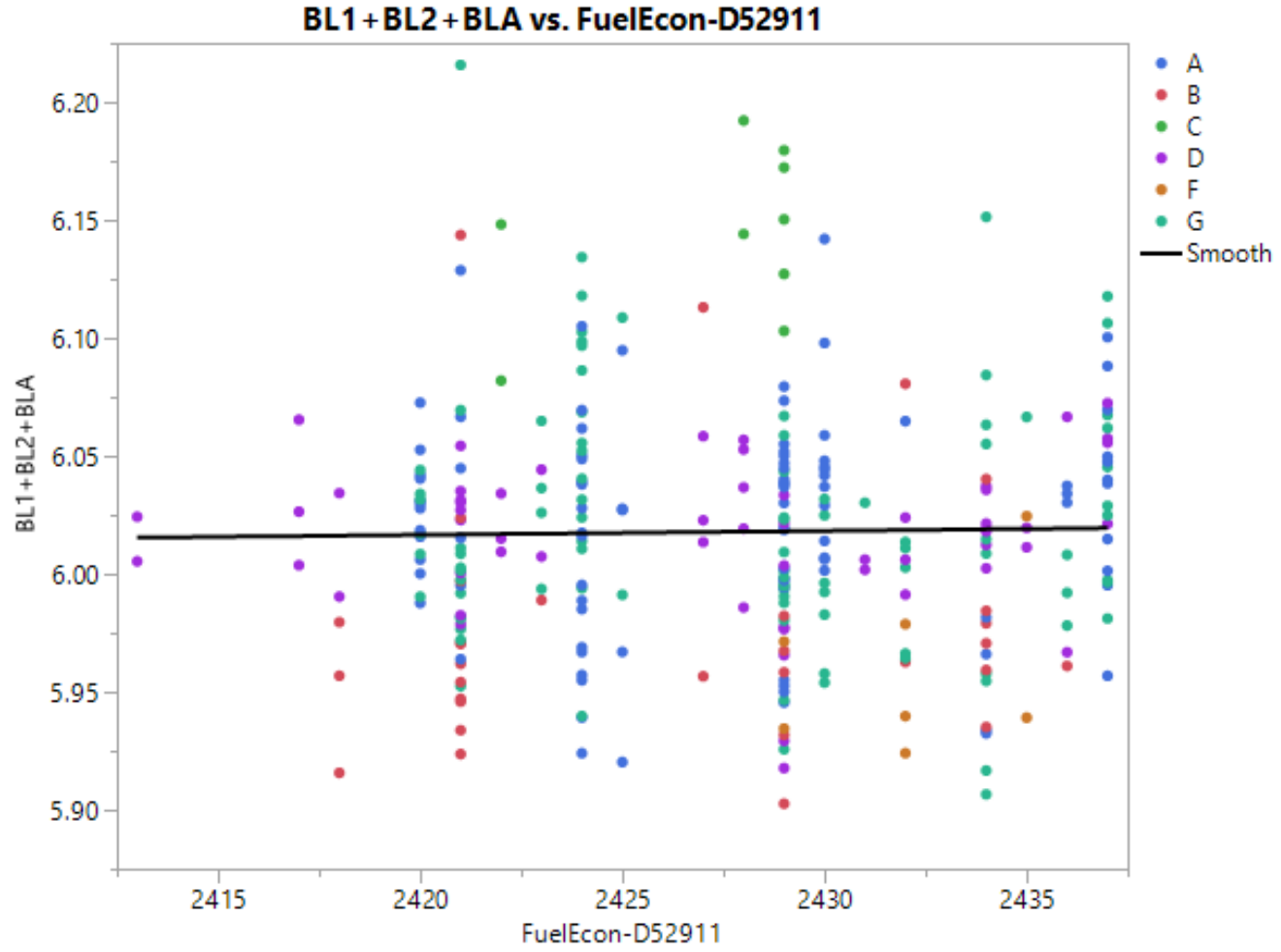

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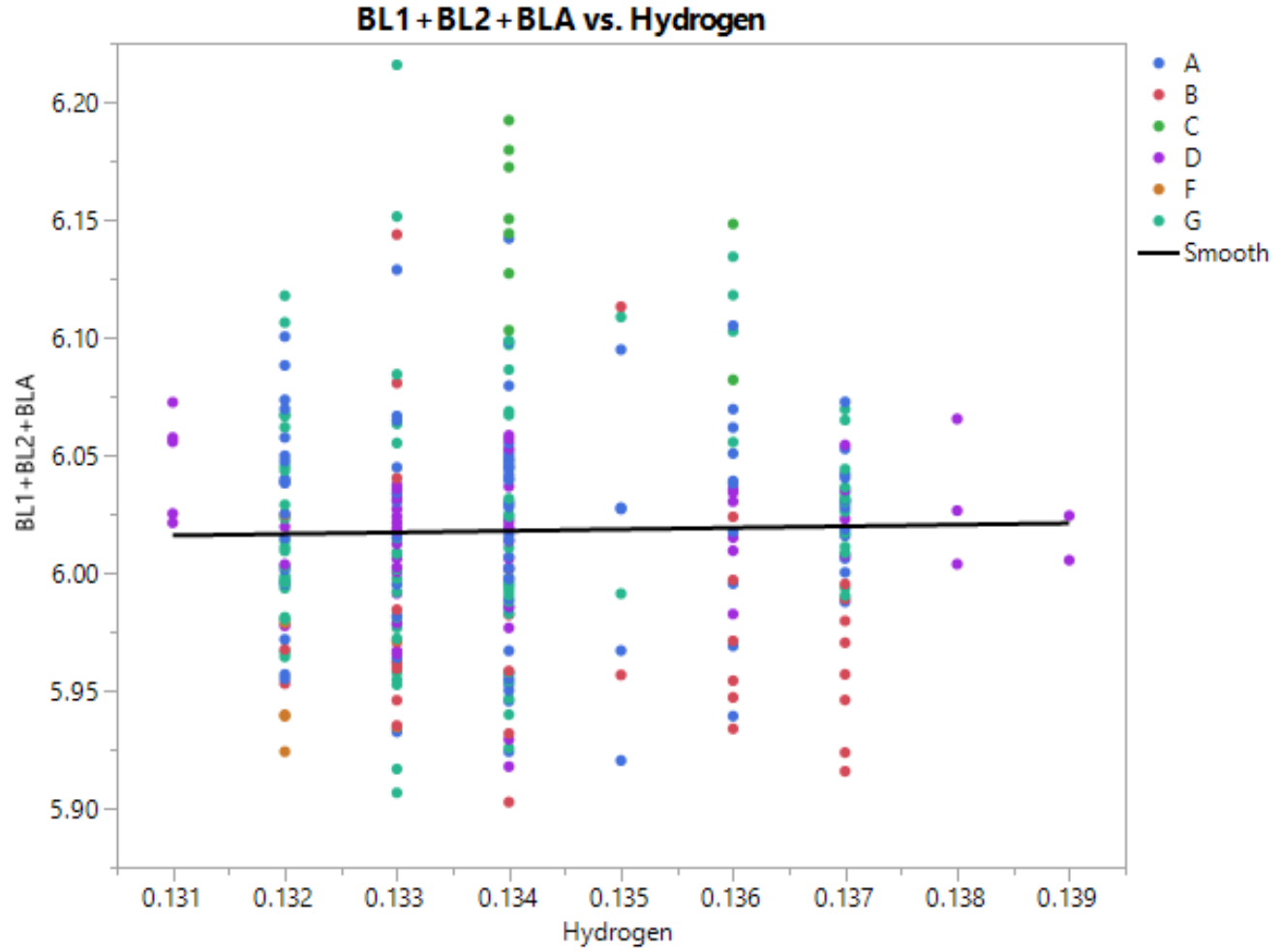

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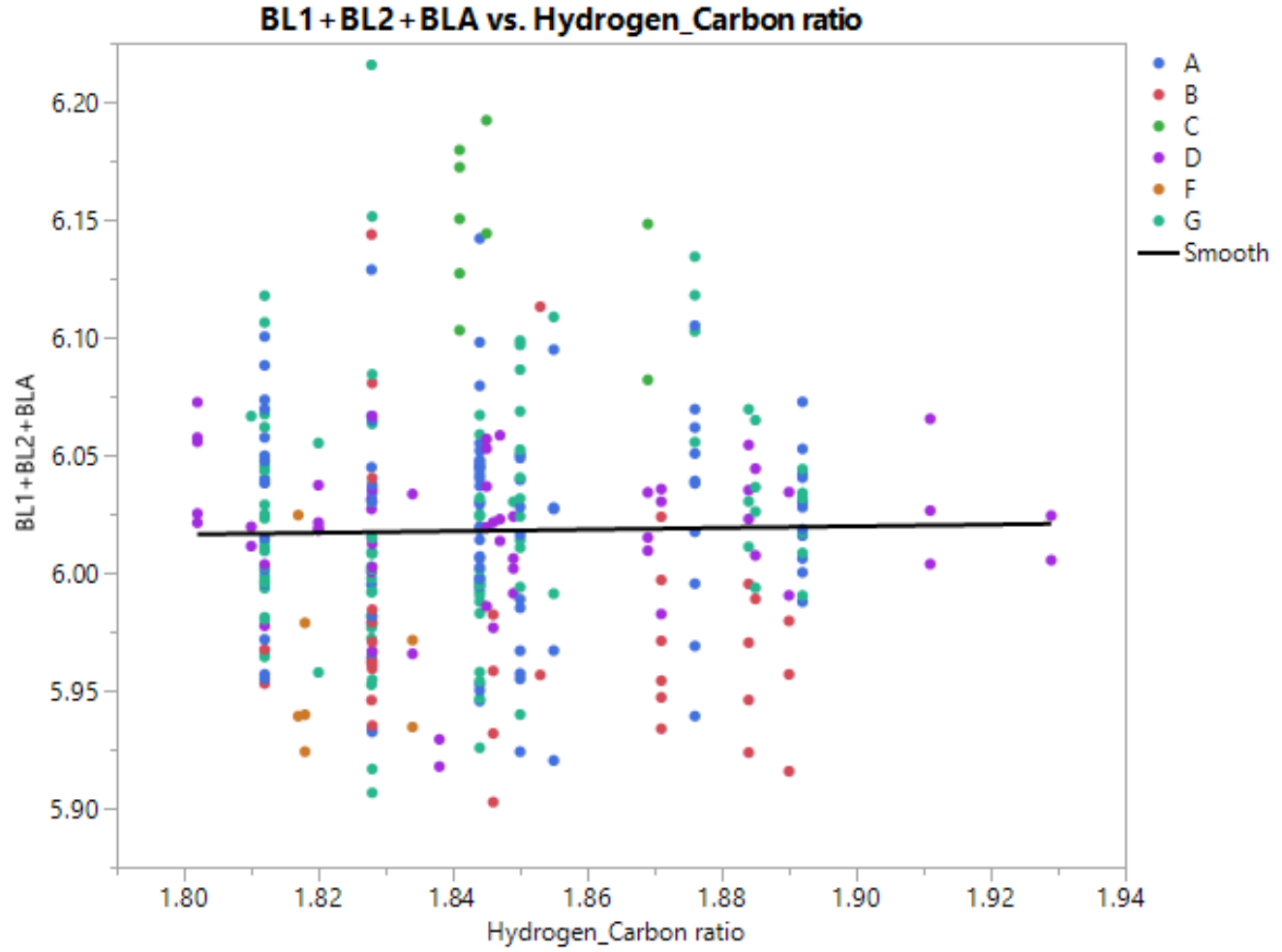
Graph Builder



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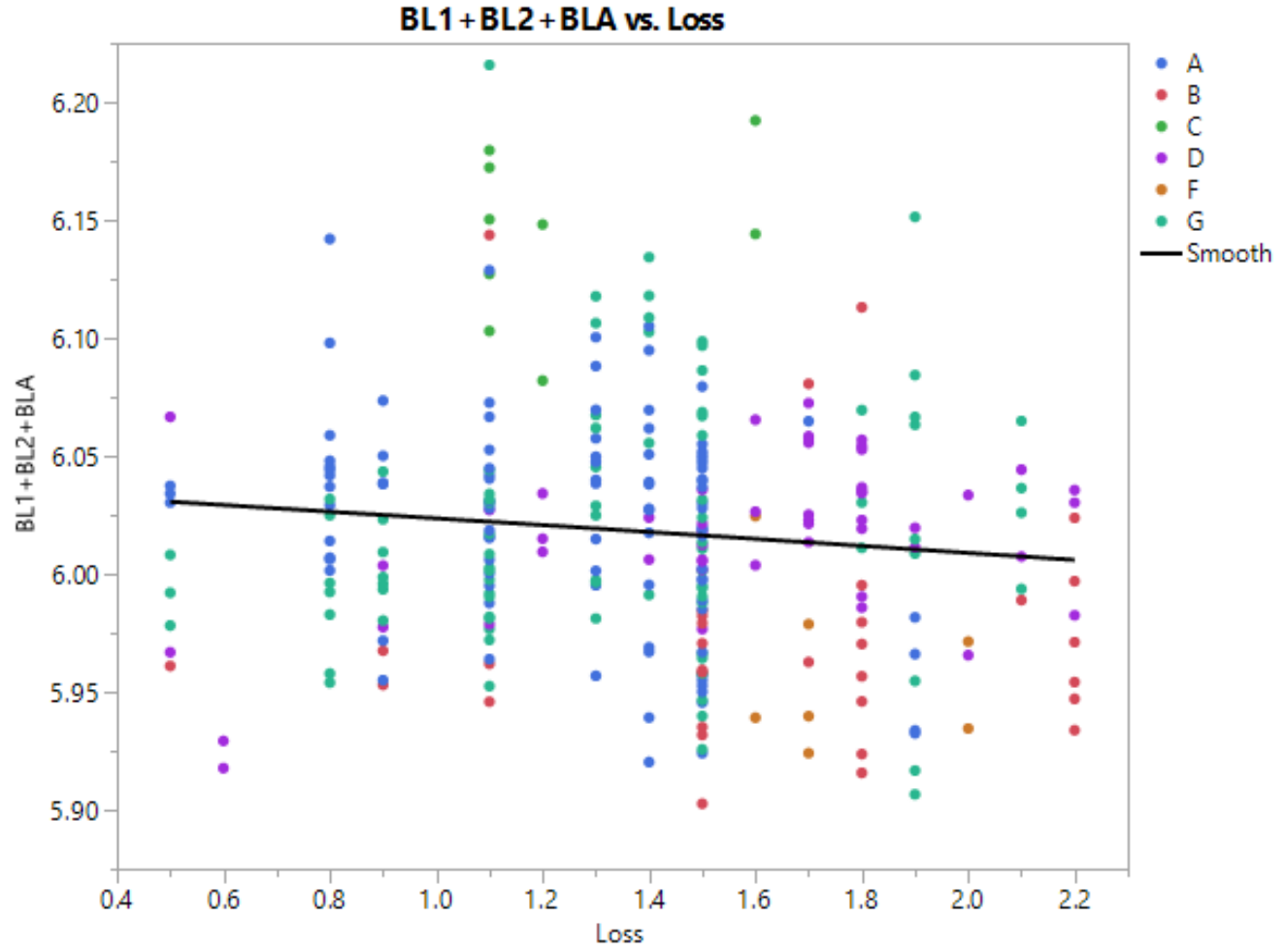

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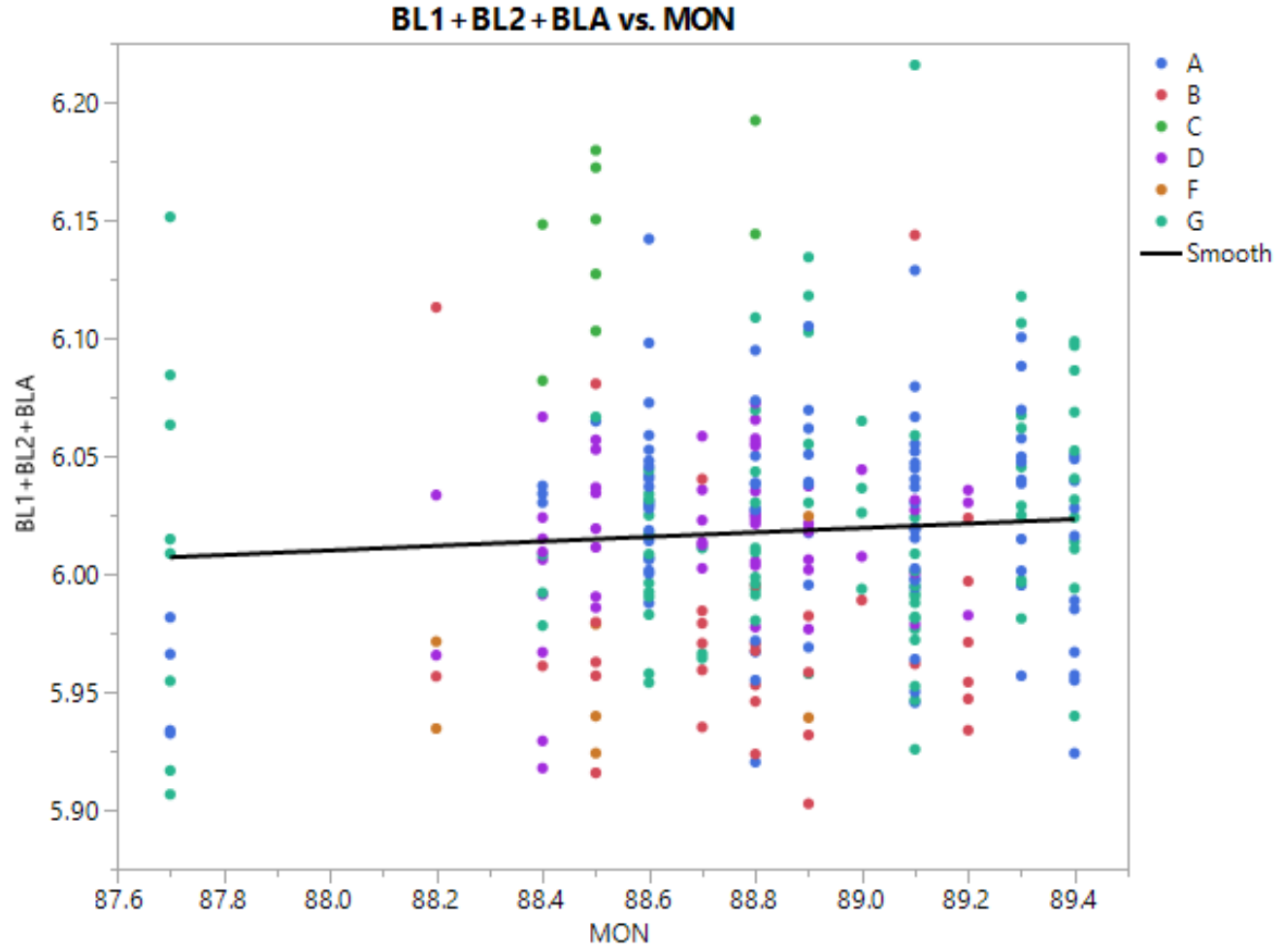
Afton CHEMICAL Passion for Solutions

Graph Builder



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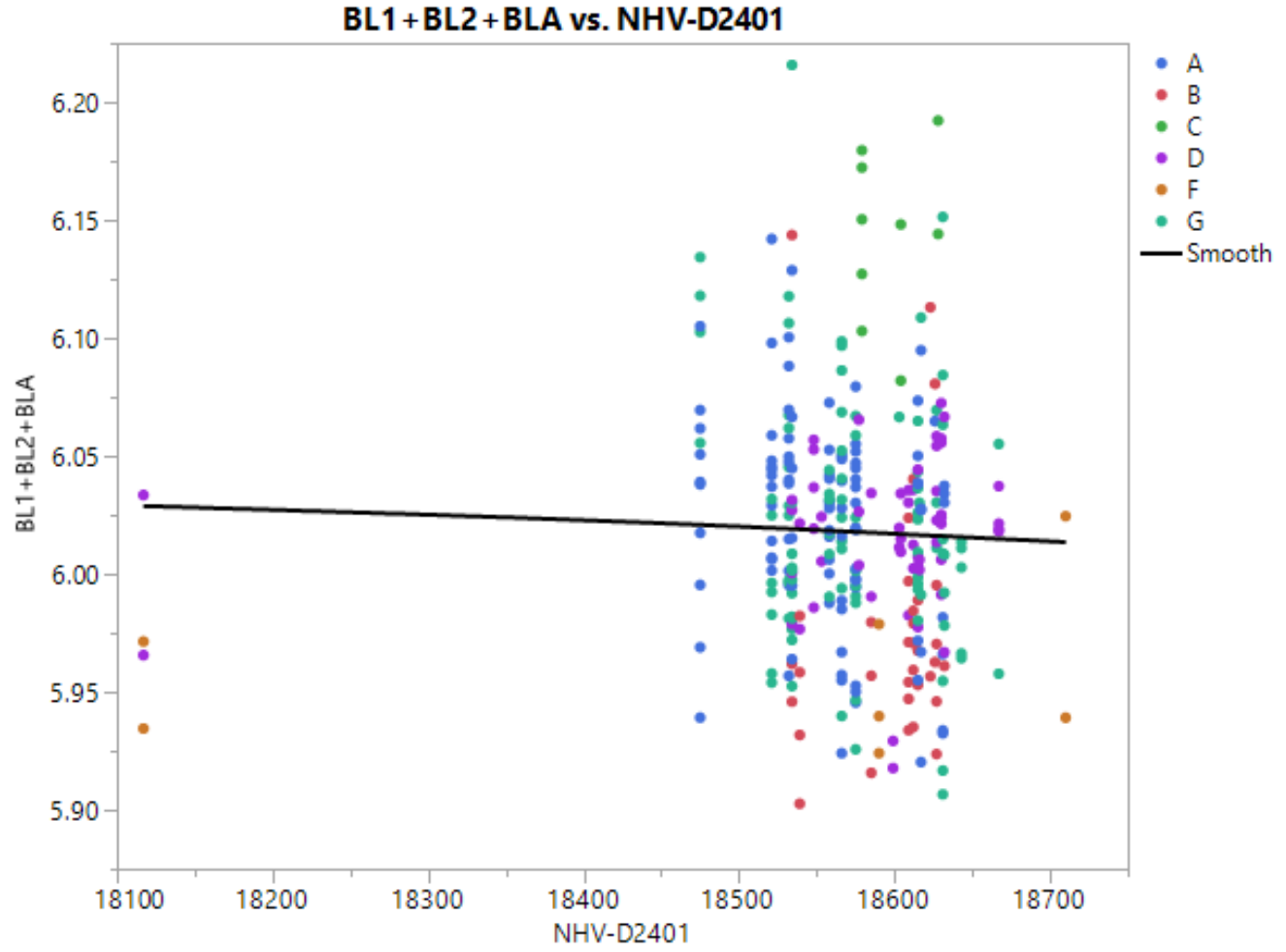

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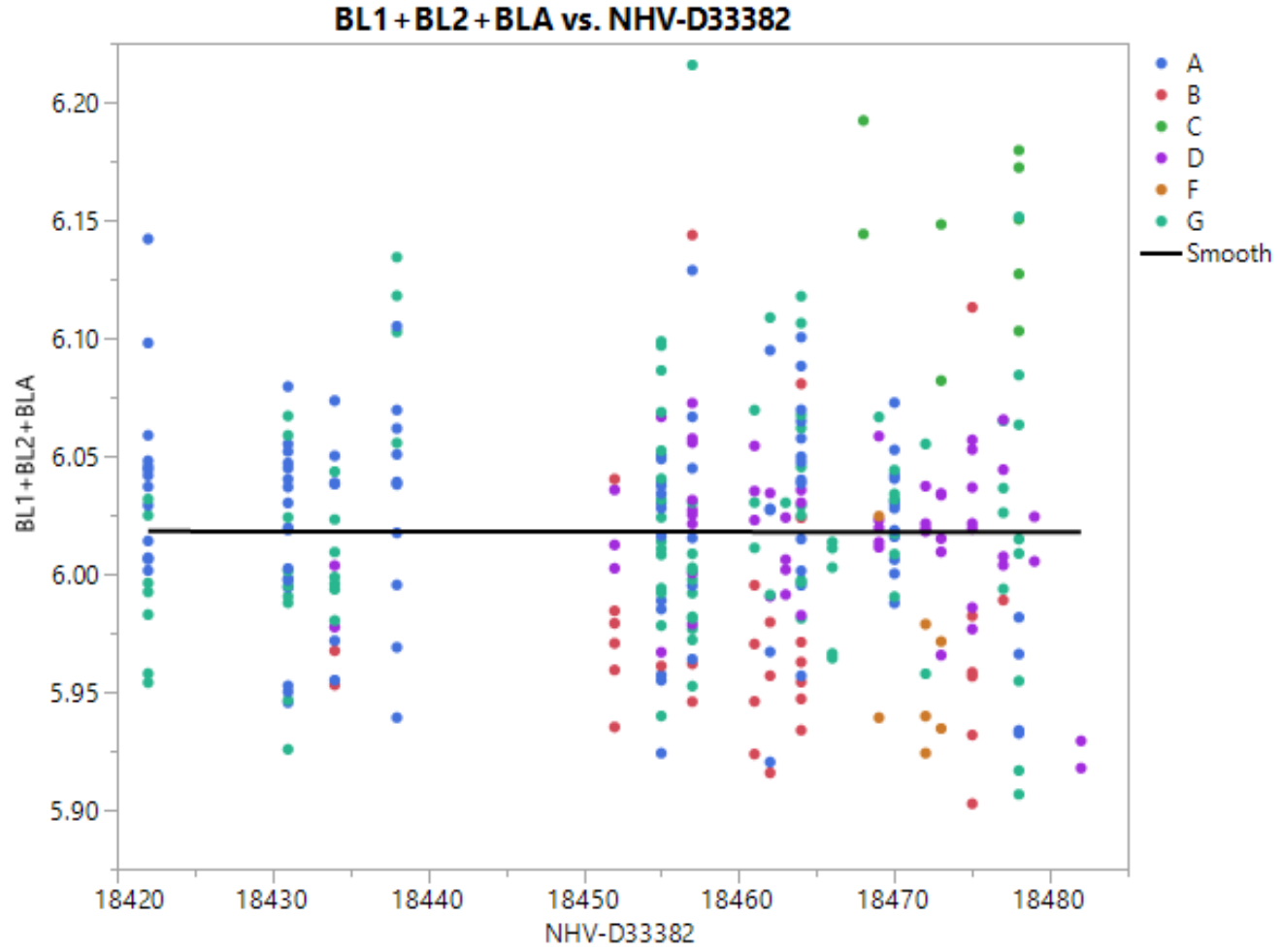

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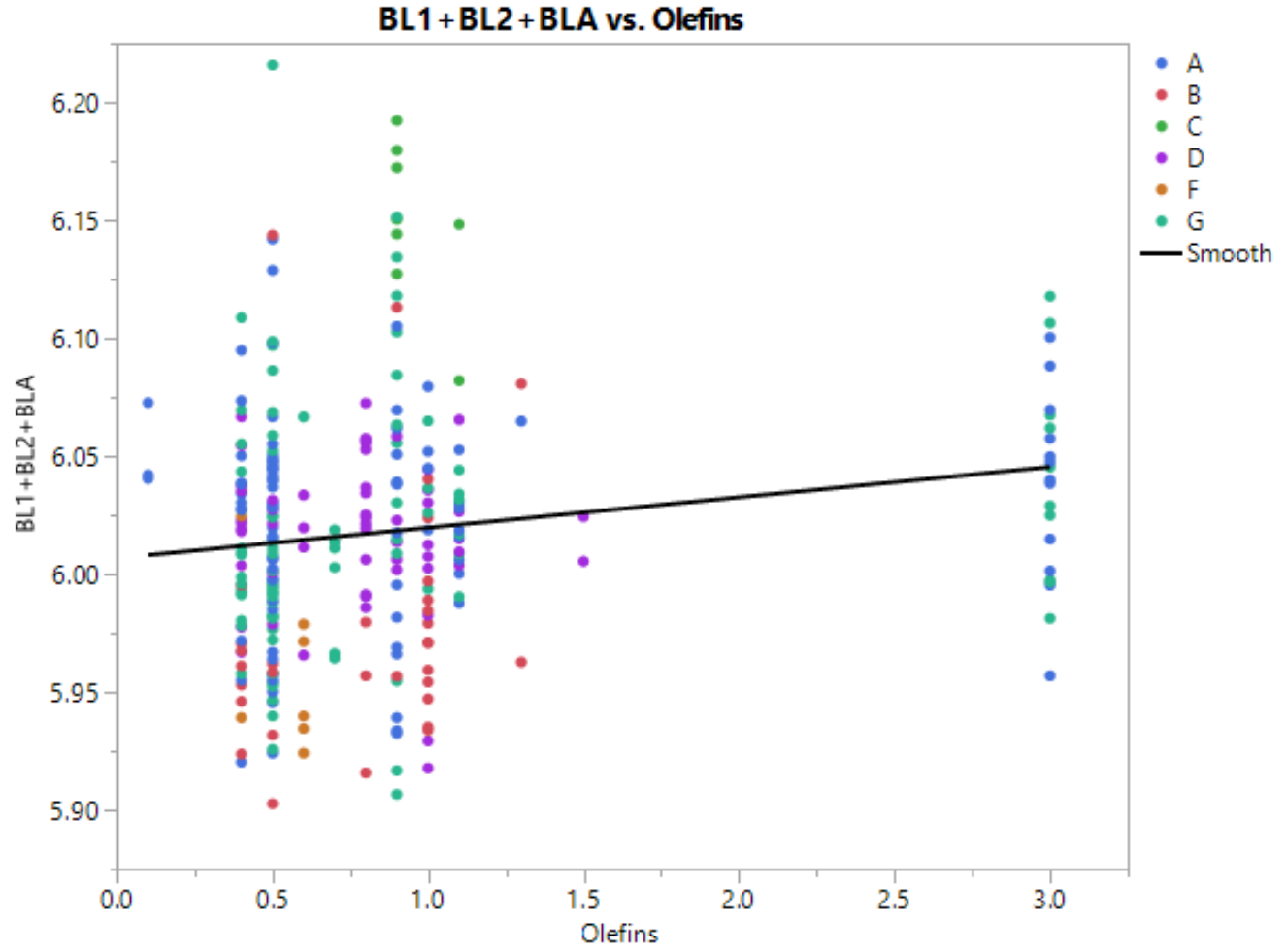

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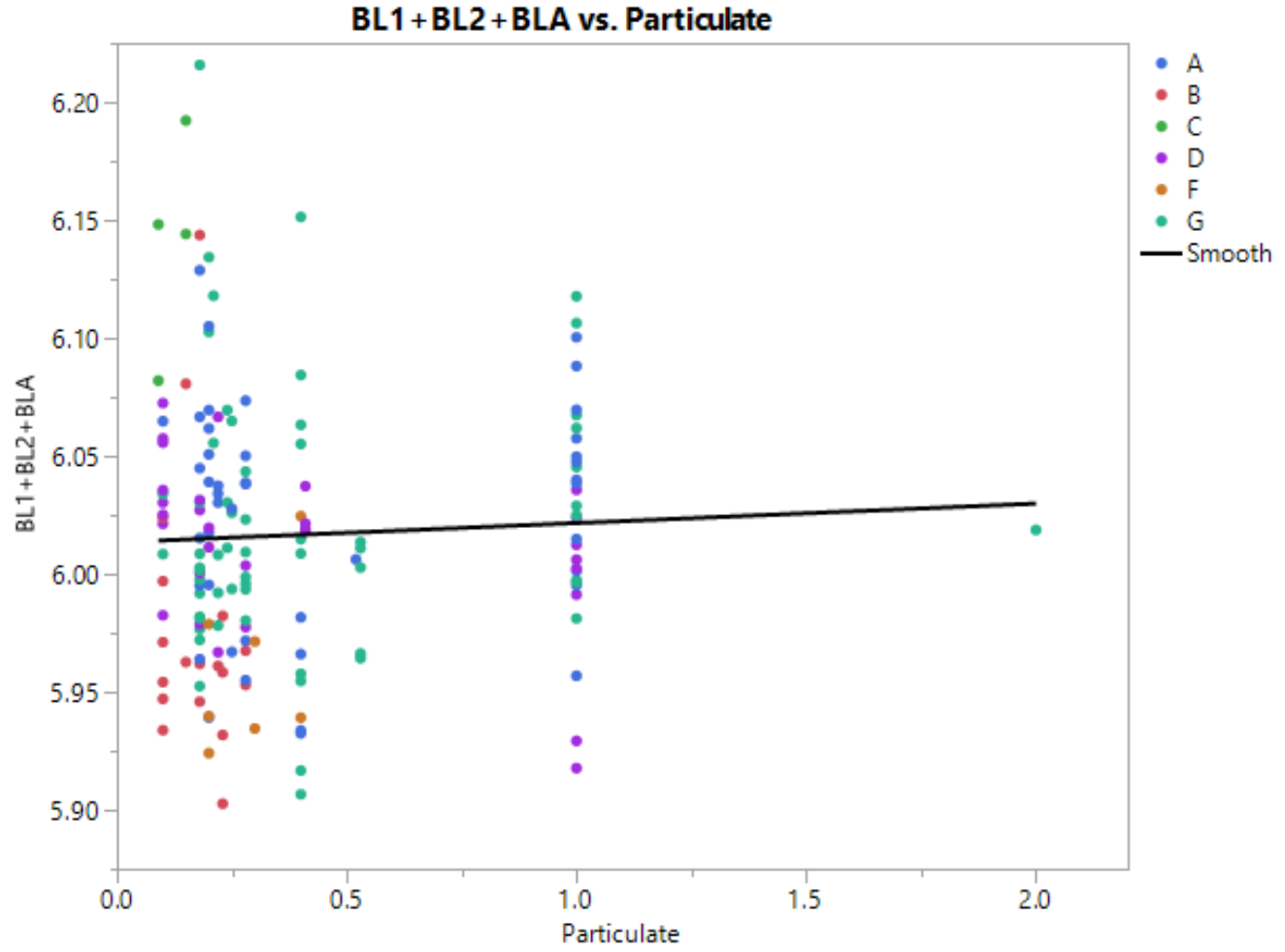

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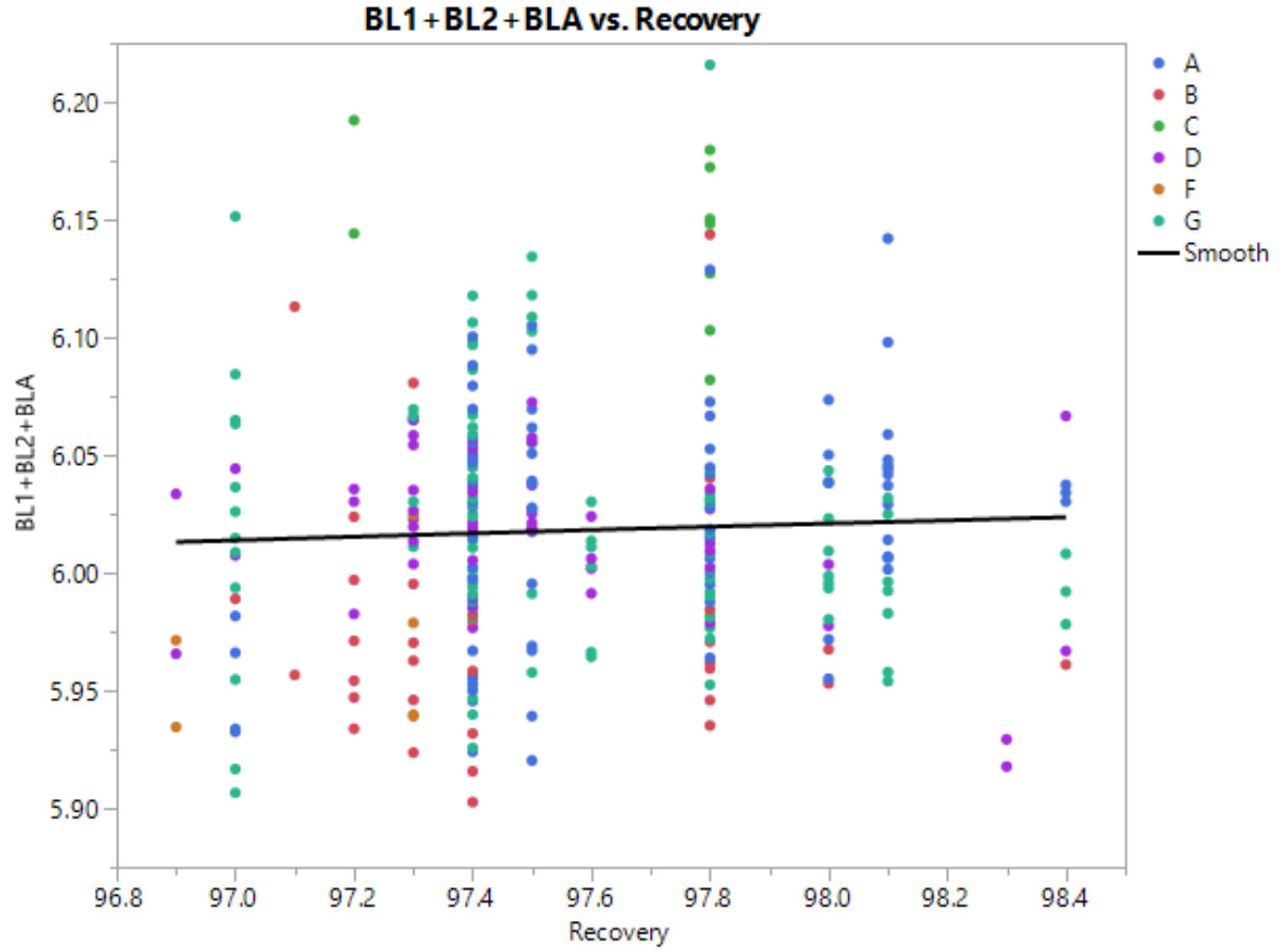

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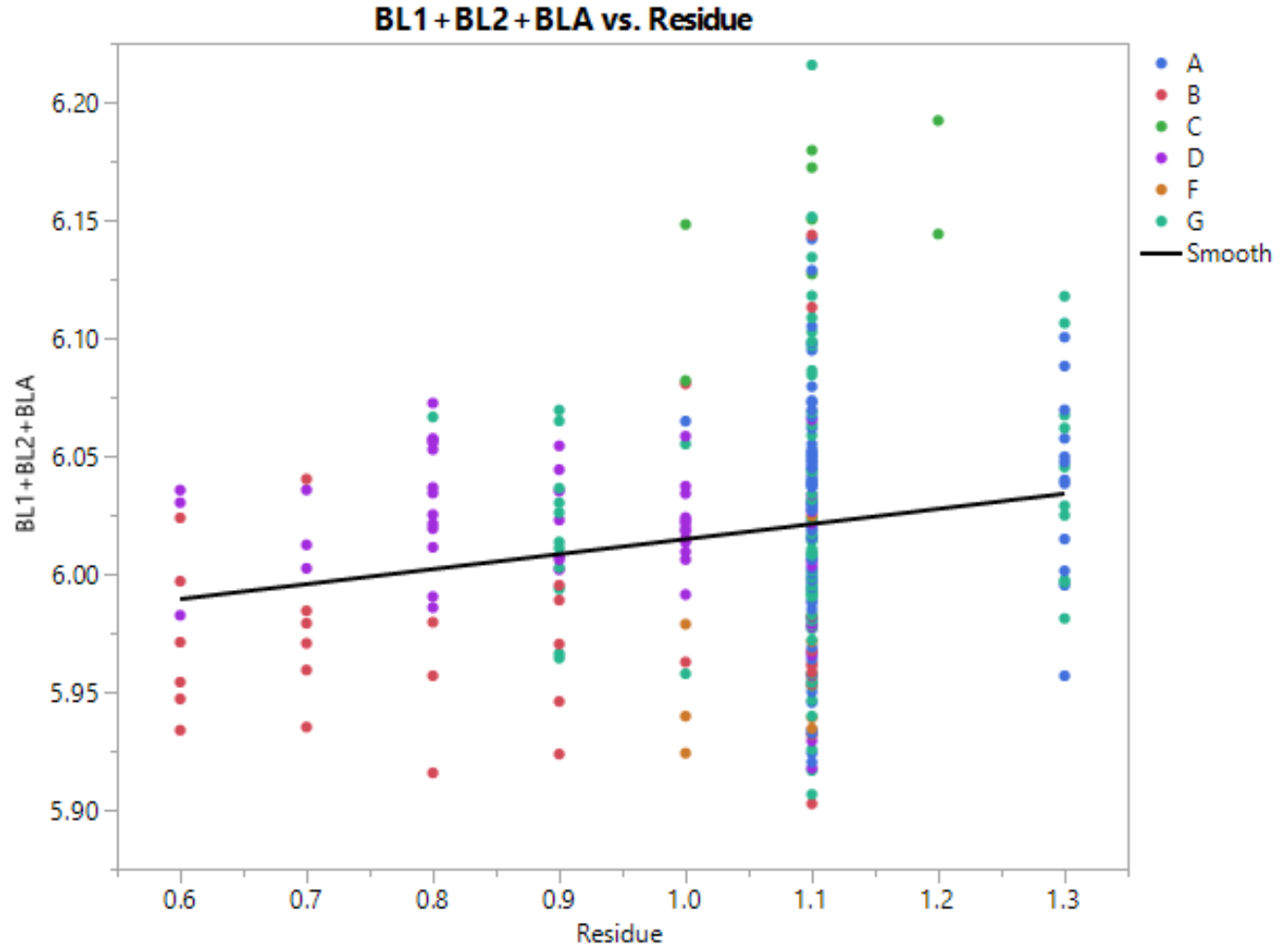

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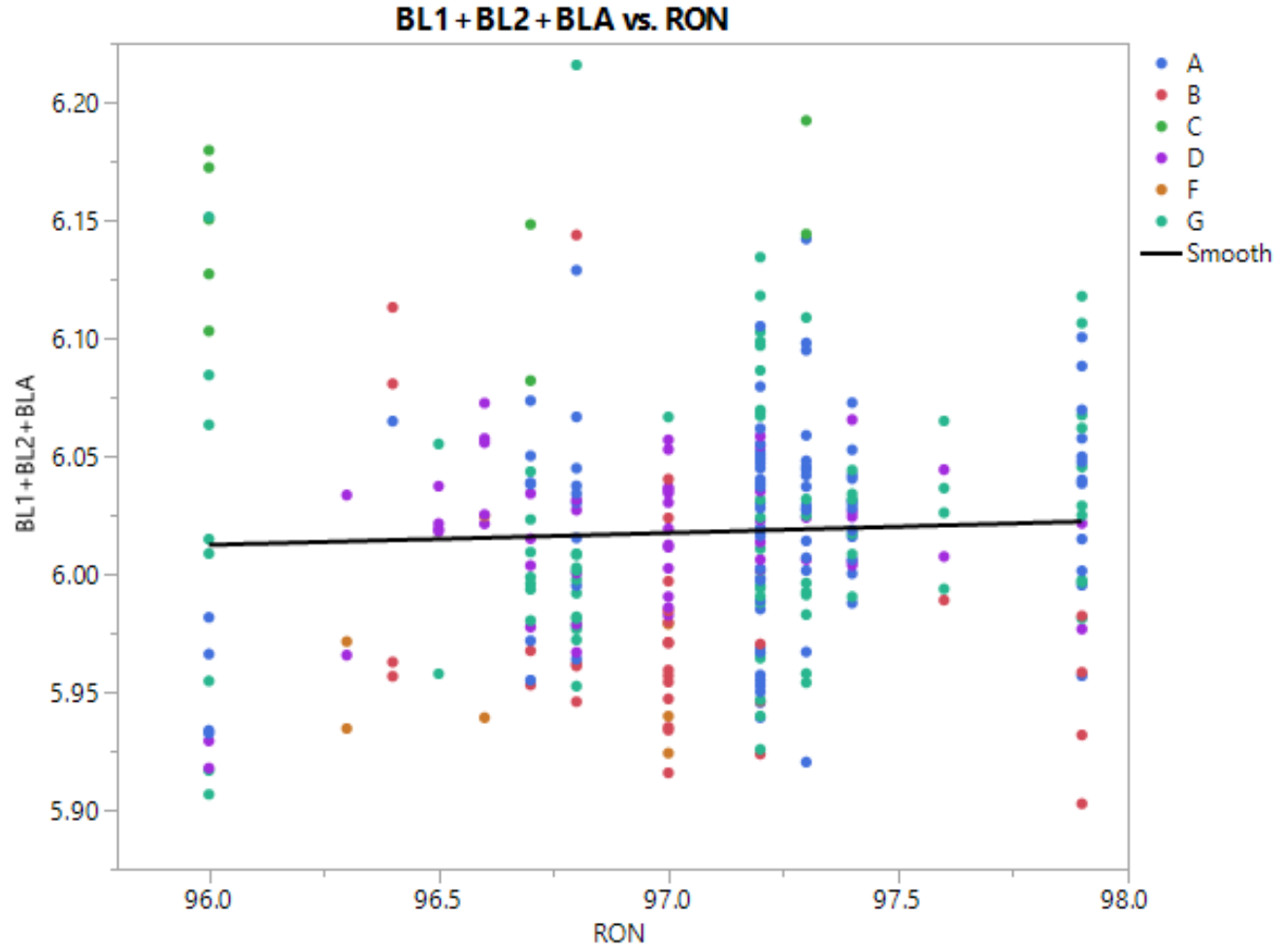

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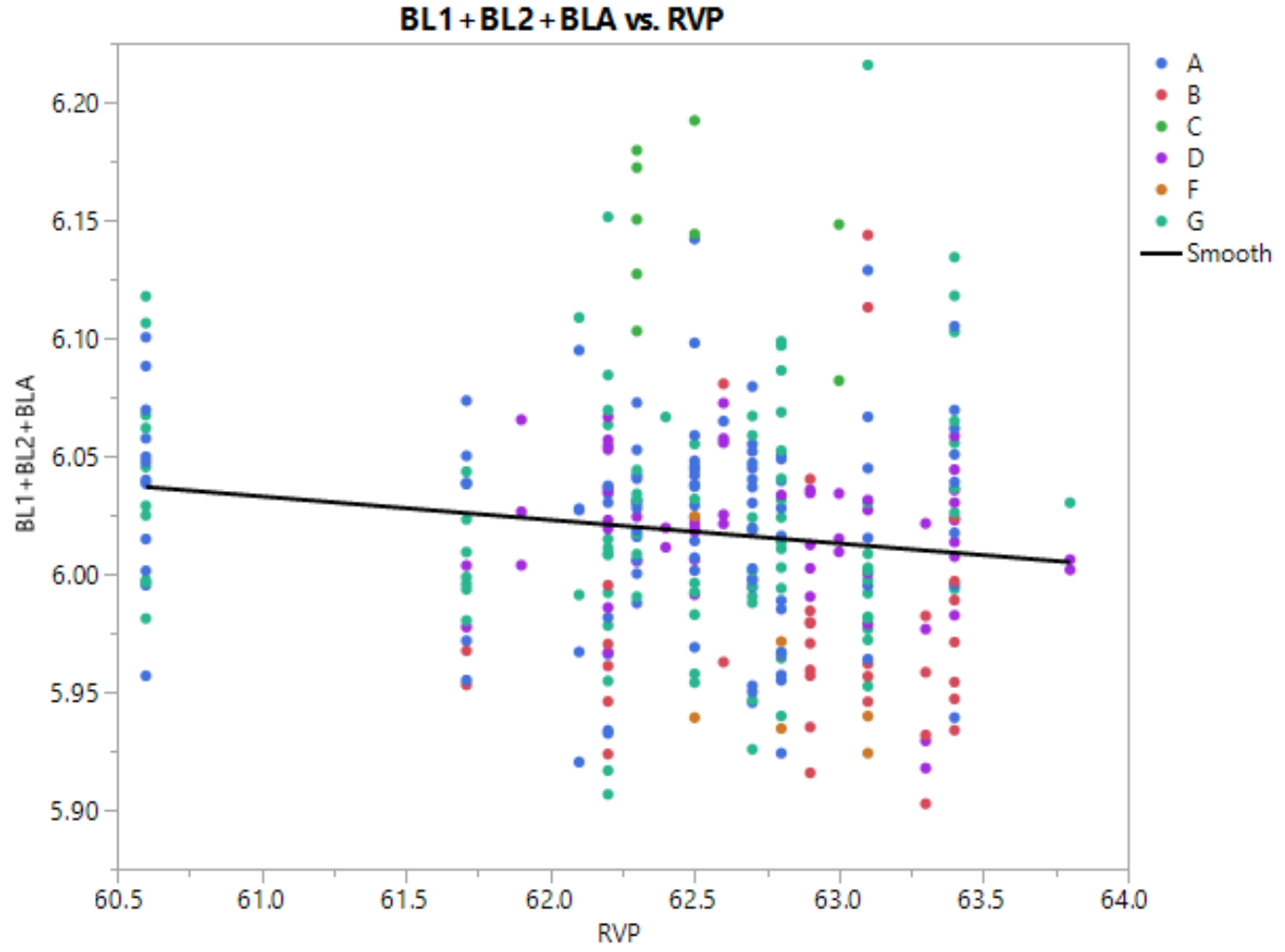

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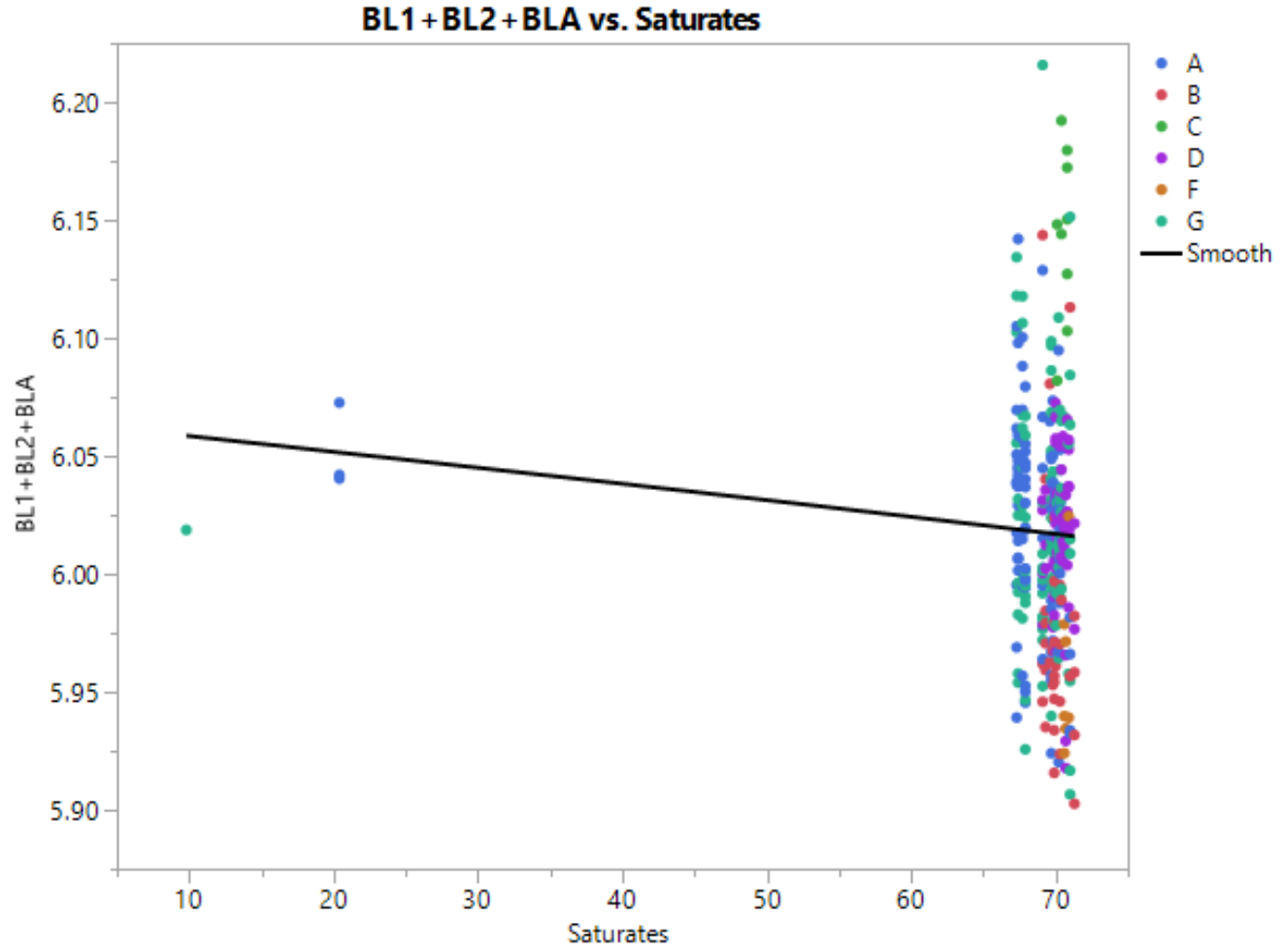
Afton CHEMICAL Passion for Solutions

Graph Builder



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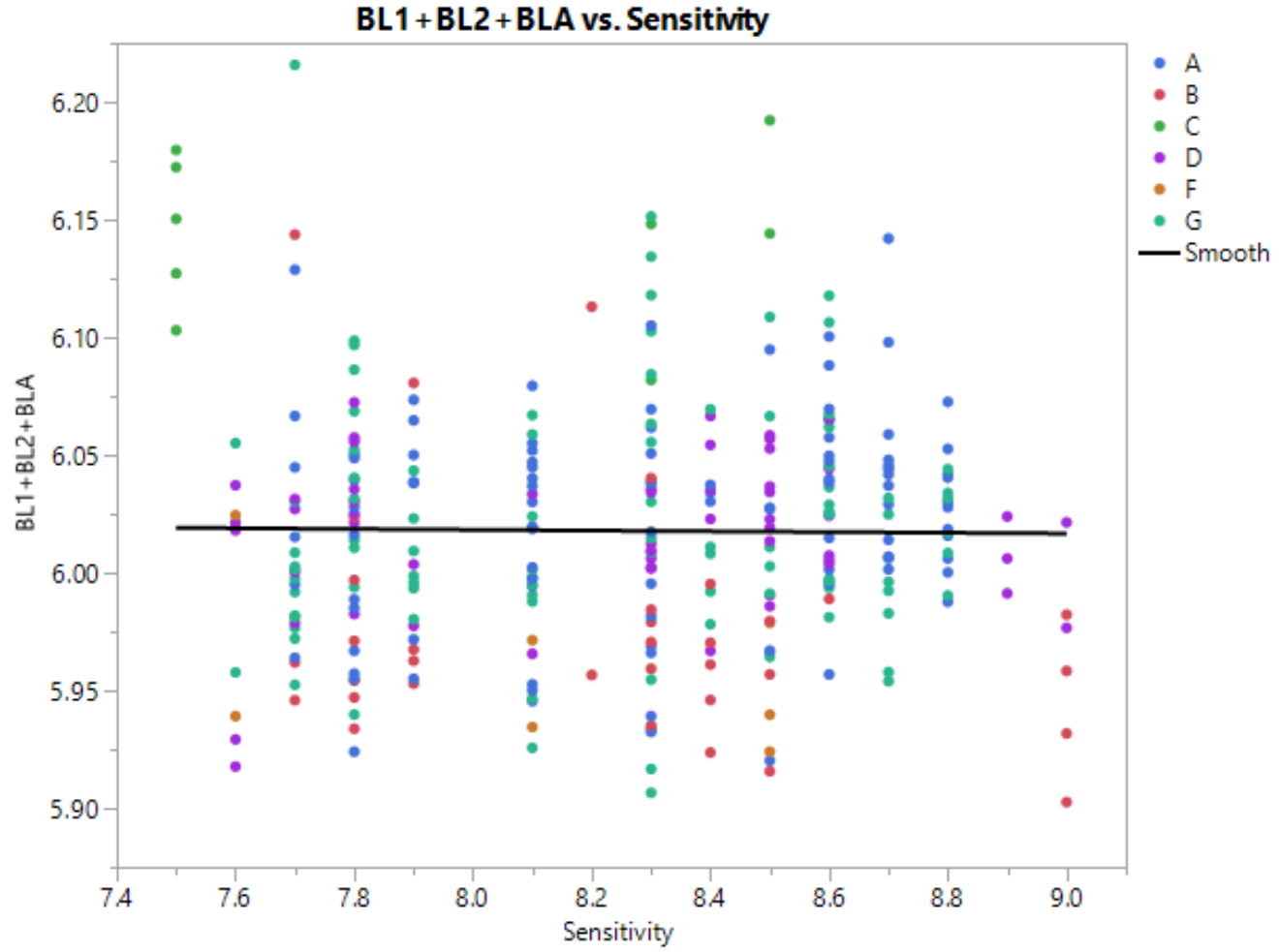

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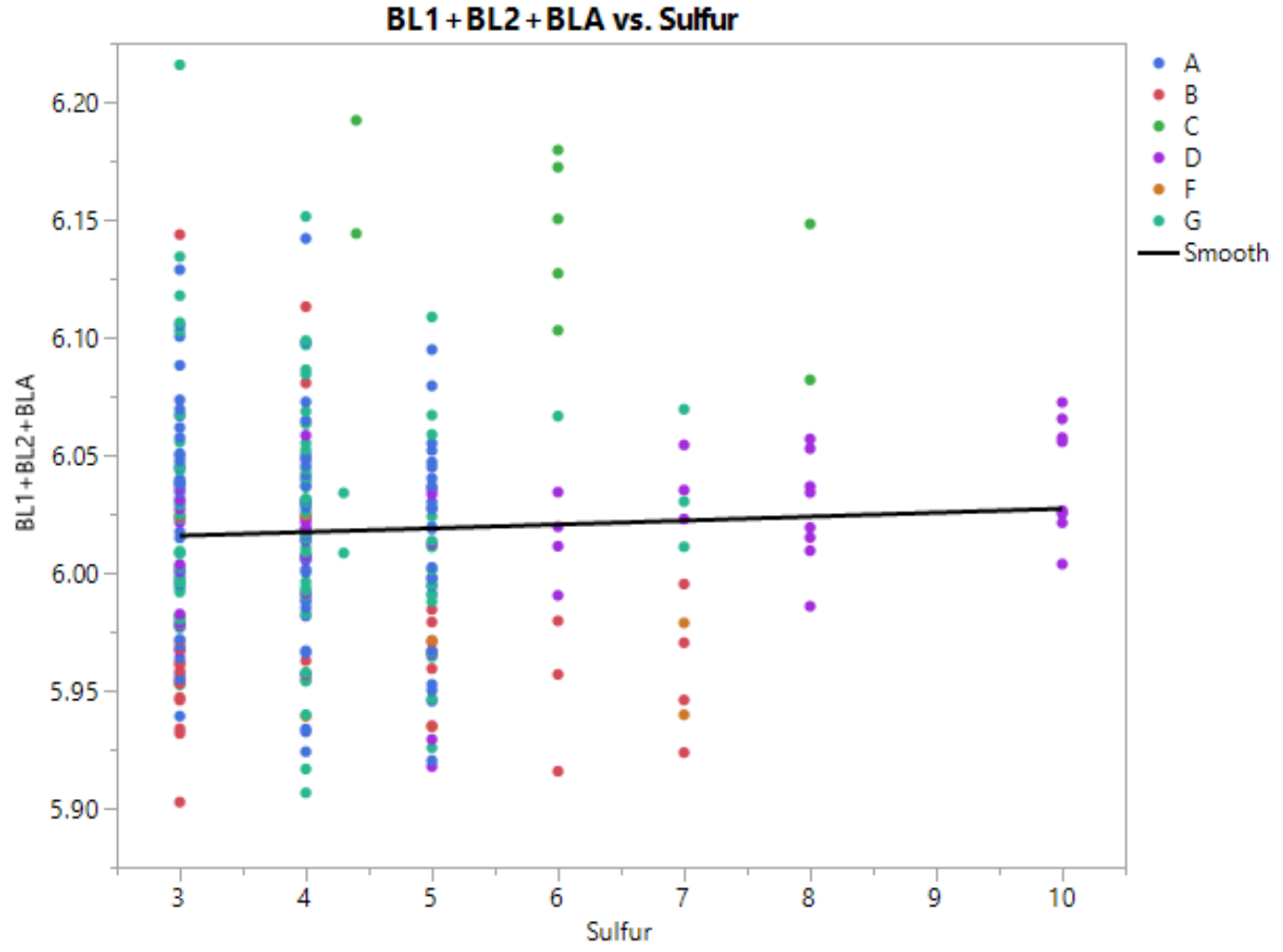

Where(1 rows excluded)

PRODUCT: **Sequence VI-E W/DCA**

PRODUCT CODE: **HF2003**

Batch No.: Lubrizol Ashland

TMO No.:

Tank No.:

Analysis Date:

Sample Date:

TEST	METHOD	UNITS	HALTERMANN Specs			RESULTS	RESULTS
			MIN	TARGET	MAX		
Distillation - IBP	ASTM D86	°C	23.9		35.0	29.5	30.4
5%		°C				44.5	43.9
10%		°C	48.9		57.2	50.9	51.1
20%		°C				60.7	60.9
30%		°C				72.2	72.9
40%		°C				87.6	88.7
50%		°C	93.3		110.0	102	103.1
60%		°C				109.8	110.4
70%		°C				115.9	116.6
80%		°C				126.3	126.3
90%		°C	151.7		162.8	157.7	157.1
95%		°C				169.8	170.9
Distillation - EP		°C			212.8	196.9	202.3
Recovery		vol %		Report		98.7	98.6
Residue		vol %		Report		1.1	0.7
Loss		vol %		Report		0.2	0.7
Gravity @ 60°F/60°F	ASTM D4052	°API	58.7		61.2	59.6	59.0
Density @ 15° C	ASTM D4052	kg/l	0.734		0.744	0.7402	0.7429
Reid Vapor Pressure	ASTM D5191	kPa	60.1		63.4	8.88	9.0300
Carbon	ASTM D3343	wt fraction		Report			
Carbon	ASTM D5291	wt fraction		Report			86.76
Hydrogen	ASTM D5291	wt fraction		Report			13.41
Hydrogen/Carbon ratio	ASTM D5291	mole/mole		Report			
Oxygen	ASTM D4815	wt %			0.05		<0.2
Sulfur	ASTM D5453	mg/kg	3		15		7.8
Lead	ASTM D3237	mg/l			2.6		<0.001
Phosphorous	ASTM D3231	mg/l			1.3		<0.05
Composition, aromatics	ASTM D1319	vol %	26.0		32.5		33.3
Composition, olefins	ASTM D1319	vol %			10.0		<1
Composition, saturates	ASTM D1319	vol %		Report			71.8
Particulate matter	ASTM D5452	mg/l			1		0.5
Oxidation Stability	ASTM D525	minutes	1000			1000+	1440
Copper Corrosion	ASTM D130				1	1a	1a
Gum content, washed	ASTM D381	mg/100mls			5.0	<0.5	<0.5
Gum content, unwashed			7		20.0	11.0	13.0
Fuel Economy Numerator/C Density	ASTM D5291		2401		2441		
C Factor	ASTM D5291			Report			
Research Octane Number	ASTM D2699		96.0				97.4
Motor Octane Number	ASTM D2700			Report			88.9
Sensitivity			7.5				
Net Heating Value, btu/lb	ASTM D3338	btu/lb		Report			
Net Heating Value, btu/lb	ASTM D240	btu/lb		Report			18590
Color	VISUAL	1.75 ptb		Red		L3.0	Red
Top Tier Additive		69.3 ptb		Report		Added at Top Tier Rate	Added at Top Tier Rate
Other							
Methanol (MeOH)		vol%					<0.2
Ethanol (EtOH)		vol%					<0.2
Isopropanol (iPA)		vol%					<0.2
tert-Butanol (tBA)		vol%					<0.2
n-Propanol (nPA)		vol%					<0.2
Methyl tert-butylether (MTBE)		vol%					<0.2
sec-Butanol (sBA)		vol%					<0.2
Diisopropylether (DIPE)		vol%					<0.2
Isobutanol (iBA)		vol%					<0.2
Ethyl tert-butylether (ETBE)		vol%					<0.2
tert-Pentanol (tPA)		vol%					<0.2
n-Butanol (nBA)		vol%					<0.2
tert-amyl methylether (TAME)		vol%					<0.2
Total Oxygen		WT%					<0.2
Aromatics by GCMS							
Benzene		Vol%					<0.1
Toluene		Vol%					21.9

Total Aromatics	Vol%	33.3
Ethylbenzene	Vol%	<0.1
m p-Xylene	Vol%	0.1
Oxylene	Vol%	0.4
Iso-propylbenzene	Vol%	<0.1
n-Propylbenzene	Vol%	0.6
1-Methyl-3-Ethylbenzene	Vol%	1.9
1-Methyl-4-Ethylbenzene	Vol%	0.9
1,3,5-Trimethylbenzene	Vol%	0.8
1-Methyl-2-Ethylbenzene	Vol%	0.9
1,2,4-Trimethylbenzene	Vol%	3.6
1,2,3-Trimethylbenzene	Vol%	0.7
Indan	Vol%	0.1
1,4 Diethylbenzene	Vol%	0.3
n -Butylbenzene	Vol%	<0.1
1,2-Diethylbenzene	Vol%	<0.1
1,2,4,5-Trimethylbenzene	Vol%	<0.1
1,2,3,5-Trimethylbenzene	Vol%	<0.1
Napthalene	Vol%	0.1
Pentamethylbenzene	Vol%	<0.1
2-Methyl-napthalene	Vol%	0.2
1-Methyl-napthalene	Vol%	0.1
C10-Benzenes	Vol%	0.6
C11-Benzenes	Vol%	<0.1
C12-Benzenes	Vol%	<0.1
Alkyl Indans	Vol%	<0.1
Composition, aromatics	**vol %**	
C6 aromatics (benzene)	**vol %**	
C7 aromatics (toluene)	**vol %**	
C8 aromatics	**vol %**	
C9 aromatics	**vol %**	
C10+ aromatics	**vol %**	0.6
Composition, olefins	**wt%**	<1

PRODUCT: **Sequence VI-E W/DCA**

PRODUCT CODE: **HF2003**

Batch No.: ExxonMobil SwRI

TMO No.: 180A

Tank No.:

Analysis Date:

Sample Date:

TEST	METHOD	UNITS	HALTERMANN Specs			RESULTS	RESULTS
			MIN	TARGET	MAX		
Distillation - IBP	ASTM D86	°C	23.9		35.0	32.2	32.1
5%		°C				43.9	45.8
10%		°C	48.9		57.2	50.6	52.2
20%		°C				60.6	62.0
30%		°C				71.7	73.7
40%		°C				87.2	88.9
50%		°C	93.3		110.0	102.2	103.3
60%		°C				110.6	110.9
70%		°C				116.7	117.1
80%		°C				126.7	127.2
90%		°C	151.7		162.8	156.1	158.2
95%		°C				169.4	169.9
Distillation - EP		°C			212.8	196.1	196.8
Recovery		vol %		Report		98.3	98.5
Residue		vol %		Report		0.6	0.7
Loss		vol %		Report		1.1	0.8
Gravity @ 60°F/60°F	ASTM D4052	°API	58.7		61.2	59.4	59.2
Density @ 15° C	ASTM D4052	kg/l	0.734		0.744	0.7408	0.742
Reid Vapor Pressure	ASTM D5191	kPa	60.1		63.4	56.52	63.4
Carbon	ASTM D3343	wt fraction		Report		Not Avail	0.8647
Carbon	ASTM D5291	wt fraction		Report		86.90	0.8598
Hydrogen	ASTM D5291	wt fraction		Report		13.58	0.1314
Hydrogen/Carbon ratio	ASTM D5291	mole/mole		Report		1.862	1.822
Oxygen	ASTM D4815	wt %			0.05	<0.01	<0.01
Sulfur	ASTM D5453	mg/kg	3		15	4	2.32
Lead	ASTM D3237	mg/l			2.6	<1	<0.001
Phosphorous	ASTM D3231	mg/l			1.3	<0.05	<0.05
Composition, aromatics	ASTM D1319	vol %	26.0		32.5	27.4	
Composition, olefins	ASTM D1319	vol %			10.0	0.9	
Composition, saturates	ASTM D1319	vol %		Report		71.8	
Particulate matter	ASTM D5452	mg/l			1	0.5	
Oxidation Stability	ASTM D525	minutes	1000			1000+	
Copper Corrosion	ASTM D130				1	1a	1
Gum content, washed	ASTM D381	mg/100mls			5.0	<0.5	<0.5
Gum content, unwashed			7		20.0	10.0	12.0
Fuel Economy Numerator/C Density	ASTM D5291		2401		2441		
C Factor	ASTM D5291			Report		0.9991	0.9991
Research Octane Number	ASTM D2699		96.0			96.4	96.9
Motor Octane Number	ASTM D2700			Report		88.4	88.0
Sensitivity			7.5			8.0	
Net Heating Value, btu/lb	ASTM D3338	btu/lb		Report		18488	
Net Heating Value, btu/lb	ASTM D240	btu/lb		Report		18590	0.7422
Color	VISUAL	1.75 ptb		Red		Red	Red
Top Tier Additive		69.3 ptb		Report		Added at Top Tier Rate	Added at Top Tier Rate
Other							
Methanol (MeOH)		vol%				<0.2	<0.2
Ethanol (EtOH)		vol%				<0.2	<0.2
Isopropanol (iPA)		vol%				<0.2	
tert-Butanol (tBA)		vol%				<0.2	
n-Propanol (nPA)		vol%				<0.2	
Methyl tert-butylether (MTBE)		vol%				<0.2	<0.2
sec-Butanol (sBA)		vol%				<0.2	
Diisopropylether (DIPE)		vol%				<0.2	
Isobutanol (iBA)		vol%				<0.2	
Ethyl tert-butylether (ETBE)		vol%				<0.2	<0.2
tert-Pentanol (tPA)		vol%				<0.2	
n-Butanol (nBA)		vol%				<0.2	
tert-amyl methylether (TAME)		vol%				<0.2	
Total Oxygen		WT%				<0.2	
Aromatics by GCMS							
Benzene		Vol%				<0.1	
Toluene		Vol%				21.9	

Total Aromatics	Vol%		33.3	
Ethylbenzene	Vol%		<0.1	
m p-Xylene	Vol%		0.1	
Oxylene	Vol%		0.4	
Iso-propylbenzene	Vol%		<0.1	
n-Propylbenzene	Vol%		0.6	
1-Methyl-3-Ethylbenzene	Vol%		1.9	
1-Methyl-4-Ethylbenzene	Vol%		0.9	
1,3,5-Trimethylbenzene	Vol%		0.8	
1-Methyl-2-Ethylbenzene	Vol%		0.9	
1,2,4-Trimethylbenzene	Vol%		3.6	
1,2,3-Trimethylbenzene	Vol%		0.7	
Indan	Vol%		0.1	
1,4 Diethylbenzene	Vol%		0.3	
n -Butylbenzene	Vol%		<0.1	
1,2-Diethylbenzene	Vol%		<0.1	
1,2,4,5-Trimethylbenzene	Vol%		<0.1	
1,2,3,5-Trimethylbenzene	Vol%		<0.1	
Napthalene	Vol%		0.1	
Pentamethylbenzene	Vol%		<0.1	
2-Methyl-napthalene	Vol%		0.2	
1-Methyl-napthalene	Vol%		0.1	
C10-Benzenes	Vol%		0.6	
C11-Benzenes	Vol%		<0.1	
C12-Benzenes	Vol%		<0.1	
Alkyl Indans	Vol%		<0.1	
Composition, aromatics	**vol %**			
C6 aromatics (benzene)	**vol %**		0.06	0.02
C7 aromatics (toluene)	**vol %**		18.46	18.6
C8 aromatics	**vol %**		1.27	
C9 aromatics	**vol %**		8.66	
C10+ aromatics	**vol %**		2.01	1.2
Composition, olefins	**wt%**		0.05	

Seq. VI Lube Certification Fuel

TEST	METHOD	UNITS	Seq. VI Specs		
			MIN	TARGET	MAX
Distillation - IBP	ASTM D86	°C	23.9		35.0
5%		°C			
10%		°C	48.9		57.2
20%		°C			
30%		°C			
40%		°C			
50%		°C	93.3		110.0
60%		°C			
70%		°C			
80%		°C			
90%		°C	151.7		162.8
95%		°C			
Distillation - EP		°C			212.8
Recovery		vol %		Report	
Residue		vol %		Report	
Loss		vol %		Report	
Gravity @ 60°F/60°F	ASTM D4052	°API	58.7		**61.2**
Density @ 15° C	ASTM D4052	kg/l	0.734		0.744
Reid Vapor Pressure	ASTM D5191	kPa	60.1		63.4
Carbon	ASTM D3343	wt fraction		Report	
Carbon	ASTM D5291	wt fraction		Report	
Hydrogen	ASTM D5291	wt fraction		Report	
Hydrogen/Carbon ratio	ASTM D5291	mole/mole		Report	
Oxygen*	ASTM D4815	wt %			0.05
Oxygenates Ethanol	ASTM D4815	%		Report	
MTBE		%		Report	
ETBE		%		Report	
Methanol		%		Report	
Sulfur	ASTM D5453	mg/kg	3		15
Benzene	ASTM D3606	vol %			1.00
Composition, aromatics	**ASTM D5769**	**vol %**	**(32.5) 26**		**(34.5) 32.5**
C6 aromatics (benzene)	**ASTM D5769**	**vol %**			**1.00**
C7 aromatics (toluene)	**ASTM D5769**	**vol %**		**Report**	
C8 aromatics	**ASTM D5769**	**vol %**		**Report**	
C9 aromatics	**ASTM D5769**	**vol %**		**Report**	
C10+ aromatics	**ASTM D5769**	**vol %**		**Report**	
Composition, olefins	**ASTM D6550**	**wt%**			**2.0**
Lead*	ASTM D3237	mg/l			2.6
Manganese*	ASTM D3831	g/gal			0.01
Phosphorus*	ASTM D3231	mg/l			1.3
Silicon *	ASTM D5185	mg/kg			4
Particulate matter	ASTM D5452	mg/l			1

Oxidation Stability	ASTM D525	minutes	1000		
Copper Corrosion	ASTM D130				1
Gum content, washed	ASTM D381	mg/100mls			5.0
Gum content, unwashed	ASTM D381	mg/100mls	7.0		20.0
Research Octane Number	ASTM D2699		96.0		
Motor Octane Number	ASTM D2700			Report	
R+M/2	D2699/2700			Report	
Sensitivity			7.5		
Net Heating Value, btu/lb	ASTM D3338	btu/lb		Report	
Gross Heating Value, btu/lb	ASTM D240	btu/lb		Report	
Net Heating Value, btu/lb	ASTM D240	btu/lb		Report	
Water and Sediment	ASTM D2709	vol%			0.01
Color **	VISUAL	1.75 ptb		Red	
Top Tier Additive***		69.3 ptb		Report	

BLANK VALUES WERE NOT REPORTED

**IAR Method for Distillation D2887

** IAR used ICP

*** Reported Dry Vapor

**** Sulfur by UV D5453

Haltermann	(outsourced) Afton	Intertek	Lubrizol	Swri	(outsourced) ExxonMobil
29.9	30.1	148.3*	29.5	31	32.2
43.5	43.3	155.2	44.5	44	43.9
50.3	50.1	158.4	50.9	51	50.6
60.4	60.4	161.1	60.7	61	60.6
72.1	72.0	163.8	72.2	72	71.7
87.7	87.5	167	87.6	88	87.2
102.7	101.9	169.8	102	102	102.2
110.8	110.1	175.1	109.8	111	110.6
116.9	116.1	180.4	115.9	117	116.7
127.1	126.4	186.7	126.3	126	126.7
157.3	155.4	219.5	157.7	157	156.1
171.1	170.2	246.3	169.8	170	169.4
198.2	196.8	365.7	196.9	195	196.1
97.9	97.9		98.7	98.5	98.3
1.1	1.1		1.1	0.7	0.6
1.0	1.0		0.2	0.8	1.1
59.5	59.6	59.0900	59.6	59.5	59.4
0.740	0.7404	0.74213	0.7402	0.7406	0.7408
60.7	61.8	62.40	8.88***		56.52***
					Not Avail
	86.6			86.72	86.90
	13.2			13.59	13.58
	1.815			1.868	1.862
<0.01	<0.02	<0.20			<0.2
	<0.1	<0.20		<0.2	< 0.2
	<0.1	<0.20		<0.2	< 0.2
	<0.1	<0.20		<0.2	<0.2
	<0.1	<0.20		<0.2	< 0.2
3	2.3	2.9		2.47****	2.3
32.2	31.6				31.16
0.1	0.0			0.02	0.05
19.4	19.4			18.1	18.82
1.5					1.3
9.1					8.93
2.2				1.2	2.06
0.5	<1.0			<0.001	0.04
	<0.1 g/USG	<0.0001**		<0.2	< 0.264
	<0.0009	<0.0001**		<0.2	< 0.00076
	<0.211	<0.0001**			<0.2
	<0.20	<0.0001**			Not Avail
	0.2				0.8

	960+	>1000			1440
1A	1A	1A	1a	1	1a
	<0.5	0	<0.5	<0.5	<0.5
	12.0	12.6	11	11	11
	96.6	97.0000		96.7	96.7
	88.5	88.7000		88.2	88
	92.6	92.85		92.4	92.35
				59.5	18359
	19740.0	19761		0.7408	19858
18565	18537.0	18965		0.7406	18639
	<0.01				<0.005
		CLEAR	L3.0	clear no color	Clear

Office of Automotive Engineering
PPRD Test Summary Report
FUELSLIMS WO-83469
Print Date: 8/14/2020

		Sample Code	Tank 180A	Tank 180B	Tank 62
		Description	HF-02003 Seq VI E w/DCA	HF-02003 Seq VI E w/DCA	HF2003
			SwRI	SwRI	Haltermann
TEST	**METHOD**	**UNITS**	**Results**	**Results**	**Results**
Distillation	ASTM D86				
IBP		°C	32	26	31
5%		°C	46	46	44
10%		°C	52	52	51
15%		°C	57	57	56
20%		°C	62	62	61
30%		°C	74	74	72
40%		°C	89	89	88
50%		°C	103	104	102
60%		°C	111	111	111
70%		°C	117	117	117
80%		°C	127	127	126
90%		°C	158	158	157
95%		°C	170	171	170
FBP		°C	197	196	195
Recovered		vol %	98.5	98.3	98.5
Residue		vol %	0.7	0.9	0.7
Loss		vol %	0.8	0.8	0.8
Gravity @ 60°F/60°F	ASTM D4052	°API	59.2	59.1	59.5
Density @ 15°C	ASTM D4052	kg/l	0.7419	0.7421	0.7406
Dry Vapor Pressure Equivalent	ASTM D5191		61.0	60.3	63.0
Carbon	ASTM D3343	wt%	pending	pending	pending
Carbon	ASTM D5291	mass %	86.38	86.76	86.72
Hydrogen	ASTM D5291	mass %	13.26	13.35	13.59
Hydrogen/Carbon ratio	ASTM D5291	mole/mole	6.5	6.5	6.4
Oxygen	ASTM D4815	wt%	<0.2	<0.2	<0.2
Oxygenates Ethanol	ASTM D4815	vol%	<0.2	<0.2	<0.2
MTBE		vol%	<0.2	<0.2	<0.2
ETBE		vol%	<0.2	<0.2	<0.2
Methanol		vol%	<0.2	<0.2	<0.2
Sulfur by UV	ASTM D5453	ppm	2.32	2.49	2.47

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		Sample Code	Tank 180A	Tank 180B	Tank 62
		Description	HF-02003 Seq VI E w/DCA	HF-02003 Seq VI E w/DCA	HF2003
			SwRI	SwRI	Haltermann
TEST	**METHOD**	**UNITS**	**Results**	**Results**	**Results**
Composition, aromatics	ASTM D5769	vol %	31.23	30.88	30.51
C6 aromatics (benzene)	ASTM D5769	Vol%	0.02	0.02	0.02
C7 aromatics (toluene)	ASTM D5769	Vol%	18.6	18.4	18.1
C8 aromatics	ASTM D5769	Vol%	1.4	1.4	1.4
C9 aromatics	ASTM D5769	Vol%	9.1	8.9	8.9
C10+ aromatics	ASTM D5769	Vol%	2.1	2.2	2.1
Lead	ASTM D3237	mg/l	<0.001	<0.001	<0.001
Manganese	ASTM D3831	g/gal	<0.2	<0.2	<0.2
Phosphorus	ASTM D3231	mg/L	<0.2	<0.2	<0.2
Silicon	ICP Method		**not available**	**not available**	**not available**
Particulate Contamination	ASTM D5452	mg/l	1.1	3.1	1
Oxidation Stability	ASTM D525	minutes	1440	1440	1440
Copper Corrosion (3hrs, 50°C)	ASTM D130		1	1	1
Unwashed Wt	ASTM D381	mg/100mls	12.0	12.5	11.0
Washed Wt	ASTM D381	mg/100mls	<0.5	0.5	<0.5
Research Octane Number (RON)	ASTM D2699	--	96.9	96.6	96.7
Motor Octane Number (MON)	ASTM D2700	--	88.0	87.5	88.2
Antiknock Index (R+M/2)	D2699/2700	*calculated*	92.4	92.0	92.4
Sensitivity			8.9	9.1	8.5
Net Heating Value, btu/lb	ASTM D3338	btu/lb	59.2	59.1	59.5
Gross Heating Value, btu/lb	ASTM D240	btu/lb	0.7422	0.7423	0.7408
Net Heating Value, btu/lb	ASTM D240	btu/lb	0.7419	0.7421	0.7406
Water & Sediment by Centrifuge	ASTM D2709	vol %	< 0.005	< 0.005	< 0.005
Observation	VISUAL	--	light red	light red	clear no color
ppm m/m	Top Tier Additive				