Sequence IV Surveillance Panel | MINUTES

REVISION DATE: 10/19/2017 9:50:00 AM

Relevant Test:	Sequence IVA and IVB
Note Taker:	Chris Mileti
Meeting Date:	10-12-2017
Comments:	This was a conference call meeting.

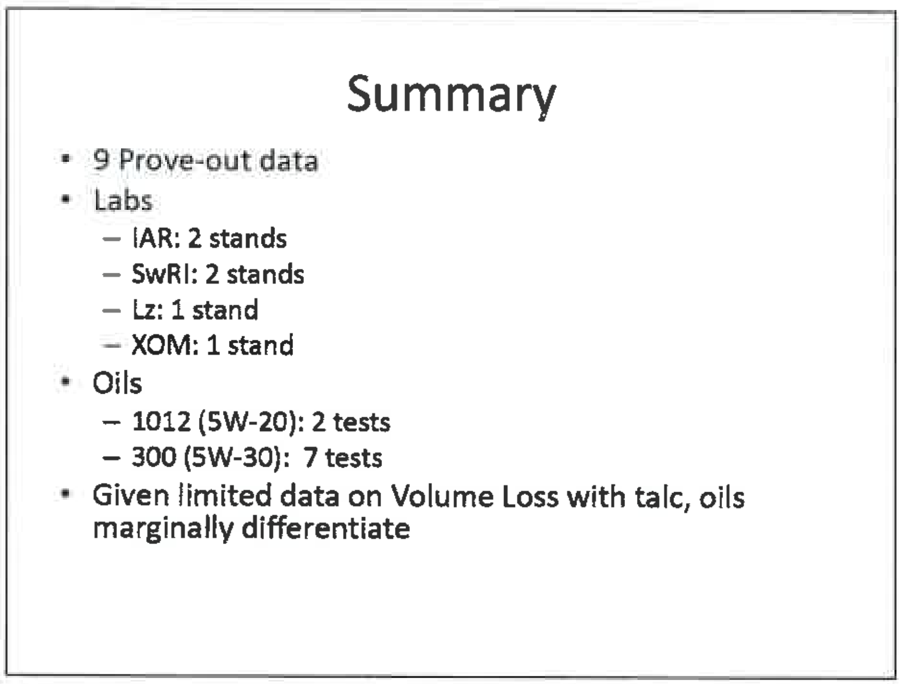
1. SEQUENCE IVB PROVE-OUT DATA ANALYSIS:

1.1. Background:

1.1.1. ***File name:*** *Sequence IVB Prove-Out Data Analysis 101117.pdf*

1.1.2. This document was compiled by the Statistics Group and presented by J. Martinez.

1.2. Slide #3:

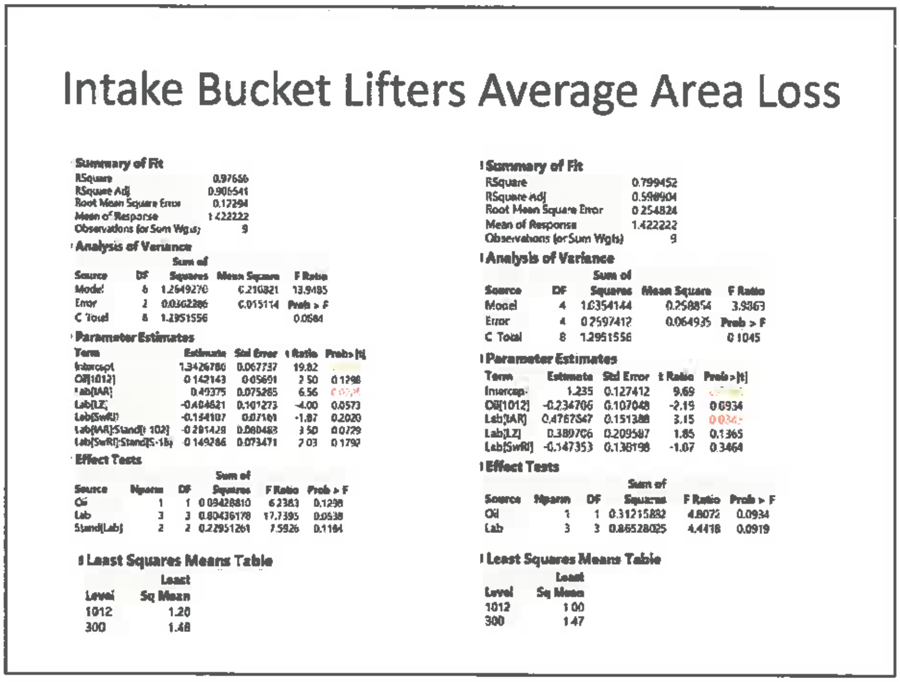


1.2.1. This analysis was done relatively quickly, so the Statistics Group has not had time to discuss this presentation at length.

1.2.2. The analysis contains data from (9) prove-out tests.

1.2.3. The p-value for oil discrimination is marginal.

1.3. Slide #5:



Intake Bucket Lifters Average Area Loss

Summary of Fit

RSquare	0.97656
RSquare Adj	0.906541
Root Mean Square Error	0.12294
Mean of Response	1.422222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	1.2649270	0.210821	13.9485
Error	2	0.0302286	0.015114	Prob > F
C Total	8	1.2951556		0.0684

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.3426786	0.067737	19.82	[illegible]
Oil[1012]	0.142143	0.05691	2.50	0.1298
Lab[IAR]	0.49375	0.075285	6.56	[illegible]
Lab[LZ]	-0.404821	0.101273	-4.00	0.0573
Lab[SwRI]	-0.134107	0.07161	-1.87	0.2020
Lab[IAR]:Stand[I-102]	-0.281428	0.080483	3.50	0.0729
Lab[SwRI]:Stand[S-18]	0.149286	0.073471	2.03	0.1792

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Oil	1	1	0.09428810	6.2383	0.1298
Lab	3	3	0.80436178	17.7395	0.0538
Stand[Lab]	2	2	0.22951261	7.5926	0.1164

Least Squares Means Table

Level	Least Sq Mean
1012	1.20
300	1.48

Summary of Fit

RSquare	0.799452
RSquare Adj	0.598904
Root Mean Square Error	0.254824
Mean of Response	1.422222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	1.0354144	0.258854	3.9863
Error	4	0.2597412	0.064935	Prob > F
C Total	8	1.2951556		0.1045

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.235	0.127412	9.69	[illegible]
Oil[1012]	-0.234706	0.107048	-2.19	0.0934
Lab[IAR]	0.4767547	0.151388	3.15	[illegible]
Lab[LZ]	0.389706	0.209587	1.86	0.1365
Lab[SwRI]	-0.147353	0.138198	-1.07	0.3464

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Oil	1	1	0.31215882	4.8072	0.0934
Lab	3	3	0.86528025	4.4418	0.0919

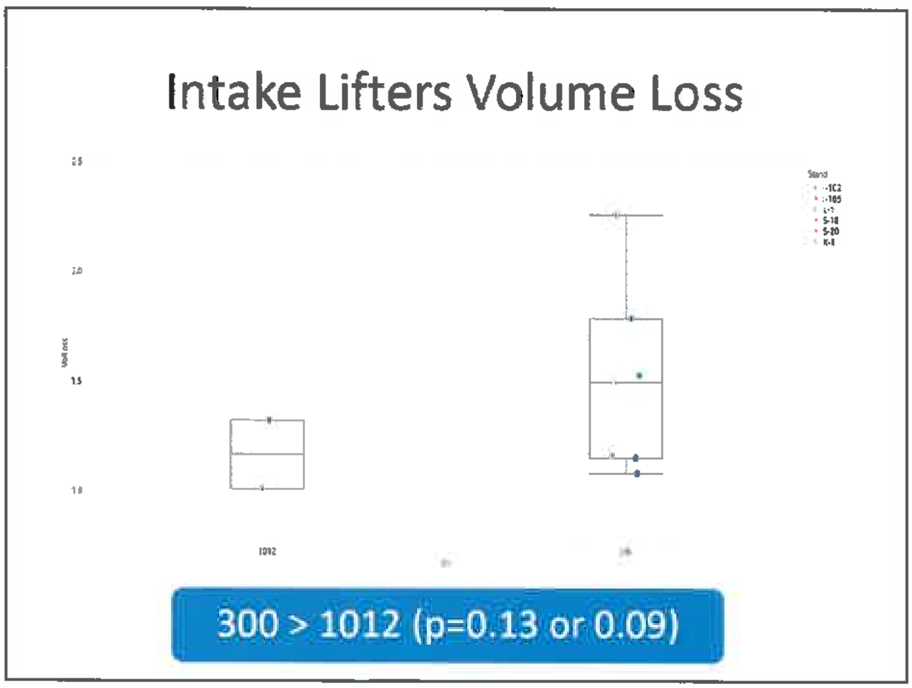
Least Squares Means Table

Level	Least Sq Mean
1012	1.00
300	1.47

1.3.1. The title from this slide should be changed from "Area Loss" to "Volume Loss".
1.3.2. The lab difference is more significant than the oil difference.
1.3.3. The statisticians ranked the significance of key differences as follows:
- 1.3.3.1. Lab Difference (most significant)
- 1.3.3.2. Stand Difference
- 1.3.3.3. Oil Difference (lease significant)

1.3.4. The left and right columns on this slide used different models with different degrees of freedom.

1.4. Slide #7:



1.4.1. Intertek's Comments:
- 1.4.1.1. It appears that precision with REO300 has degraded.
- 1.4.1.2. The reason for this degradation is unclear.

1.4.1.3. Three of the prove-out matrix stands (one stand from Intertek, Southwest and Exxon) operated in a similar manner.

1.4.1.4. One of the prove-out matrix stands (Intertek) is more severe than the others.

1.4.1.5. Two of the prove-out matrix stands (Southwest and Lubrizol) are milder than the others.

1.4.2. Toyota's Comments:

1.4.2.1. Toyota has been working with Intertek and Southwest to develop a procedure and standardize test performance.

1.4.2.2. They expect REO300 to deliver an average intake lifter volume loss of 1.5-2.0mm^3.

1.4.2.3. They would like to stick with the two independent laboratories to set targets during the Precision Matrix.

1.4.3. Afton's Comments:

1.4.3.1. The statistical data shows lab differences.

1.5. Lifter Crown:

1.5.1. Intertek and Toyota have discussed the issues regarding lifter crown.

1.5.2. There is some concern that relaxing the lifter crown tolerances was a mistake.

2. OPERATIONAL DATA REVIEW:

2.1. Background:

2.1.1. Kevin O'Malley led the operational data review.

2.1.2. There was no presentation to accompany this review (the data was displayed using his statistical software).

2.2. Air-to-Fuel Ratio:

2.2.1. The AFR measurements between Intertek and Lubrizol look similar.

2.2.2. The AFR measurements between Southwest and Exxon look similar.

2.2.3. Lubrizol cautioned that the AFR measurements can be extremely misleading.

2.2.3.1. The data acquisition system at each lab may react differently to the AFR measurement as the sensor saturates.

2.2.4. Exxon noted that the peak AFR will be heavily influenced by the speed ramps.

2.2.4.1. Exxon and Southwest have less variability in their AFR measurements than the other two labs.

2.2.5. Intertek noted that the differences in fuel dilution at each lab do not correlate to the AFR measurements.

2.3. Humidity:

2.3.1. Southwest may have had a problem with their humidity system during the time that the data was captured.

2.4. Blowby Flow Rate and Crankcase Pressure:

2.4.1. The blowby check valve on Exxon's stand malfunctioned during this test.

2.4.1.1. The check valve has since been replaced.

2.4.2. The blowby flow rates are similar at both Intertek and Southwest.

2.4.3. The blowby flow rate at Lubrizol is generally lower than at the other laboratories.

2.4.3.1. The Lubrizol lab also tends to have a lower crankcase pressure (especially in Stage 1).

2.4.4. Intertek Stand #102 has a lot of noise in its crankcase pressure measurement.

2.5. BMEP:

2.5.1. There is an offset between the calculated BMEP parameter at Lubrizol and that of the other labs.

2.6. Engine Coolant Temperature Differential:

2.6.1. The temperature differential is very similar between the four laboratories.

2.7. Engine Coolant Temperature (Inlet):

2.7.1. There is a lot of variability in this measurement between the various Southwest tests.

2.7.1.1. Southwest noted that they have not changed their PID coefficients since the control point was changed from the inlet to the outlet of the engine.

2.7.2. In general, the coolant inlet temperatures at Southwest and Lubrizol are warmer than at the other two laboratories.

2.7.3. Intertek noted that coolant temperature differences have played a role in unexplained severity shifts with the Sequence IVA test.

2.8. Engine Coolant Temperature (Outlet):

2.8.1. Lubrizol is more like Intertek in terms of the outlet temperature.

2.9. Engine Coolant Flow:

2.9.1. Exxon has encountered a lot of noise issues with this parameter.

2.9.2. Intertek suggested that power supply changes to the Golden Stand could improve control at all the labs.

2.10. Exhaust Backpressure:

2.10.1. Lubrizol continues to struggle with this parameter (especially when there are drastic weather changes).

2.10.2. The backpressure measurements at Intertek and Southwest are more similar than they have been in the past.

2.10.3. The Southwest stands have different exhaust backpressure measurements under Stage 1 conditions.

2.10.3.1. These differences cannot currently be explained.

2.10.3.2. The Stage 1 backpressure on these stands does not match the barometric pressure.

2.11. Exhaust Gas Temperature:

2.11.1. Lubrizol feels that the differences in exhaust gas temperature from lab-to-lab and stand-to-stand are significant.

2.11.1.1. Differences in exhaust gas temperature can be an indication of different cylinder head temperatures.

2.11.2. Intertek noted a significant difference in the exhaust gas temperature between Stand 102 and Stand 165.

2.11.3. Intertek's Comments on the Exhaust Blower:

2.11.3.1. Could the blower be playing a role in these temperature differences?

2.11.3.2. The blower was used as a safety device on the Sequence IVA stand.

2.11.3.3. Nissan was worried that excessive exhaust pipe temperatures could damage the oxygen sensor.

2.11.4. Afton's Comments:

2.11.4.1. It is unlikely that a blower can cause 50°C temperature differences in the exhaust gas.

2.12. Engine Speed:

2.12.1. Lubrizol's Comments:

2.12.1.1. Lubrizol finally fixed the 0.5-1.0 second lag in its speed ramps.

2.12.1.2. The throttle control was upgraded to a 100Hz cRio controller.

2.12.1.3. Lubrizol can now achieve QI values of around 0.6-0.8.

2.13. Intake Manifold Pressure:

2.13.1. There are big differences in the intake manifold pressure between the four laboratories.

2.13.2. Lubrizol feels that these big differences in manifold pressure cannot be explained by the subtle differences in engine speed.

2.13.2.1. The lab-to-lab differences in this parameter also do not match the severity differences seen in the test results.

2.14. Fuel Temperature and Pressure:

2.14.1. There were no significant differences between the labs or stands in terms of fuel temperature and pressure.

2.15. Intake Air Pressure:

2.15.1. Intertek struggles with this parameter.

2.15.1.1. They have had to resort to aggressive tuning.

2.15.2. All labs use very different control strategies for intake air pressure.

2.15.3. The increase in the intake air pressure set point has significantly reduced the frequency of labs experiencing a vacuum in their air cleaner box.

2.15.4. Exxon needs to change their intake air pressure set-point to 0.25kPa.

2.16. Oil Gallery Pressure:

2.16.1. The oil gallery pressure has become very consistent between labs and test stands.

2.16.1.1. This shows that the recent oil aeration problem has been resolved.

2.16.2. There are still subtle differences between labs.

2.16.2.1. The oil pressure curves from Exxon and Lubrizol look different than the oil pressure curves from Intertek and Southwest (especially during the Stage 1→2 Transition).

2.17. Oil Gallery Temperature:

2.17.1. The small differences between stands may be due to ambient conditions.

2.17.2. Intertek suggested that oil pan insulation could help improve the control of this parameter.

2.18. Rocker Cover Coolant Temperature (Inlet):

2.18.1. There is a lot of noise in the measurement from Intertek Stand 102.

2.19. Rocker Cover Coolant Temperature (Outlet):

2.19.1. There are differences between labs, but these differences in temperature do not align with differences in severity.

2.19.2. Southwest and Intertek have more noise in this measurement than Lubrizol or Exxon.

2.20. Oil Sump Temperature:

2.20.1. Lubrizol's oil sump temperature curve is moving in the opposite direction as the curves from the other labs during the last 15-seconds of the test cycle.

2.20.2. The two tests conducted at Southwest on the same test stand have different oil sump temperatures.

2.20.3. The laboratories agree that the oil sump thermocouple should be fully submerged with the larger initial oil charge.

2.20.4. The oil sump temperature of the northern labs is about 5°C cooler than that of the San Antonio labs.

2.20.5. Temperature control at dependent labs:

2.20.5.1. Lubrizol's Golden Stand is not in a test cell, but the laboratory is temperature controlled.

2.20.5.2. Exxon's Golden Stand is in a test cell that has heat control but no air conditioning.

2.20.5.2.1. The fan in their test cell turns over a large volume of air.

2.21. Torque:

2.21.1. All the labs have made drastic improvements in their torque control.

2.22. Rocker Arm Cover Coolant Flow:

2.22.1. Exxon's Comments:

2.22.1.1. Their coolant flow experiences a small "bump" approximately 20-seconds into the test cycle.

2.22.1.2. The Afton and Exxon stands use similar plumbing for their rocker arm cover coolant flow.

2.22.1.2.1. Afton will check their test stand to see if they experience a similar "bump" in the flow measurement.

2.23. Blowby Gas Temperature:

2.23.1. Intertek Stand 165 experiences more variability in this measurement than their other stands.

2.24. Temperature of Blowby Oil Separator:

2.24.1. Intertek is the only laboratory that is using a thermocouple inside of the oil separator.

2.24.2. Southwest has a thermocouple inside of the cross fitting underneath the oil separator.

2.25. Absolute Throttle Position:

2.25.1. Lubrizol's speed ramps are almost identical to those of the two San Antonio laboratories, but its absolute throttle position is very different.

2.25.2. Intertek and Lubrizol confirmed that their throttle linkages are approximately the same length.

2.26. Oxygen Sensor Voltage:

2.26.1. The oxygen sensor voltage at all the labs is between 0-1V (which is where the sensors should be operating).

2.27. Short Term Fuel Trim (STFT):

2.27.1. There is very little movement in the data from the Intertek stands.

2.27.2. Intertek will confirm that they are pulling data from the correct channel.

2.28. Open Discussion:

2.28.1. Intertek was surprised by Lubrizol's mild result with REO300.

2.28.1.1. The iron data from Lubrizol's test indicated that the result should have been around 1.50mm^3.

2.28.2. Exxon's Comments:

2.28.2.1. They will change their intake air pressure set-point to 0.25kPa.

2.28.2.2. They will investigate the anomaly in their engine and rocker arm cover coolant flows.

2.28.2.3. They will check their blowby flow meter.

2.28.3. Southwest's Comments:

2.28.3.1. They will check the exhaust backpressure control on their test stands.

2.28.4. Intertek's Comments:

2.28.4.1. They are concerned by the differences in blowby gas temperature.

2.28.5. Comments from Lubrizol and Afton:

2.28.5.1. Lubrizol is concerned by the large differences in exhaust gas temperature between labs and test stands.

2.28.5.2. Lubrizol will conduct an experiment with its REO1012 test (that is running) to determine if the magnitude of the exhaust temperature measurement is influenced by the age of the thermocouple.

2.28.5.3. Afton is concerned about the differences in the <u>slopes</u> of the exhaust gas temperatures.

2.28.5.3.1. They requested that each lab confirm the insertion depth of their thermocouples.

2.28.6. Stand Vibration:

2.28.6.1. Afton questioned whether vibration can be impacting stand vibration.

2.28.6.2. Lubrizol noted that there was extensive work done to measure the vibration of each Golden Stand in the industry.

2.28.6.2.1. The results were inconclusive.

2.28.7. Lifter Wear vs. Lifter Position:

2.28.7.1. Afton inquired whether the Surveillance Panel has looked at the distribution of lifter wear from the front to the back of the engine.

2.28.7.2. Lubrizol agreed that it would be useful to analyze the lifter wear vs. position data.

2.28.7.2.1. An unusually severe lifter (i.e. Lifter #2) can skew the results for an entire test.

2.28.7.2.2. Does the wear profile, from the front to the back of the engine, look the same at each laboratory?

2.29. Lifter Profile/Crown:

2.29.1. The decision was made at the recent Metrology Workshop to relax the acceptability criteria for lifter crown.

2.29.1.1. Intertek and Toyota now believe that relaxing these acceptability limits may have been a mistake.

2.29.1.2. They would like to reinstitute some type of lifter prescreening.

2.29.2. Afton is not opposed to prescreening these lifters, but they would like it to be done before the hardware is shipped to the labs.

2.29.2.1. OHT will consider options for performing this screening.

2.29.3. Lubrizol's Comments:

2.29.3.1. Lubrizol does not believe that the lifter profile is a significant driver of test severity.

2.29.3.2. Lubrizol also believes that it will be difficult for OHT to efficiently screen lifter profiles without an expensive metrology instrument like the Keyence.

2.29.3.3. Lubrizol will determine a way to use the existing Keyence pre-test measurements to monitor crown.

3. QUALITY INDEX CALCULATIONS – COOLANT TEMPERATURE AT ENGINE OUTLET:

3.1. Background:

3.1.1. Travis Kostan presented this material.

3.1.2. ***File name:*** *IVB_TEngineCoolantOutQI.ppt*

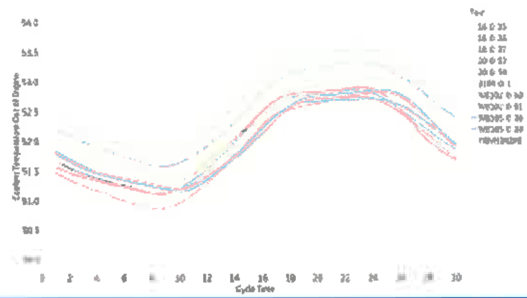
3.2. Slide #3:

How to Control Coolant Temp Out

This parameter behaves cyclically. Two options to use QIs are:

1. Have a single target and window for all data.
2. Have separate stage 1 and stage 2 targets and windows.

Though the first option is certainly the easiest, it does not allow us to control the "swing" between stage 1 and 2. Is a test that swings very little around 52C the same as a tests we are running now?



FUELS & LUBRICANT RESEARCH

3.2.1. The coolant outlet temperature behaves cyclically.

3.2.2. There are two options to calculate the QI:

3.2.2.1. *Option #1* – Utilize a single target and window of the entire cycle.

3.2.2.2. *Option #2* – Utilize separate targets and windows for Stage 1and Stage 2.

3.3. QI Option #1 – Slide #9:

Engine Coolant Temp Out QI

- Target : 52 C
- Window size 1: +/- 1.75 C
- Window size 2: +/- 1.50 C
- Window size 3: +/- 1.25 C

Test no.	Window 1 QI	Window 2 QI	Window 3 QI
IVB102-0-60	0.86	0.53	0.73
IVB102-0-61	0.87	0.82	0.75
IVB165-0-26	0.87	0.83	0.75
IVB165-0-28	0.89	0.85	0.78
18-0-35	0.87	0.82	0.74
18-0-36	0.71	0.61	0.44
18-0-37	0.79	0.72	0.59
20-0-52	0.84	0.78	0.68
20-0-54	0.86	0.80	0.72
TRNN2RZPB	0.87	0.82	0.74
3100-0-1	0.88	0.84	0.77
Average	0.85	0.79	0.70

Full Test QI

W1	W2	W3
0.81	0.74	0.63
0.55	0.45	0.35

FUELS & LUBRICANT RESEARCH

3.3.1. Kostan evaluated three different window sizes for Option #1.
3.3.2. It will be difficult for laboratories to achieve QI values around 0.9 because the temperature swings drastically over the test cycle.
3.3.2.1. One option to mitigate this is to use a very wide window.

3.4. QI Option #2:

3.4.1. Utilizing two separate windows/targets will result in higher QI values.
3.4.2. A similar approach could also be used for the oil gallery temperature.

3.5. The Surveillance Panel convened the conference call without deciding on this issue.
3.5.1. This topic will be revisited in the next conference call.

Action Items	Person responsible	Completion Date

Follow-up Notes/Updates	Initials	Date Added

Attendees	Organization	Contact Information
See attached list.		

Sequence IV Surveillance Panel

Conference Call
October 12, 2017
8:30 a.m. - 11:30 a.m.

AGENDA

1. Prove-out testing statistical analysis review
2. Prove-out testing oil analysis review
3. Prove-out testing operational data analysis review
4. Precision and oil discrimination degradation discussion
5. Engine coolant out temperature Qi target and limits review
6. Keyence, PDI and mass loss correlation analysis review
7. Precision matrix design review
8. Sequence IVB next steps
9. Sequence IVB timeline review
10. Previous action item review
11. Motion and action item review
12. Next meeting
13. Adjourn

MEMBERSHIP
SEQUENCE IV SURVEILLANCE PANEL

October 12, 2017

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MEMBERSHIP
SEQUENCE IV SURVEILLANCE PANEL

October 12, 2017

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October 12, 2017

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NON-MEMBER MAILING LIST
SEQUENCE IV SURVEILLANCE PANEL

October 12, 2017

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October 12, 2017

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October 12, 2017

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	Phone No.: Fax No.: Email:	
	Phone No.: Fax No.: Email:	
	Phone No.: Fax No.: Email:	

IVB Keyence and PDI Correlation Analysis

Statistics Group

October 10, 2017

Statistics Group

- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Kevin O'Malley, Lubrizol
- Martin Chadwick, Intertek
- Richard Grundza, TMC
- Lisa Dingwell, Afton
- Todd Dvorak, Afton
- Travis Kostan, SwRI

Conclusions and Recommendation

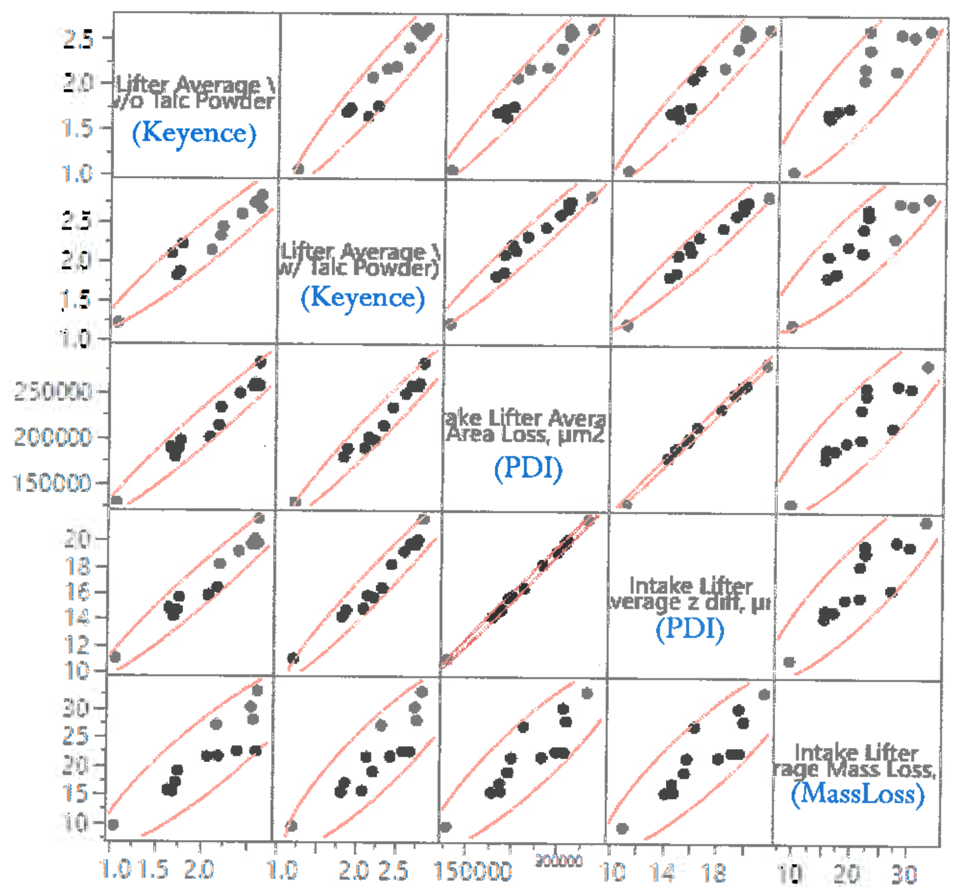
- Conclusions are valid in the range of 1.2-2.8 mm3 Intake Lifter Volume Loss as measured by Keyence with Talc
- Keyence measurements are highly correlated with PDI measurements.
- Keyence measurements are correlated with Mass Loss.

Recommendation:

- PDI lifter area loss and lifter z diff wear measurements, as well as the lifter mass loss measurements, can be eliminated.

Intake Lifter

- Keyence Intake Lifter Volume Loss With and Without Talc Powder are highly correlated with PDI Intake Lifter Area Loss, Average z Diff and Mass Loss (p-values<0.0001)

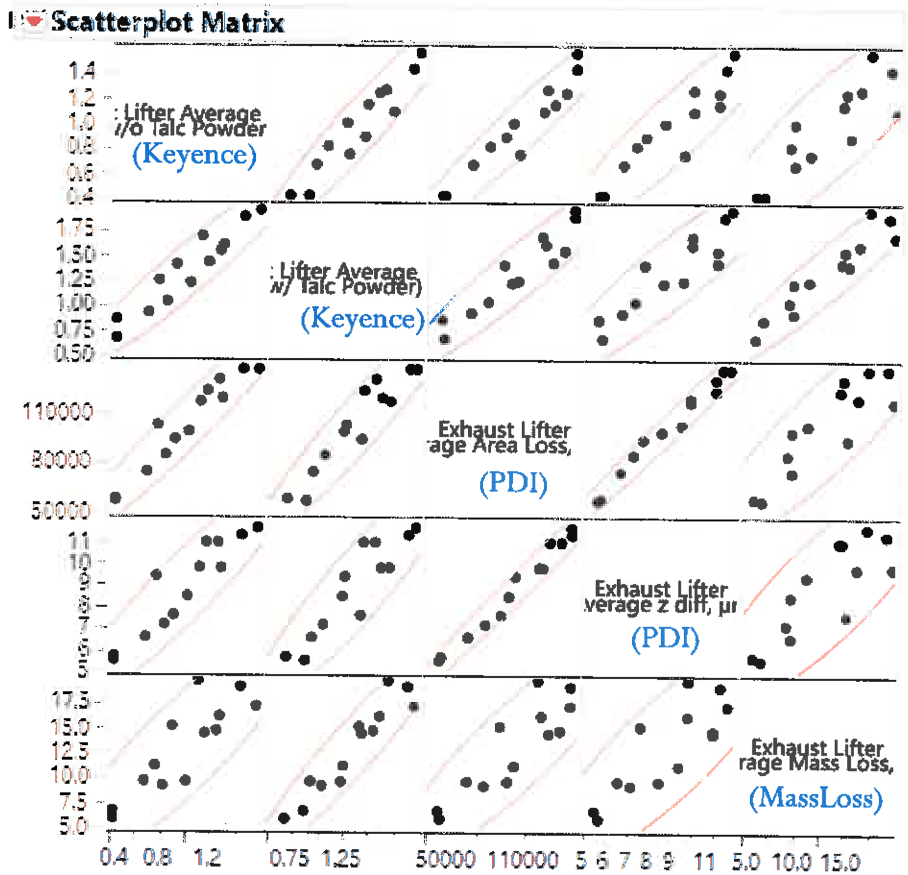


Correlations

	Intake Lifter Average Volume Loss (w/o Talc Powder), mm3	Intake Lifter Average Volume Loss (w/ Talc Powder), mm3
Intake Lifter Average Volume Loss (w/o Talc Powder), mm3	1.0000	0.9670
Intake Lifter Average Volume Loss (w/ Talc Powder), mm3	0.9670	1.0000
Intake Lifter Average Area Loss, µm2	0.9772	0.9808
Intake Lifter Average z diff, µm	0.9725	0.9773
Intake Lifter Average Mass Loss, mg	0.9025	0.8961

Exhaust Lifter

- Keyence Exhaust Lifter Volume Loss With and Without Talc Powder are highly correlated with PDI Exhaust Lifter Area Loss, Average z Diff and Mass Loss (p-values<0.0001)



Correlations

	Exhaust Lifter Average Volume Loss (w/o Talc Powder), mm3	Exhaust Lifter Average Volume Loss (w/ Talc Powder), mm3
Exhaust Lifter Average Volume Loss (w/o Talc Powder), mm3	1.0000	0.9511
Exhaust Lifter Average Volume Loss (w/ Talc Powder), mm3	0.9511	1.0000
Exhaust Lifter Average Area Loss, µm2	0.9623	0.9469
Exhaust Lifter Average z diff, µm	0.9296	0.9121
Exhaust Lifter Average Mass Loss, mg	0.8588	0.9483

Abbreviations used in the Individual Lifter Correlations

- IVLKT – Intake Volume Loss Keyence with Talc
- IVLK – Intake Volume Loss Keyence without Talc
- IALP – Intake Area Loss PDI
- IMZDP – Intake Max Z Diff PDI
- IML – Intake Mass Loss
- EVLKT – Exhaust Volume Loss Keyence with Talc
- EVLK – Exhaust Volume Loss Keyence without Talc
- EALP – Exhaust Area Loss PDI
- EMZDP – Exhaust Max Z Diff PDI
- EML – Exhaust Mass Loss
- 1-8 --- Lifters 1 to 8

Intake Lifter 1

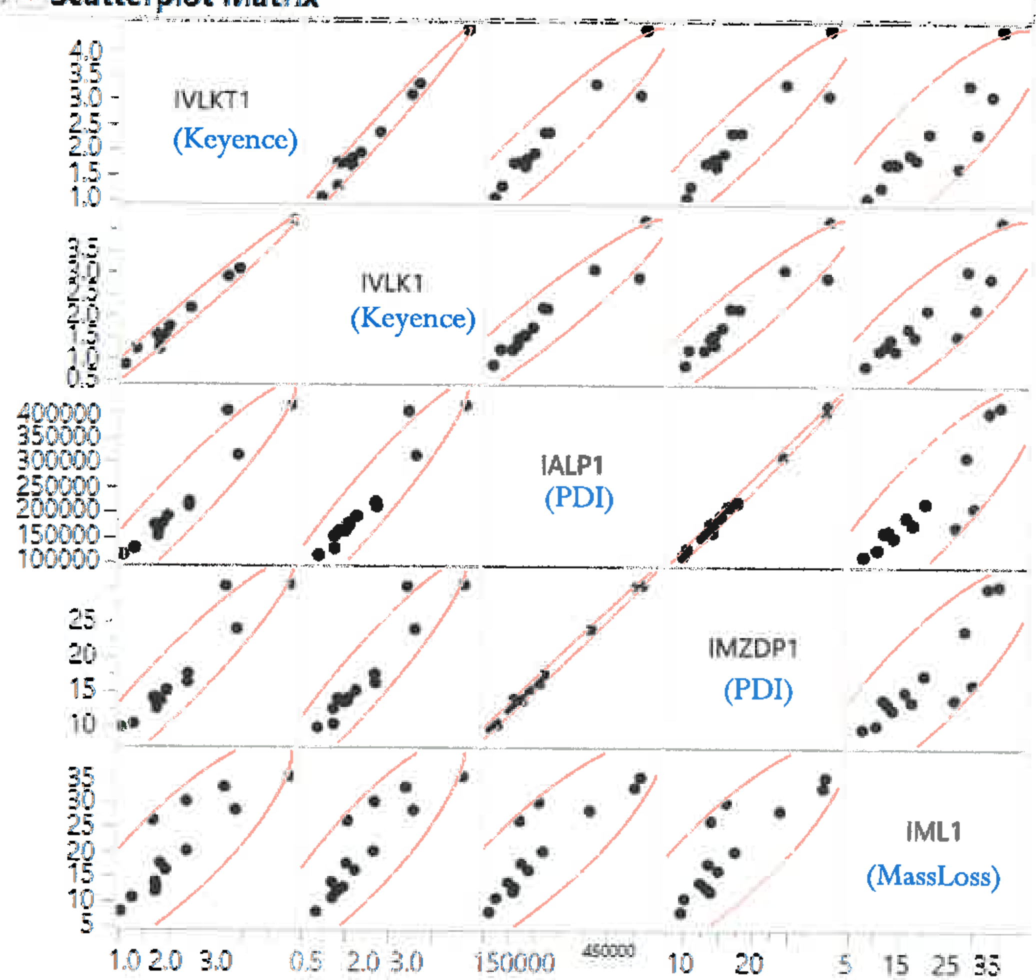
Correlations

	IVLKT1	IVLK1	IALP1	IMZDP1	IML1
IVLKT1	1.0000	0.9915	0.9500	0.9466	0.8506
IVLK1	0.9915	1.0000	0.9515	0.9447	0.8726
IALP1	0.9500	0.9515	1.0000	0.9984	0.8653
IMZDP1	0.9466	0.9447	0.9984	1.0000	0.8553
IML1	0.8506	0.8726	0.8653	0.8553	1.0000

Correlation Probability

	IVLKT1	IVLK1	IALP1	IMZDP1	IML1
IVLKT1	<.0001	<.0001	<.0001	<.0001	0.0002
IVLK1	<.0001	<.0001	<.0001	<.0001	<.0001
IALP1	<.0001	<.0001	<.0001	<.0001	0.0001
IMZDP1	<.0001	<.0001	<.0001	<.0001	0.0002
IML1	0.0002	<.0001	0.0001	0.0002	<.0001

Scatterplot Matrix



Intake Lifter 2

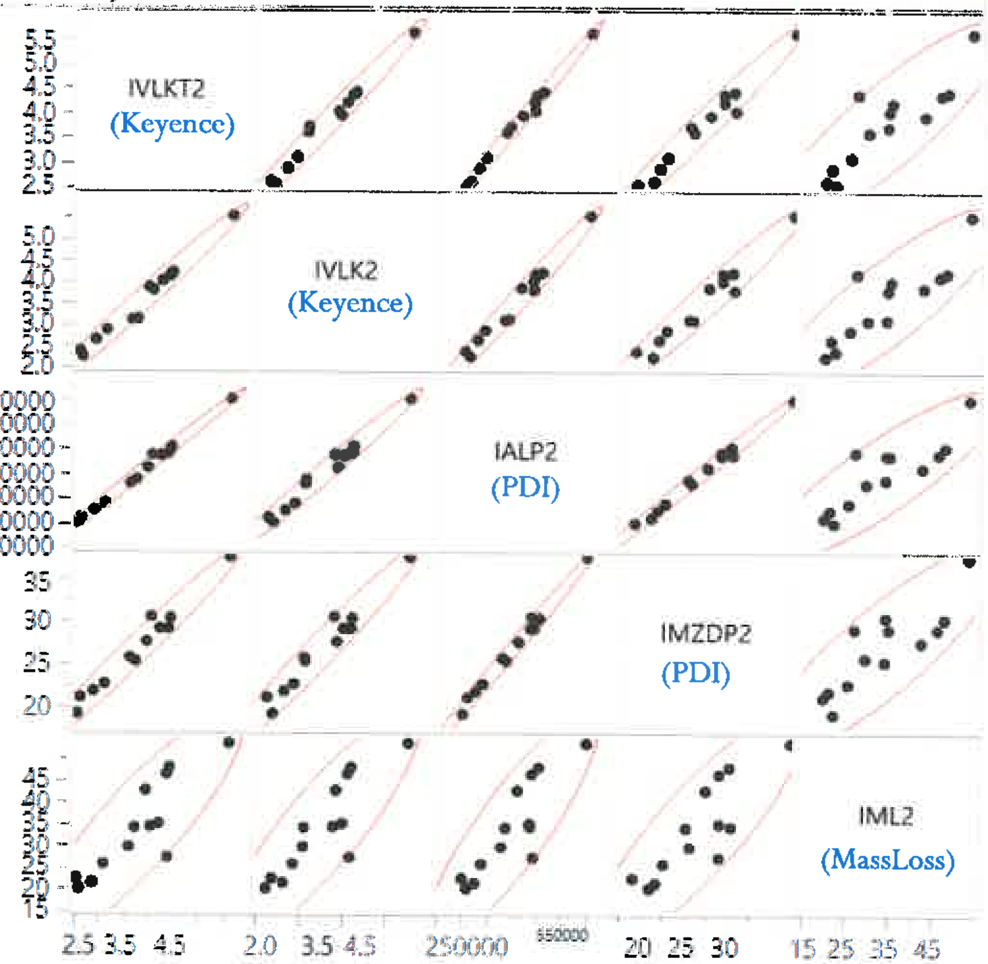
Correlations

	IVLKT2	IVLK2	IALP2	IMZDP2	IML2
IVLKT2	1.0000	0.9883	0.9956	0.9829	0.8709
IVLK2	0.9883	1.0000	0.9882	0.9763	0.8684
IALP2	0.9956	0.9882	1.0000	0.9944	0.8662
IMZDP2	0.9829	0.9763	0.9944	1.0000	0.8528
IML2	0.8709	0.8684	0.8662	0.8528	1.0000

Correlation Probability

	IVLKT2	IVLK2	IALP2	IMZDP2	IML2
IVLKT2	<.0001	<.0001	<.0001	<.0001	0.0001
IVLK2	<.0001	<.0001	<.0001	<.0001	0.0001
IALP2	<.0001	<.0001	<.0001	<.0001	0.0001
IMZDP2	<.0001	<.0001	<.0001	<.0001	0.0002
IML2	0.0001	0.0001	0.0001	0.0002	<.0001

Scatterplot Matrix



Intake Lifter 3

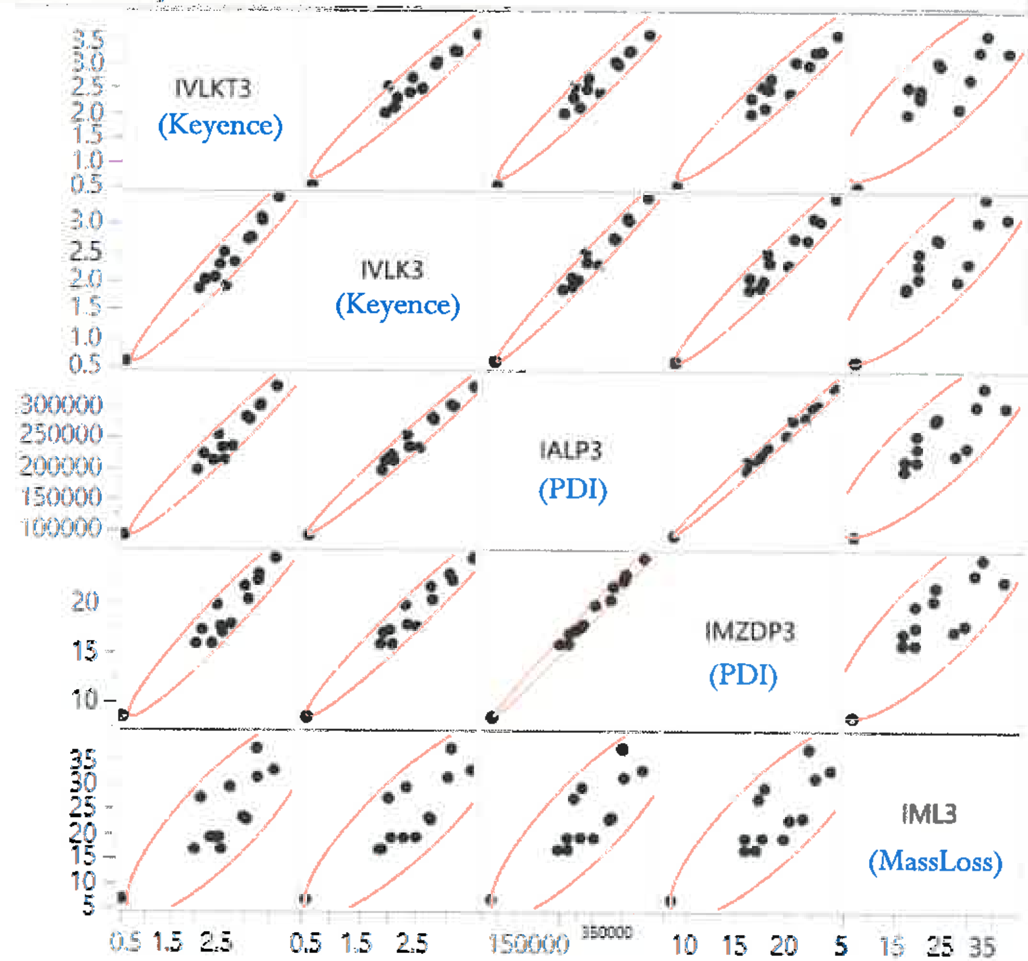
Correlations

	IVLKT3	IVLK3	IALP3	IMZDP3	IML3
IVLKT3	1.0000	0.9746	0.9754	0.9653	0.8330
IVLK3	0.9746	1.0000	0.9877	0.9750	0.8554
IALP3	0.9754	0.9877	1.0000	0.9957	0.8459
IMZDP3	0.9653	0.9750	0.9957	1.0000	0.8329
IML3	0.8330	0.8554	0.8459	0.8329	1.0000

Correlation Probability

	IVLKT3	IVLK3	IALP3	IMZDP3	IML3
IVLKT3	<.0001	<.0001	<.0001	<.0001	0.0004
IVLK3	<.0001	<.0001	<.0001	<.0001	0.0002
IALP3	<.0001	<.0001	<.0001	<.0001	0.0003
IMZDP3	<.0001	<.0001	<.0001	<.0001	0.0004
IML3	0.0004	0.0002	0.0003	0.0004	<.0001

Scatterplot Matrix



Intake Lifter 4

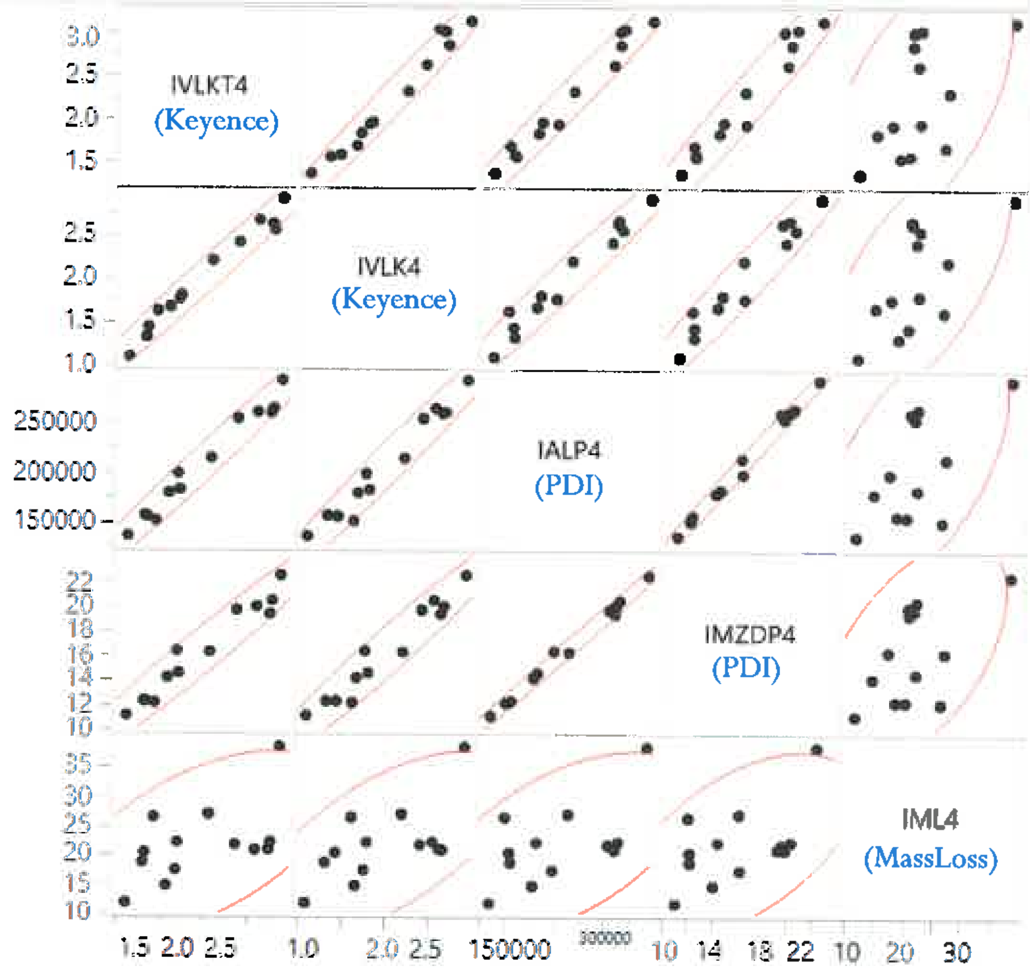
Correlations

	IVLKT4	IVLK4	IALP4	IMZDP4	IML4
IVLKT4	1.0000	0.9868	0.9856	0.9737	0.5586
IVLK4	0.9868	1.0000	0.9812	0.9704	0.6311
IALP4	0.9856	0.9812	1.0000	0.9962	0.5593
IMZDP4	0.9737	0.9704	0.9962	1.0000	0.5514
IML4	0.5586	0.6311	0.5593	0.5514	1.0000

Correlation Probability

	IVLKT4	IVLK4	IALP4	IMZDP4	IML4
IVLKT4	<.0001	<.0001	<.0001	<.0001	0.0472
IVLK4	<.0001	<.0001	<.0001	<.0001	0.0207
IALP4	<.0001	<.0001	<.0001	<.0001	0.0469
IMZDP4	<.0001	<.0001	<.0001	<.0001	0.0508
IML4	0.0472	0.0207	0.0469	0.0508	<.0001

Scatterplot Matrix



Intake Lifter 5

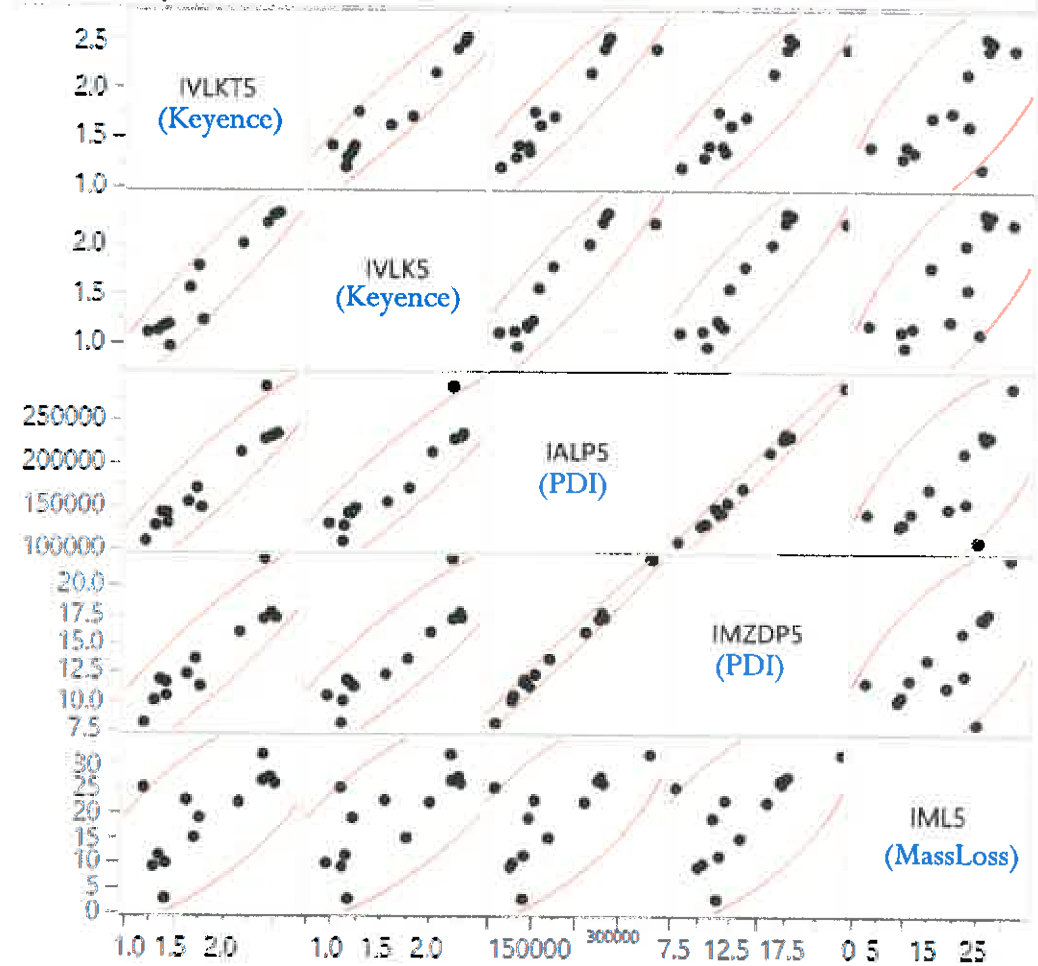
Correlations

	IVLKT5	IVLK5	IALP5	IMZDP5	IML5
IVLKT5	1.0000	0.9576	0.9430	0.9118	0.7298
IVLK5	0.9576	1.0000	0.9319	0.9063	0.7467
IALP5	0.9430	0.9319	1.0000	0.9938	0.7094
IMZDP5	0.9118	0.9063	0.9938	1.0000	0.6594
IML5	0.7298	0.7467	0.7094	0.6594	1.0000

Correlation Probability

	IVLKT5	IVLK5	IALP5	IMZDP5	IML5
IVLKT5	<.0001	<.0001	<.0001	<.0001	0.0046
IVLK5	<.0001	<.0001	<.0001	<.0001	0.0034
IALP5	<.0001	<.0001	<.0001	<.0001	0.0066
IMZDP5	<.0001	<.0001	<.0001	<.0001	0.0142
IML5	0.0046	0.0034	0.0066	0.0142	<.0001

Scatterplot Matrix



Intake Lifter 6

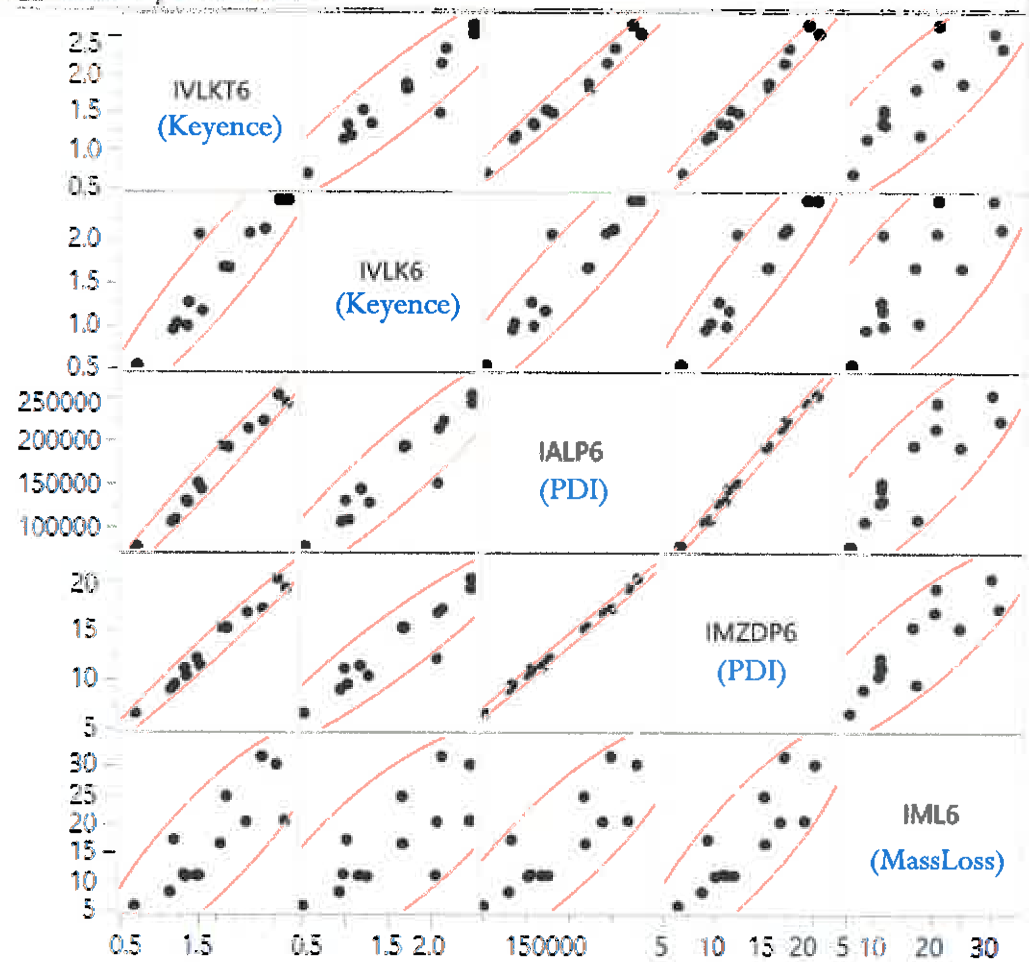
Correlations

	IVLKT6	IVLK6	IALP6	IMZDP6	IML6
IVLKT6	1.0000	0.9321	0.9877	0.9872	0.8458
IVLK6	0.9321	1.0000	0.9362	0.9346	0.7568
IALP6	0.9877	0.9362	1.0000	0.9978	0.8496
IMZDP6	0.9872	0.9346	0.9978	1.0000	0.8523
IML6	0.8458	0.7568	0.8496	0.8523	1.0000

Correlation Probability

	IVLKT6	IVLK6	IALP6	IMZDP6	IML6
IVLKT6	<.0001	<.0001	<.0001	<.0001	0.0003
IVLK6	<.0001	<.0001	<.0001	<.0001	0.0027
IALP6	<.0001	<.0001	<.0001	<.0001	0.0002
IMZDP6	<.0001	<.0001	<.0001	<.0001	0.0002
IML6	0.0003	0.0027	0.0002	0.0002	<.0001

Scatterplot Matrix



Intake Lifter 7

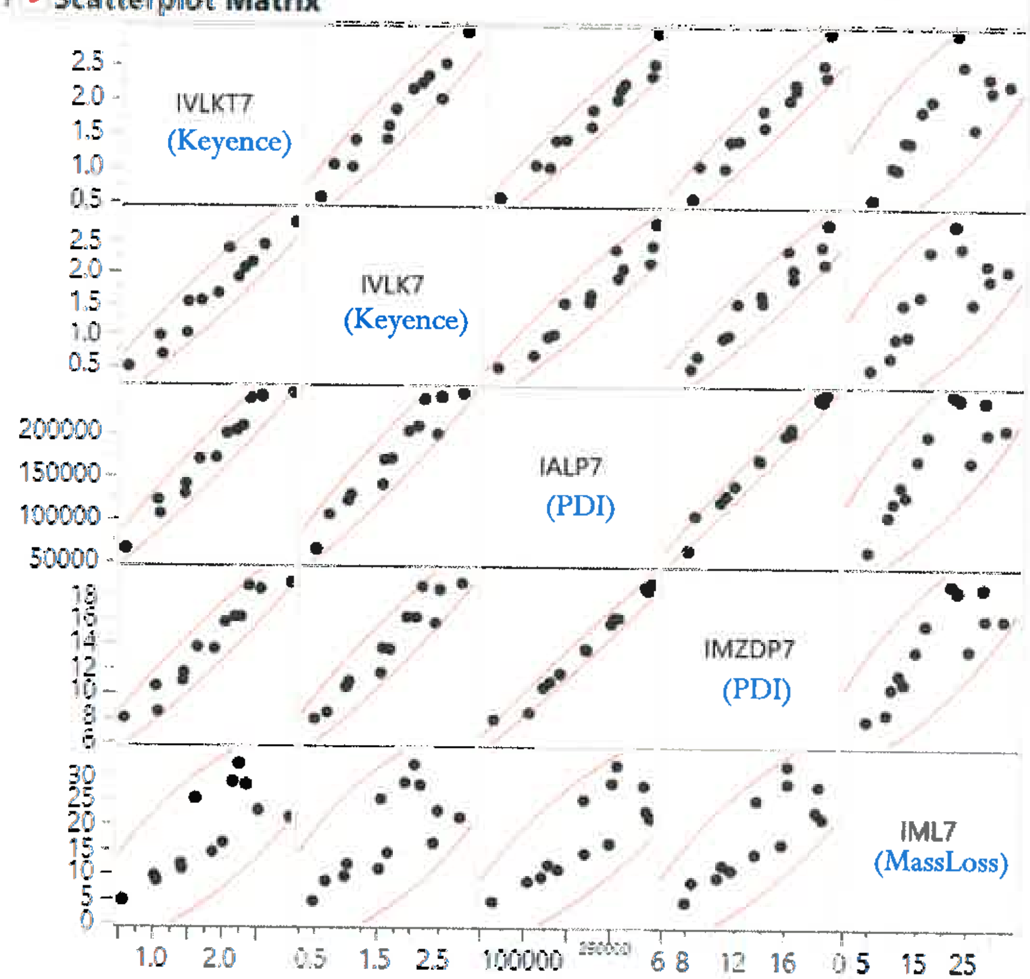
Correlations

	IVLKT7	IVLK7	IALP7	IMZDP7	IML7
IVLKT7	1.0000	0.9617	0.9775	0.9679	0.7788
IVLK7	0.9617	1.0000	0.9630	0.9616	0.7248
IALP7	0.9775	0.9630	1.0000	0.9923	0.8270
IMZDP7	0.9679	0.9616	0.9923	1.0000	0.8278
IML7	0.7788	0.7248	0.8270	0.8278	1.0000

Correlation Probability

	IVLKT7	IVLK7	IALP7	IMZDP7	IML7
IVLKT7	<.0001	<.0001	<.0001	<.0001	0.0017
IVLK7	<.0001	<.0001	<.0001	<.0001	0.0051
IALP7	<.0001	<.0001	<.0001	<.0001	0.0005
IMZDP7	<.0001	<.0001	<.0001	<.0001	0.0005
IML7	0.0017	0.0051	0.0005	0.0005	<.0001

Scatterplot Matrix



Intake Lifter 8

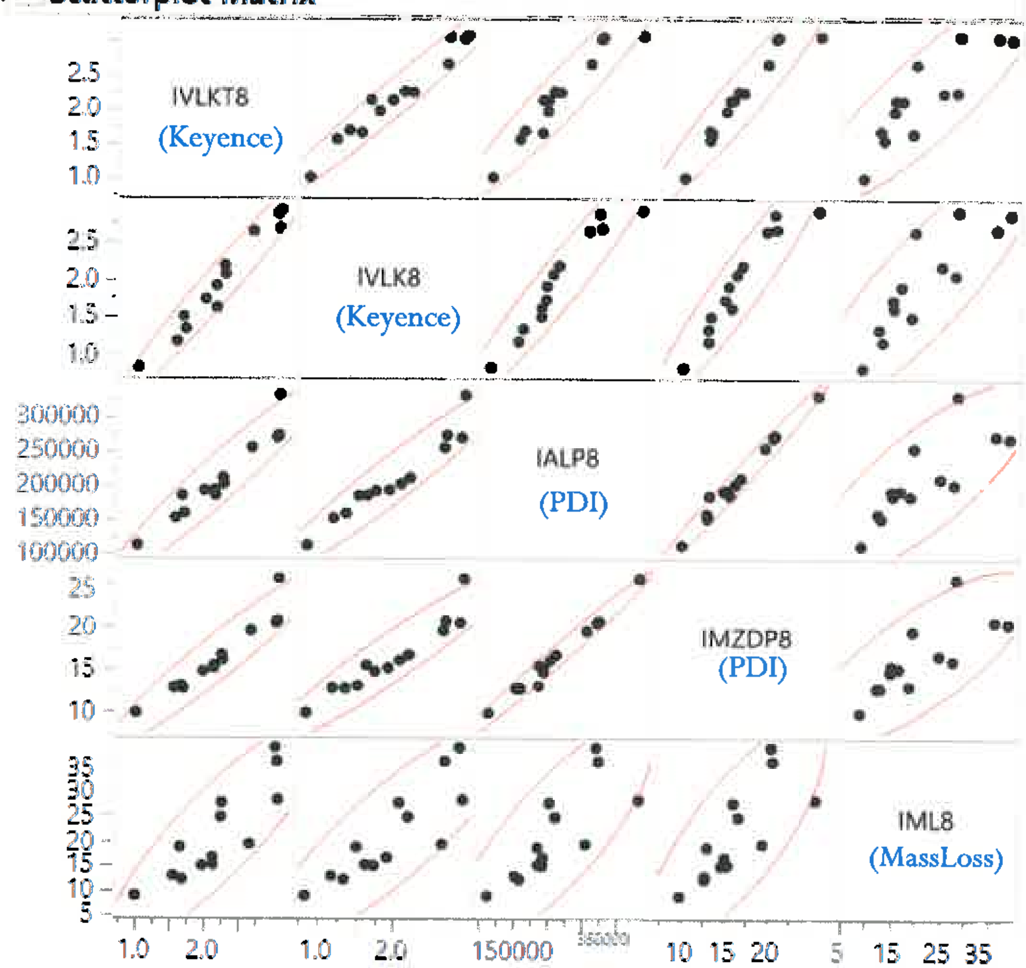
Correlations

	IVLKT8	IVLK8	IALP8	IMZDP8	IML8
IVLKT8	1.0000	0.9790	0.9556	0.9533	0.8623
IVLK8	0.9790	1.0000	0.9610	0.9491	0.8579
IALP8	0.9556	0.9610	1.0000	0.9902	0.7983
IMZDP8	0.9533	0.9491	0.9902	1.0000	0.7747
IML8	0.8623	0.8579	0.7983	0.7747	1.0000

Correlation Probability

	IVLKT8	IVLK8	IALP8	IMZDP8	IML8
IVLKT8	<.0001	<.0001	<.0001	<.0001	0.0001
IVLK8	<.0001	<.0001	<.0001	<.0001	0.0002
IALP8	<.0001	<.0001	<.0001	<.0001	0.0011
IMZDP8	<.0001	<.0001	<.0001	<.0001	0.0019
IML8	0.0001	0.0002	0.0011	0.0019	<.0001

Scatterplot Matrix



Exhaust Lifter 1

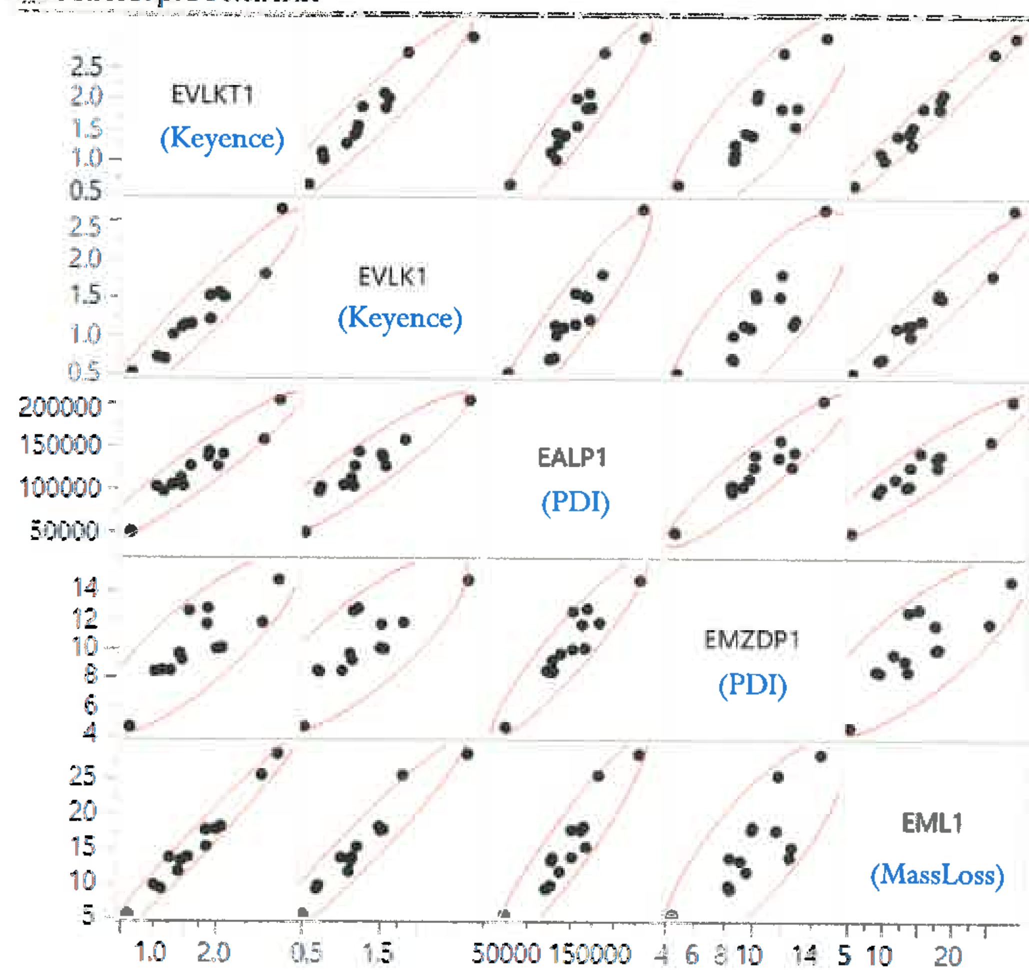
Correlations

	EVLKT1	EVLK1	EALP1	EMZDP1	EML1
EVLKT1	1.0000	0.9573	0.9477	0.8299	0.9862
EVLK1	0.9573	1.0000	0.9329	0.8029	0.9672
EALP1	0.9477	0.9329	1.0000	0.9313	0.9367
EMZDP1	0.8299	0.8029	0.9313	1.0000	0.8021
EML1	0.9862	0.9672	0.9367	0.8021	1.0000

Correlation Probability

	EVLKT1	EVLK1	EALP1	EMZDP1	EML1
EVLKT1	<.0001	<.0001	<.0001	0.0004	<.0001
EVLK1	<.0001	<.0001	<.0001	0.0010	<.0001
EALP1	<.0001	<.0001	<.0001	<.0001	<.0001
EMZDP1	0.0004	0.0010	<.0001	<.0001	0.0010
EML1	<.0001	<.0001	<.0001	0.0010	<.0001

Scatterplot Matrix



Exhaust Lifter 2

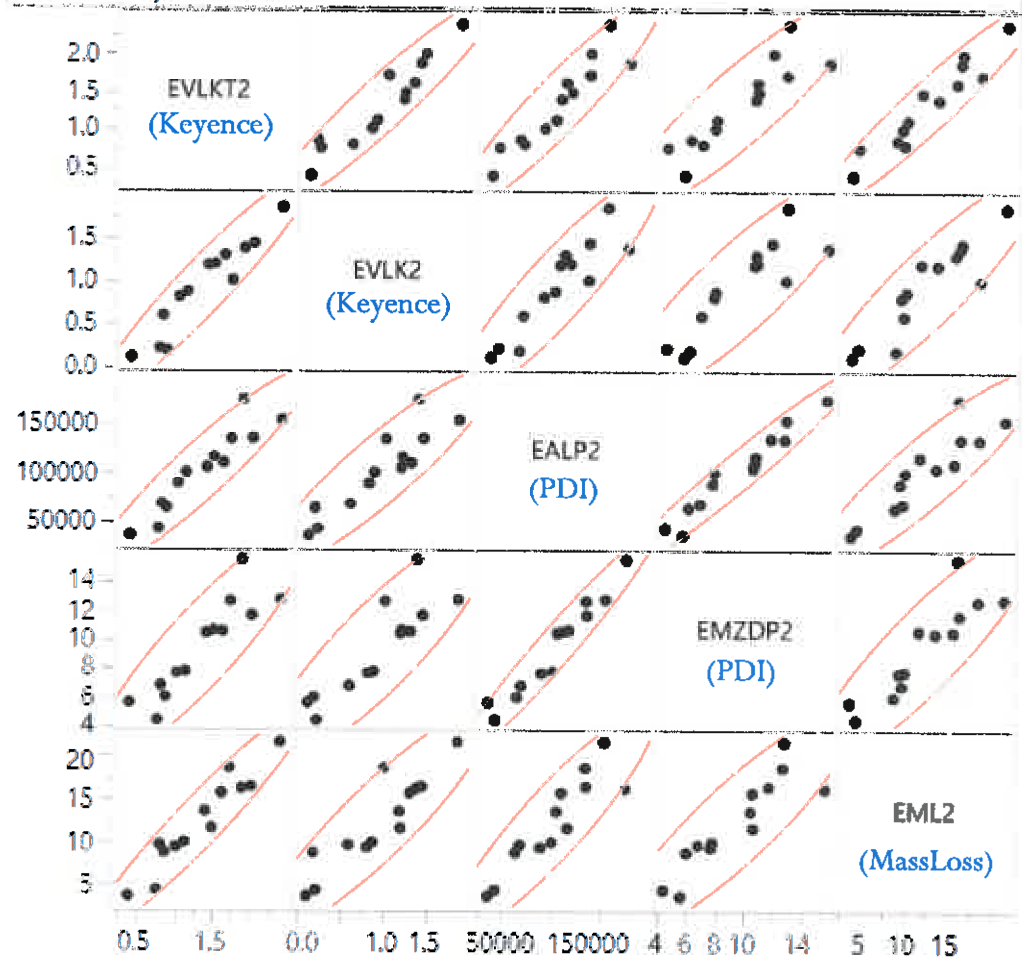
Correlations

	EVLKT2	EVLK2	EALP2	EMZDP2	EML2
EVLKT2	1.0000	0.9467	0.9340	0.8970	0.9539
EVLK2	0.9467	1.0000	0.9094	0.8738	0.9021
EALP2	0.9340	0.9094	1.0000	0.9724	0.9061
EMZDP2	0.8970	0.8738	0.9724	1.0000	0.8913
EML2	0.9539	0.9021	0.9061	0.8913	1.0000

Correlation Probability

	EVLKT2	EVLK2	EALP2	EMZDP2	EML2
EVLKT2	<.0001	<.0001	<.0001	<.0001	<.0001
EVLK2	<.0001	<.0001	<.0001	<.0001	<.0001
EALP2	<.0001	<.0001	<.0001	<.0001	<.0001
EMZDP2	<.0001	<.0001	<.0001	<.0001	<.0001
EML2	<.0001	<.0001	<.0001	<.0001	<.0001

Scatterplot Matrix



Exhaust Lifter 3

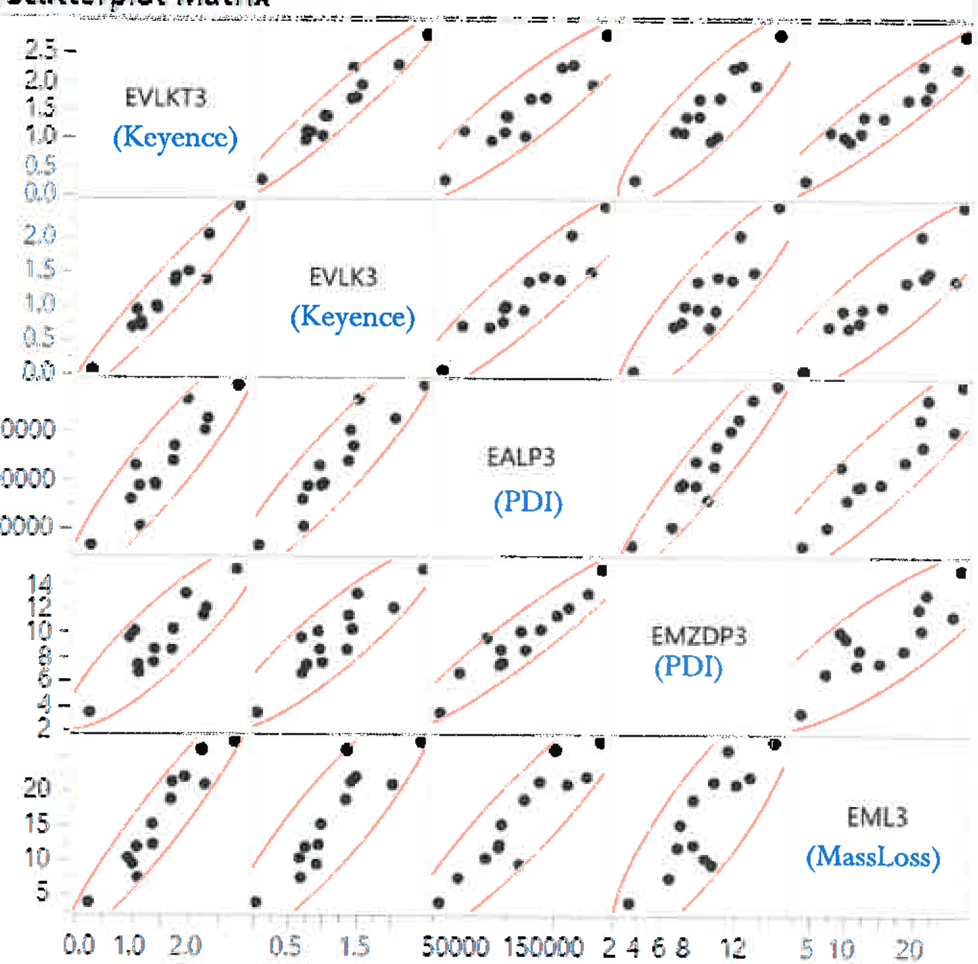
Correlations

	EVLKT3	EVLK3	EALP3	EMZDP3	EML3
EVLKT3	1.0000	0.9656	0.9178	0.8810	0.9498
EVLK3	0.9656	1.0000	0.9265	0.8980	0.8925
EALP3	0.9178	0.9265	1.0000	0.9482	0.9214
EMZDP3	0.8810	0.8980	0.9482	1.0000	0.8400
EML3	0.9498	0.8925	0.9214	0.8400	1.0000

Correlation Probability

	EVLKT3	EVLK3	EALP3	EMZDP3	EML3
EVLKT3	<.0001	<.0001	<.0001	<.0001	<.0001
EVLK3	<.0001	<.0001	<.0001	<.0001	<.0001
EALP3	<.0001	<.0001	<.0001	<.0001	<.0001
EMZDP3	<.0001	<.0001	<.0001	<.0001	0.0003
EML3	<.0001	<.0001	<.0001	0.0003	<.0001

Scatterplot Matrix



Exhaust Lifter 4

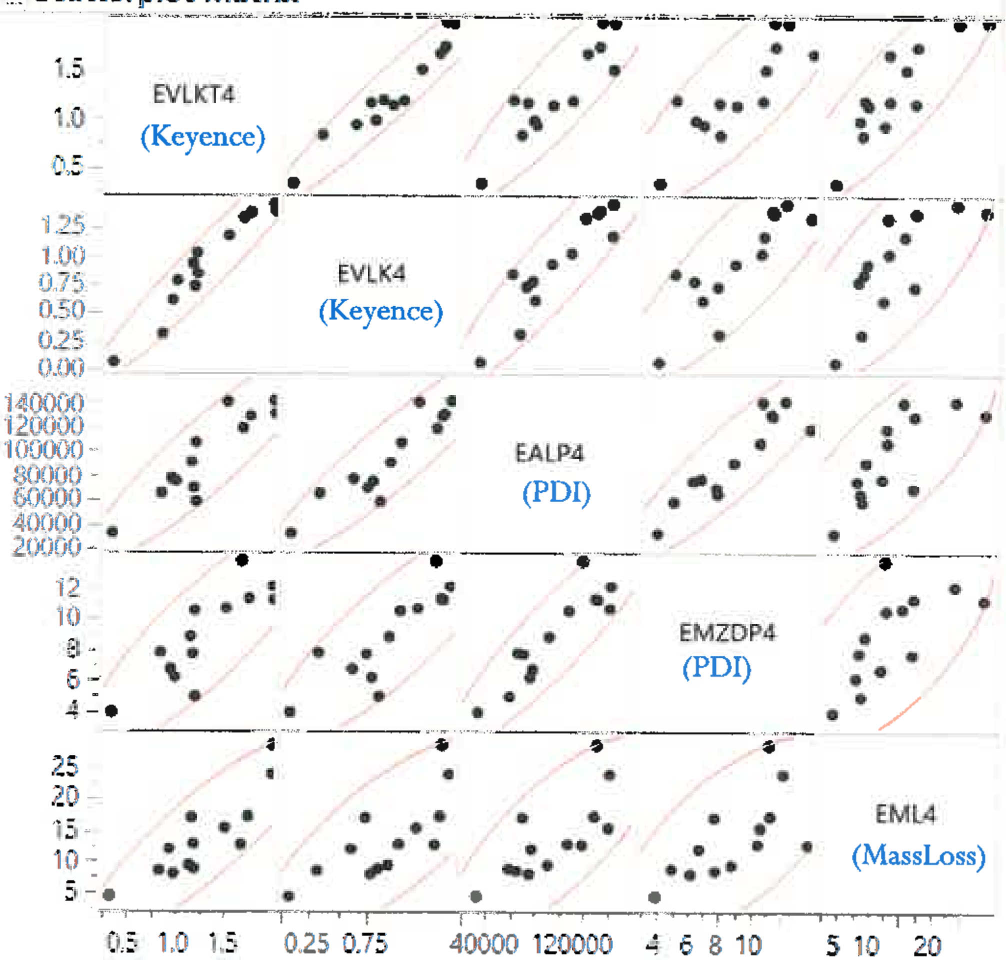
Correlations

	EVLKT4	EVLK4	EALP4	EMZDP4	EML4
EVLKT4	1.0000	0.9630	0.9040	0.8428	0.8652
EVLK4	0.9630	1.0000	0.9213	0.8528	0.7548
EALP4	0.9040	0.9213	1.0000	0.9094	0.7605
EMZDP4	0.8428	0.8528	0.9094	1.0000	0.6659
EML4	0.8652	0.7548	0.7605	0.6659	1.0000

Correlation Probability

	EVLKT4	EVLK4	EALP4	EMZDP4	EML4
EVLKT4	<.0001	<.0001	<.0001	0.0003	0.0001
EVLK4	<.0001	<.0001	<.0001	0.0002	0.0029
EALP4	<.0001	<.0001	<.0001	<.0001	0.0025
EMZDP4	0.0003	0.0002	<.0001	<.0001	0.0130
EML4	0.0001	0.0029	0.0025	0.0130	<.0001

Scatterplot Matrix



Exhaust Lifter 5

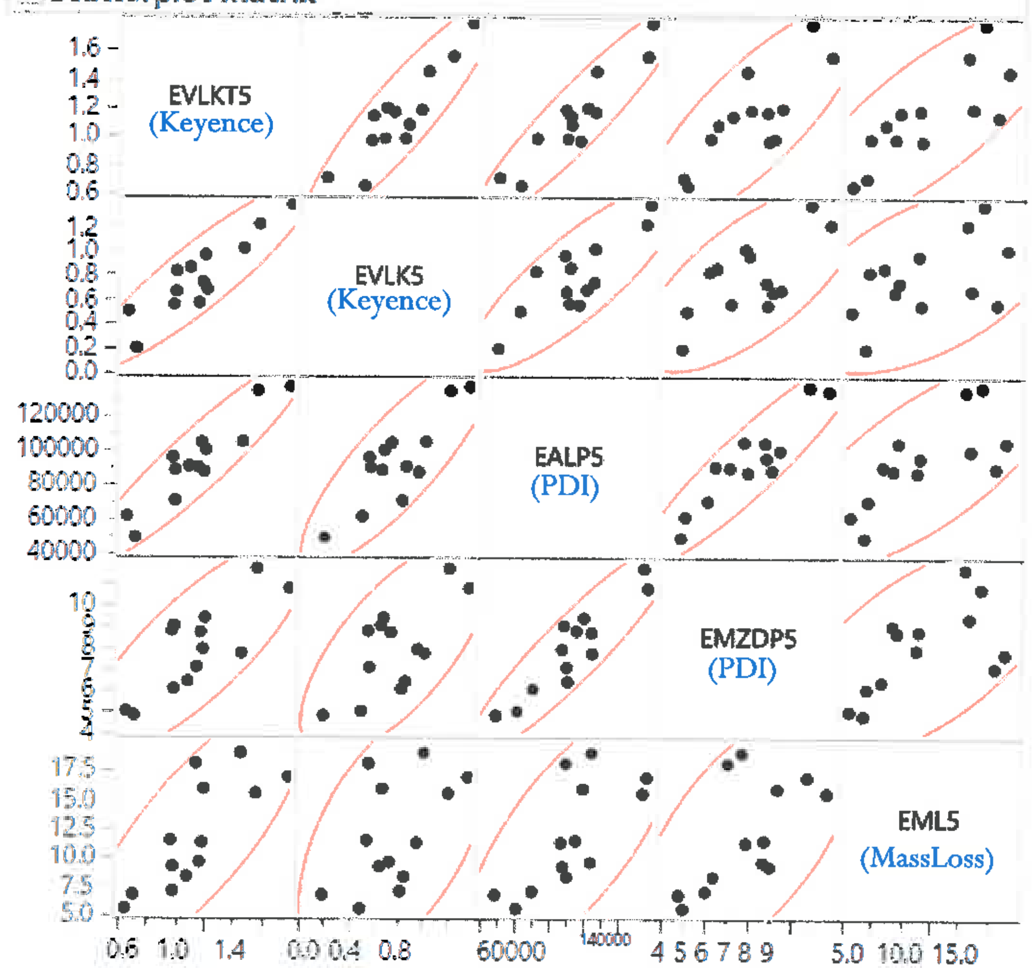
Correlations

	EVLKT5	EVLK5	EALP5	EMZDP5	EML5
EVLKT5	1.0000	0.9021	0.9298	0.7974	0.7870
EVLK5	0.9021	1.0000	0.8365	0.6898	0.5243
EALP5	0.9298	0.8365	1.0000	0.9206	0.7161
EMZDP5	0.7974	0.6898	0.9206	1.0000	0.6148
EML5	0.7870	0.5243	0.7161	0.6148	1.0000

Correlation Probability

	EVLKT5	EVLK5	EALP5	EMZDP5	EML5
EVLKT5	<.0001	<.0001	<.0001	0.0011	0.0014
EVLK5	<.0001	<.0001	0.0004	0.0091	0.0659
EALP5	<.0001	0.0004	<.0001	<.0001	0.0059
EMZDP5	0.0011	0.0091	<.0001	<.0001	0.0253
EML5	0.0014	0.0659	0.0059	0.0253	<.0001

Scatterplot Matrix



Exhaust Lifter 6

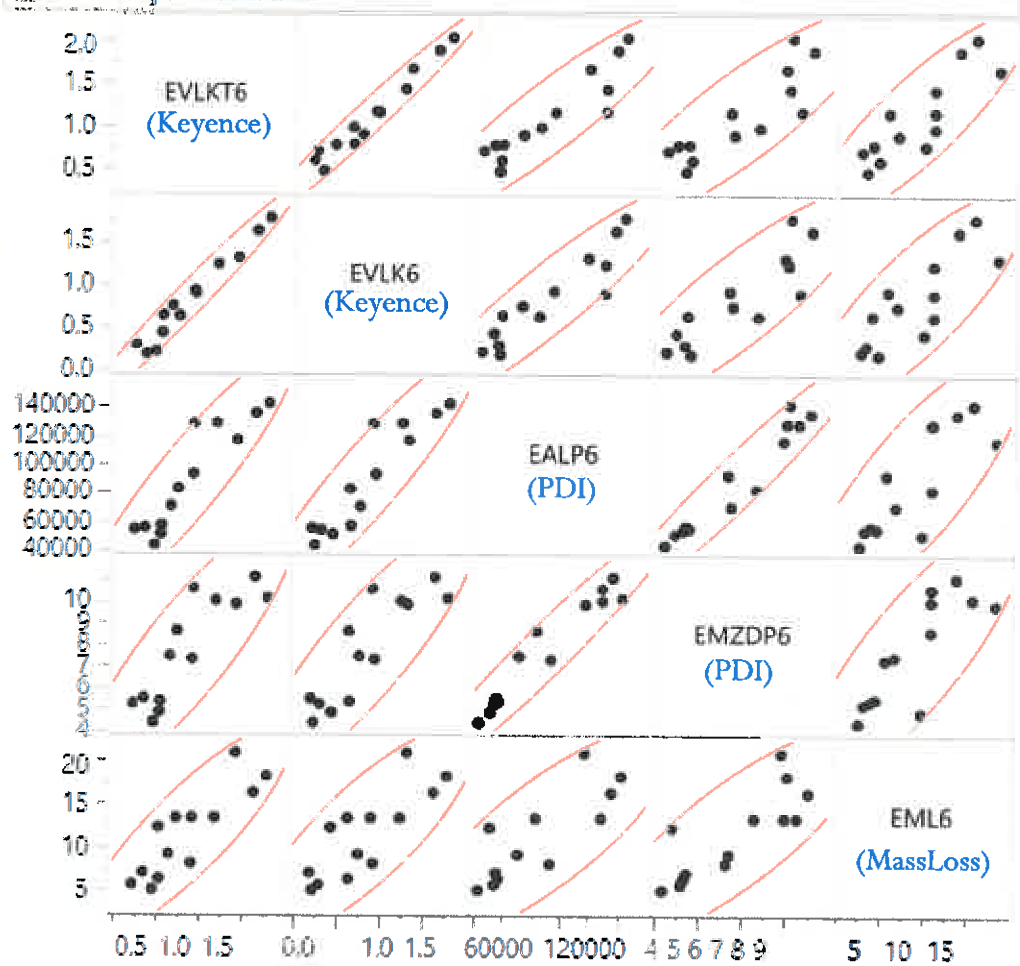
Correlations

	EVLKT6	EVLK6	EALP6	EMZDP6	EML6
EVLKT6	1.0000	0.9794	0.9171	0.8610	0.8589
EVLK6	0.9794	1.0000	0.9243	0.8683	0.8124
EALP6	0.9171	0.9243	1.0000	0.9656	0.8048
EMZDP6	0.8610	0.8683	0.9656	1.0000	0.8178
EML6	0.8589	0.8124	0.8048	0.8178	1.0000

Correlation Probability

	EVLKT6	EVLK6	EALP6	EMZDP6	EML6
EVLKT6	<.0001	<.0001	<.0001	0.0002	0.0002
EVLK6	<.0001	<.0001	<.0001	0.0001	0.0007
EALP6	<.0001	<.0001	<.0001	<.0001	0.0009
EMZDP6	0.0002	0.0001	<.0001	<.0001	0.0006
EML6	0.0002	0.0007	0.0009	0.0006	<.0001

Scatterplot Matrix



Exhaust Lifter 7

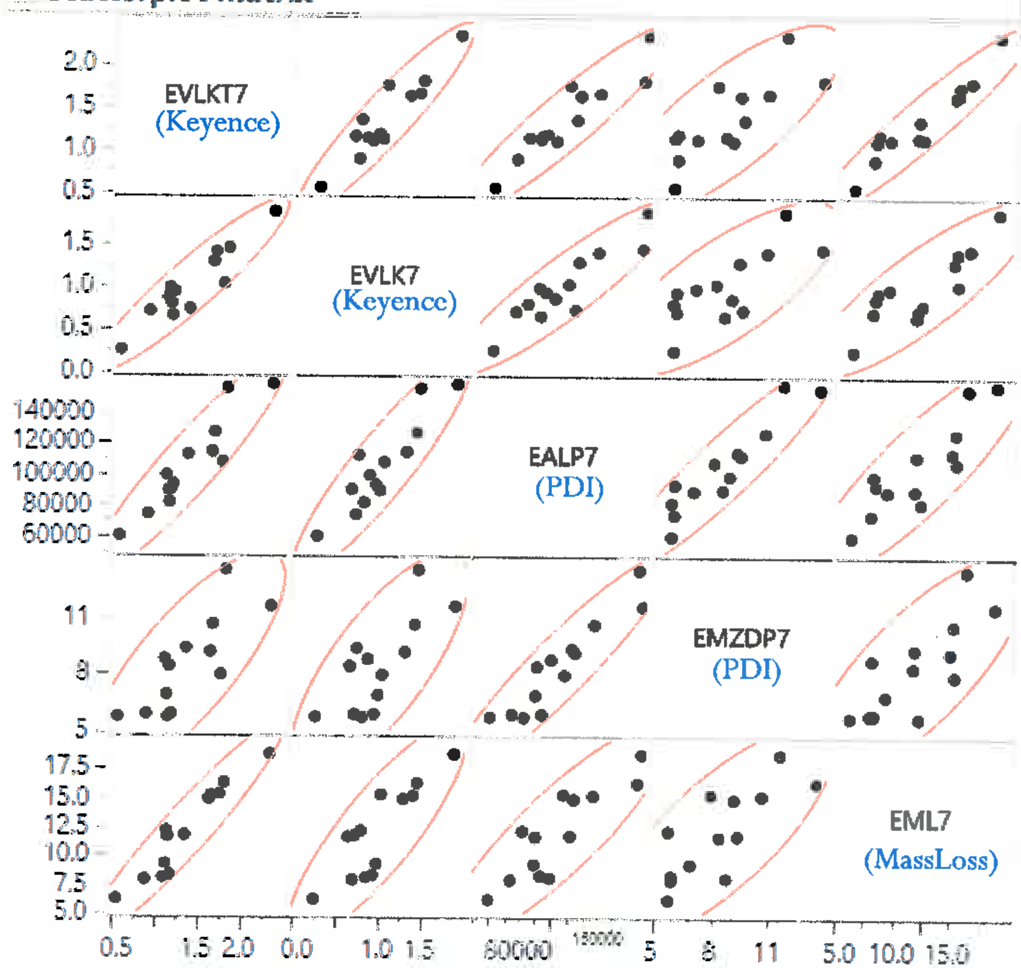
Correlations

	EVLKT7	EVLK7	EALP7	EMZDP7	EML7
EVLKT7	1.0000	0.9301	0.9306	0.7831	0.9486
EVLK7	0.9301	1.0000	0.9082	0.7548	0.8477
EALP7	0.9306	0.9082	1.0000	0.9334	0.8695
EMZDP7	0.7831	0.7548	0.9334	1.0000	0.7732
EML7	0.9486	0.8477	0.8695	0.7732	1.0000

Correlation Probability

	EVLKT7	EVLK7	EALP7	EMZDP7	EML7
EVLKT7	<.0001	<.0001	<.0001	0.0015	<.0001
EVLK7	<.0001	<.0001	<.0001	0.0029	0.0003
EALP7	<.0001	<.0001	<.0001	<.0001	0.0001
EMZDP7	0.0015	0.0029	<.0001	<.0001	0.0019
EML7	<.0001	0.0003	0.0001	0.0019	<.0001

Scatterplot Matrix



Exhaust Lifter 8

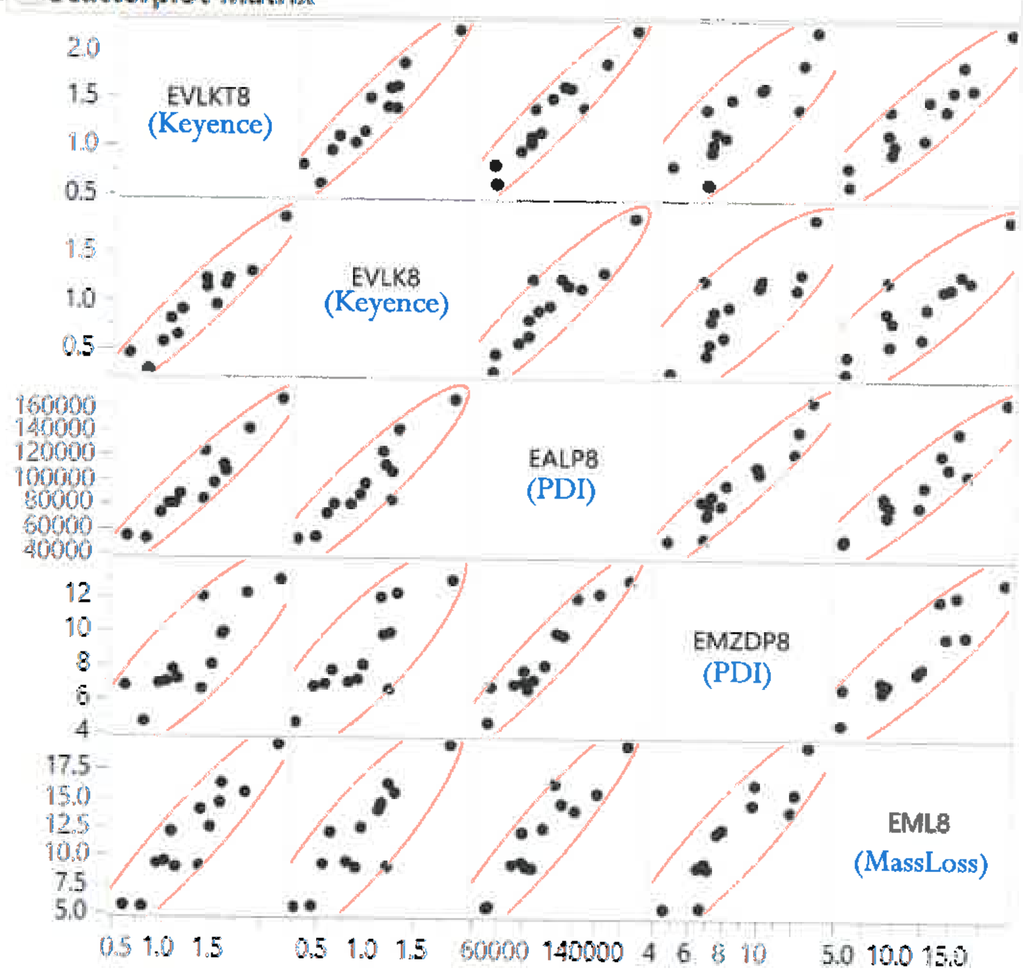
Correlations

	EVLKT8	EVLK8	EALP8	EMZDP8	EML8
EVLKT8	1.0000	0.9474	0.9492	0.8426	0.9298
EVLK8	0.9474	1.0000	0.9239	0.8274	0.8700
EALP8	0.9492	0.9239	1.0000	0.9505	0.9337
EMZDP8	0.8426	0.8274	0.9505	1.0000	0.9074
EML8	0.9298	0.8700	0.9337	0.9074	1.0000

Correlation Probability

	EVLKT8	EVLK8	EALP8	EMZDP8	EML8
EVLKT8	<.0001	<.0001	<.0001	0.0003	<.0001
EVLK8	<.0001	<.0001	<.0001	0.0005	0.0001
EALP8	<.0001	<.0001	<.0001	<.0001	<.0001
EMZDP8	0.0003	0.0005	<.0001	<.0001	<.0001
EML8	<.0001	0.0001	<.0001	<.0001	<.0001

Scatterplot Matrix



IVB Operational Data Review
11 Prove Out Tests

Prepared by: Kevin O'Malley

10-12-17

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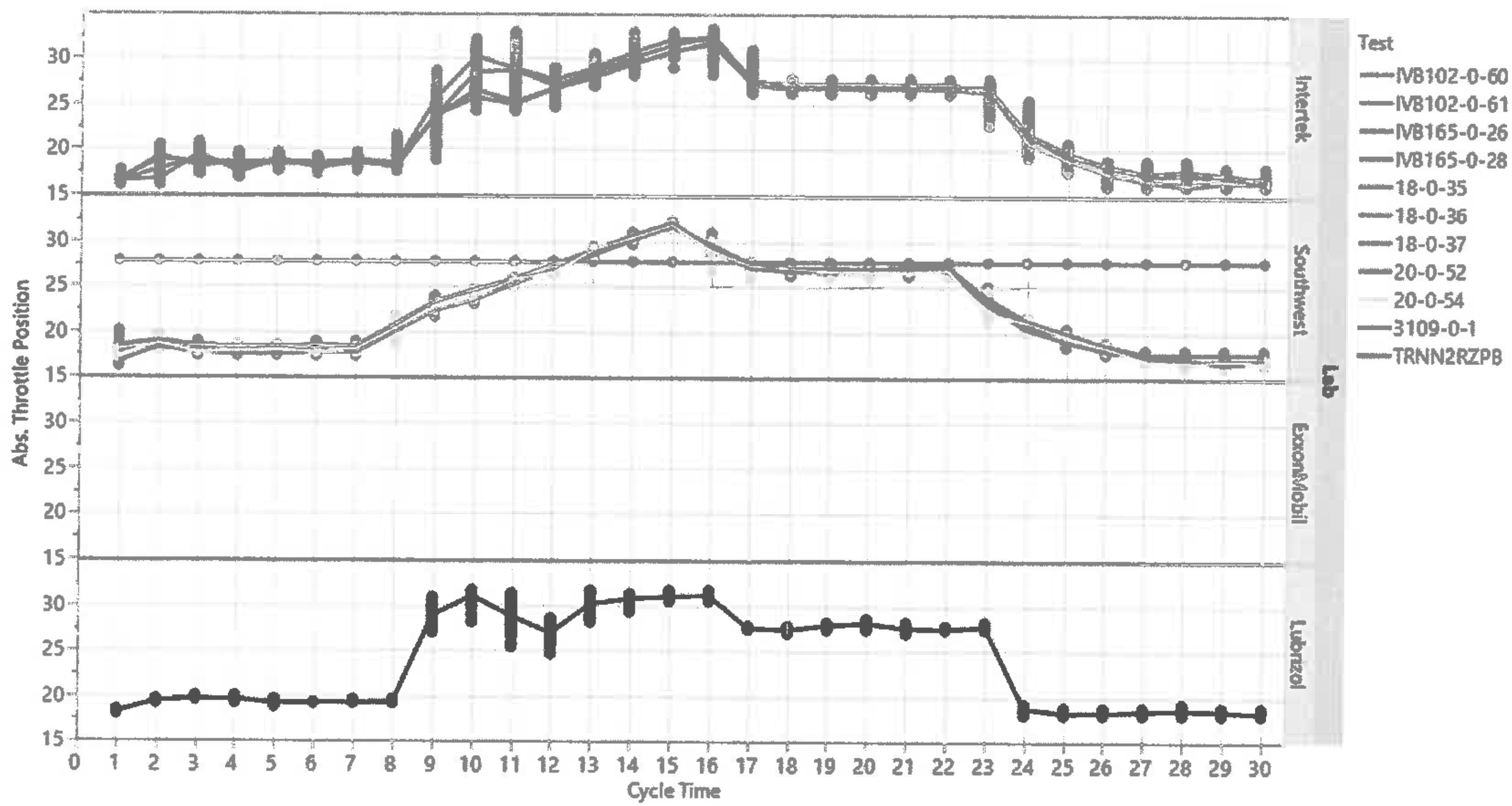

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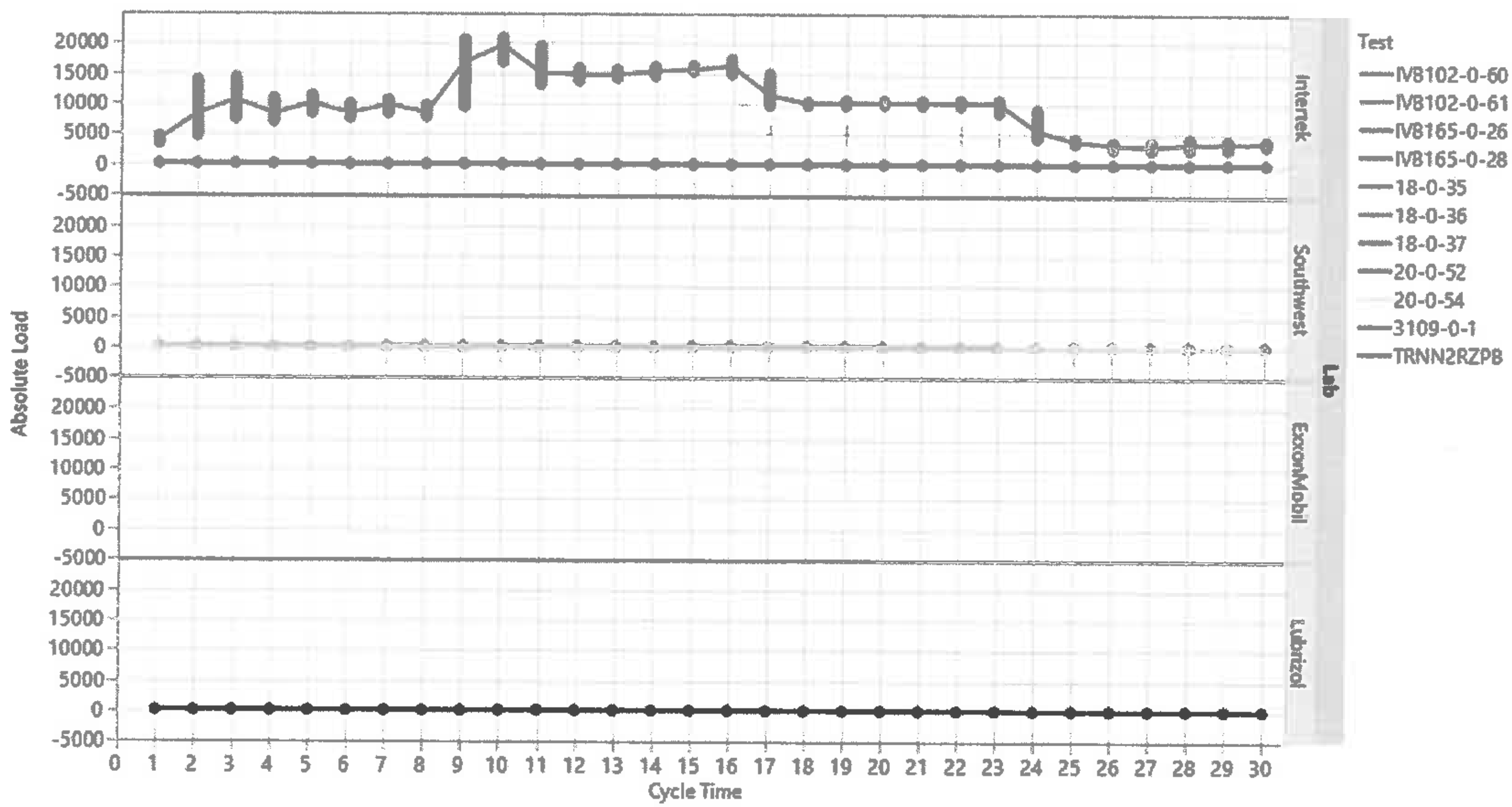

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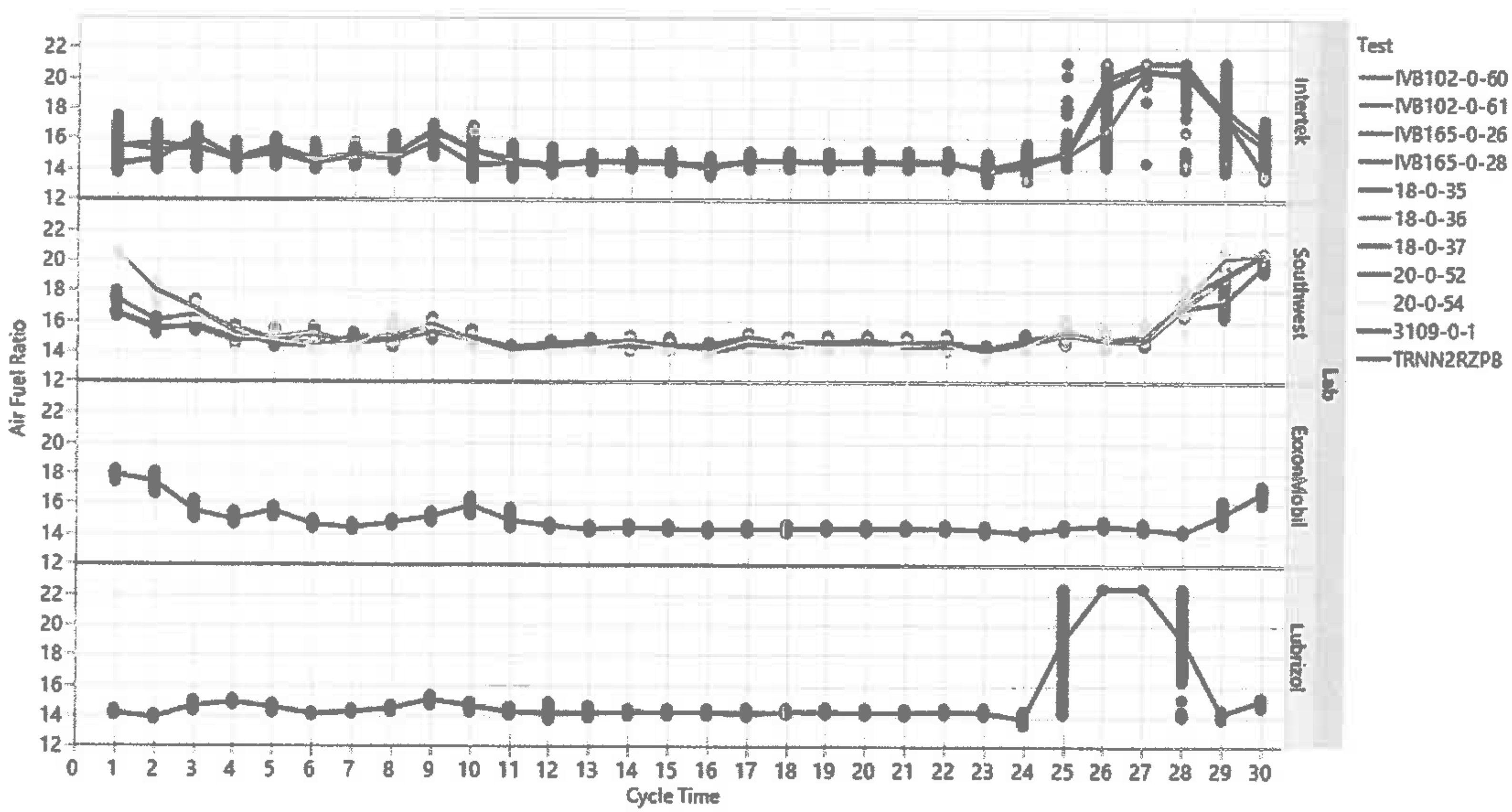

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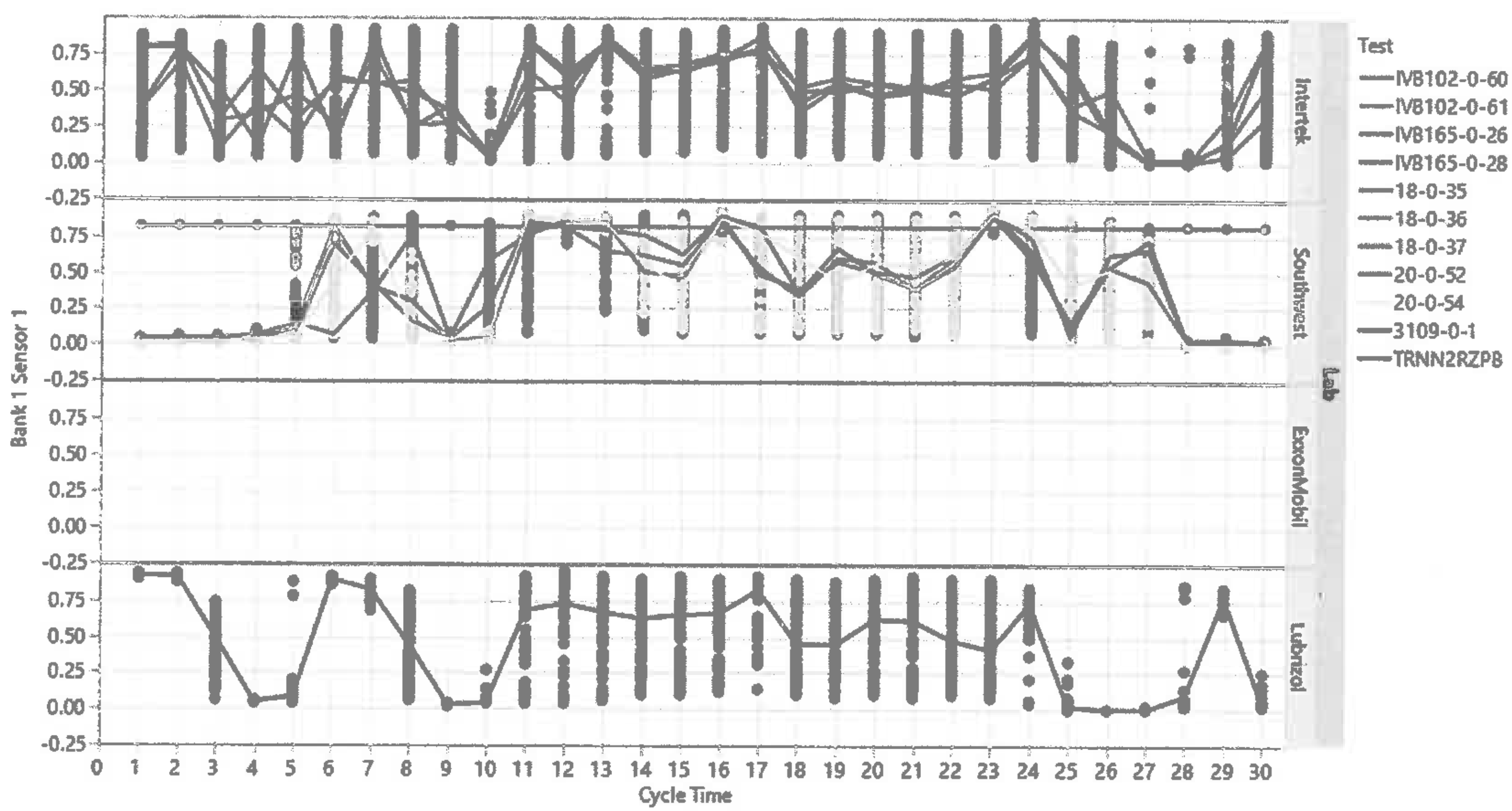

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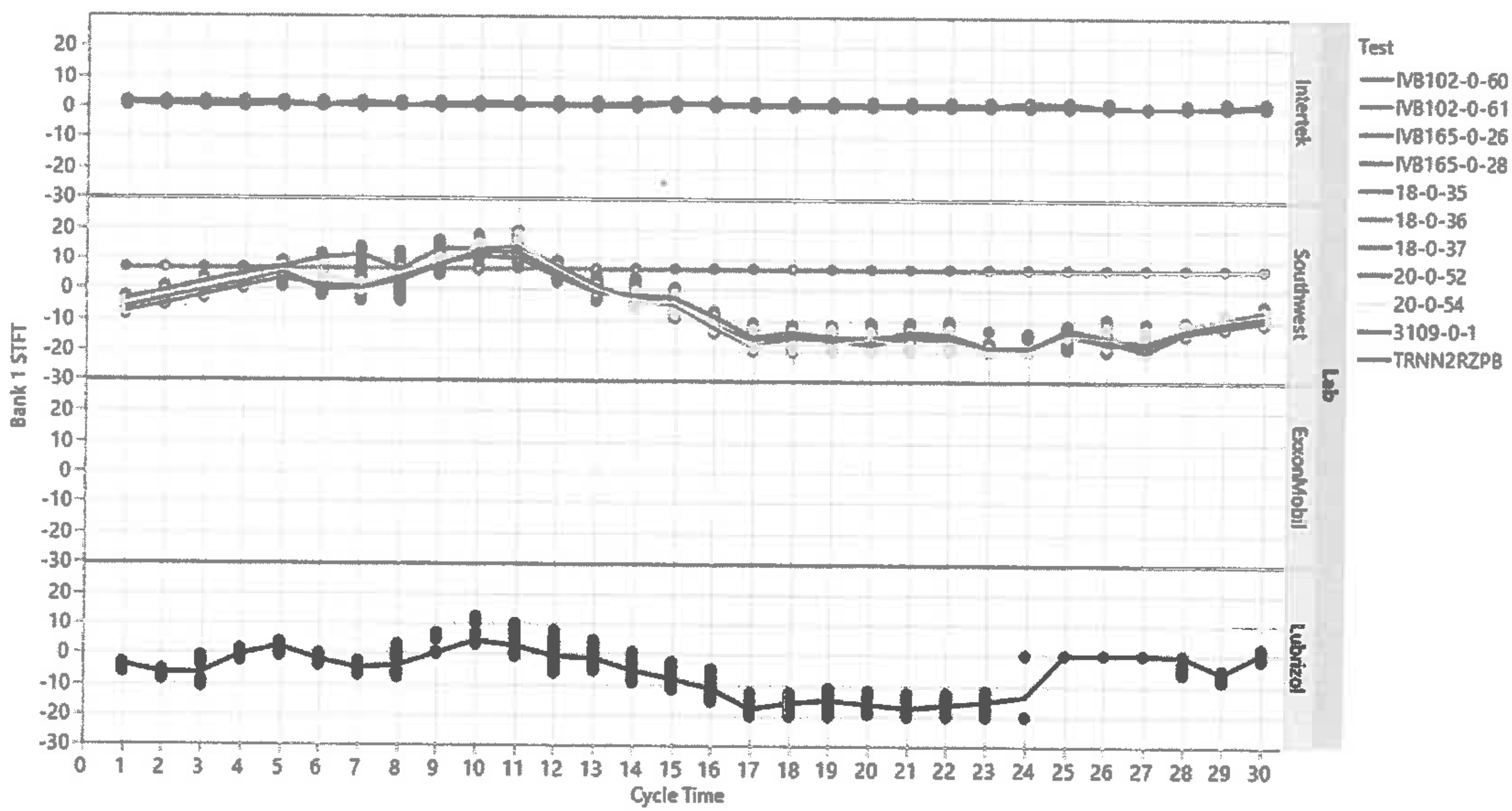

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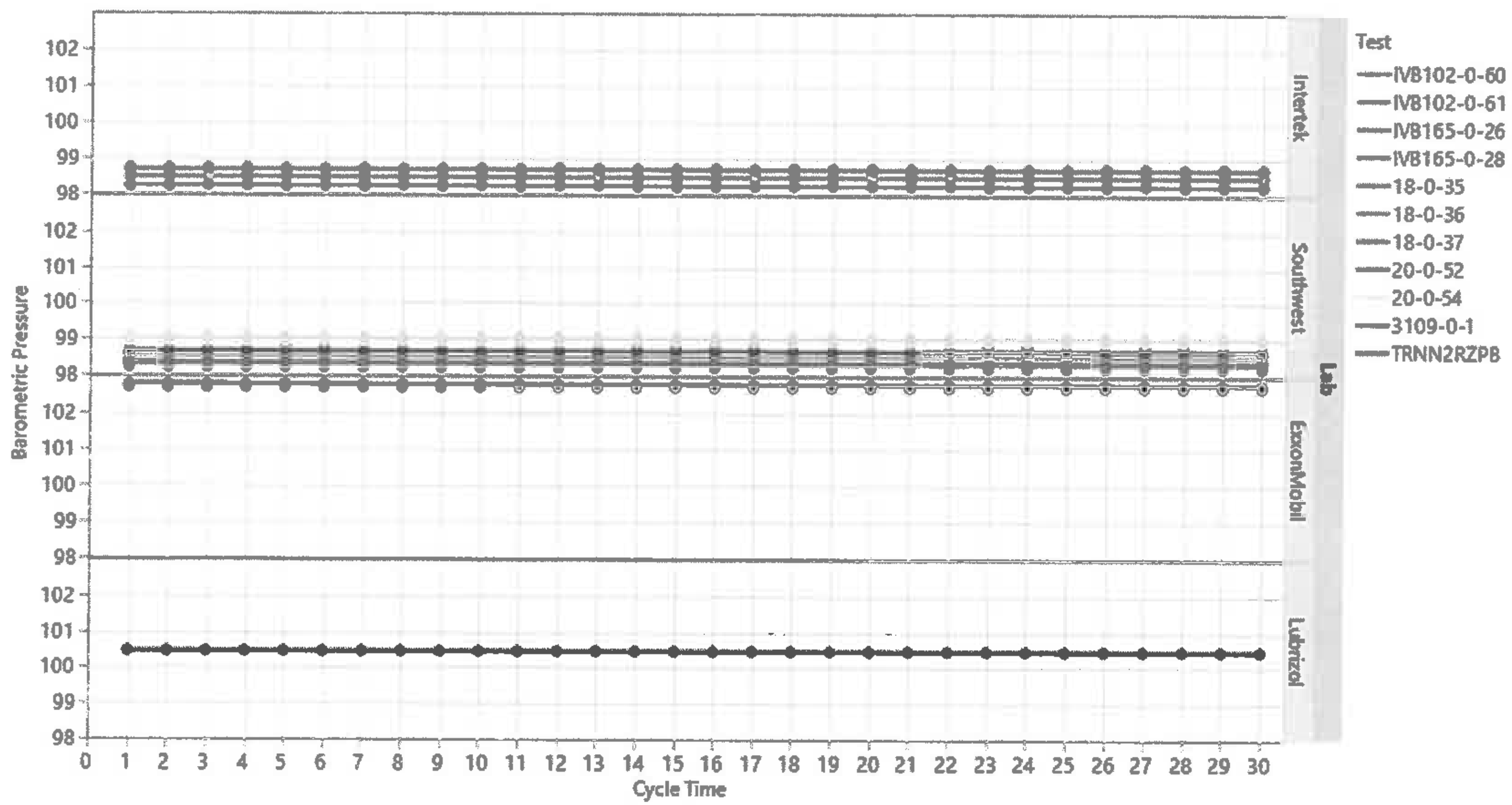

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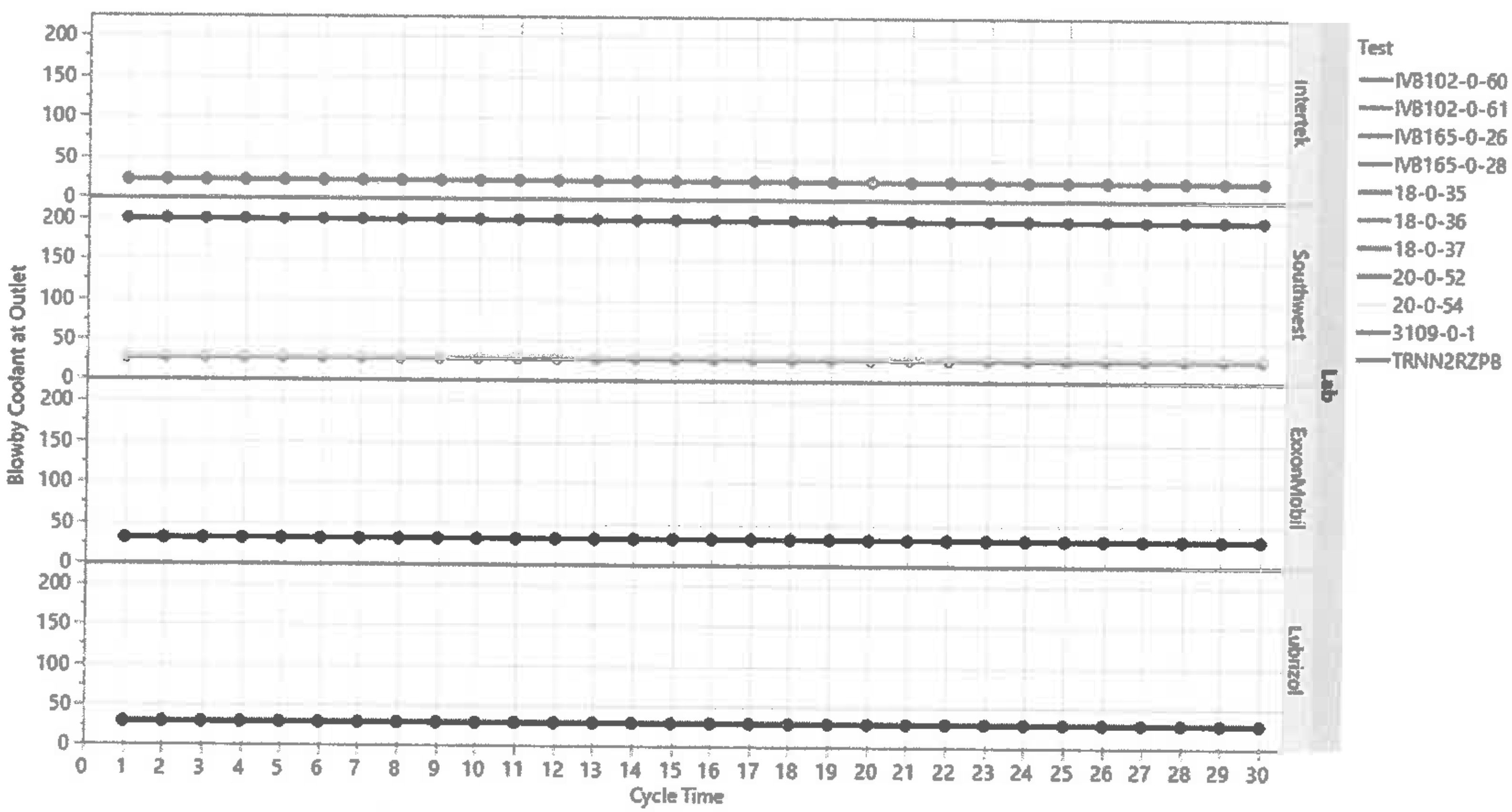

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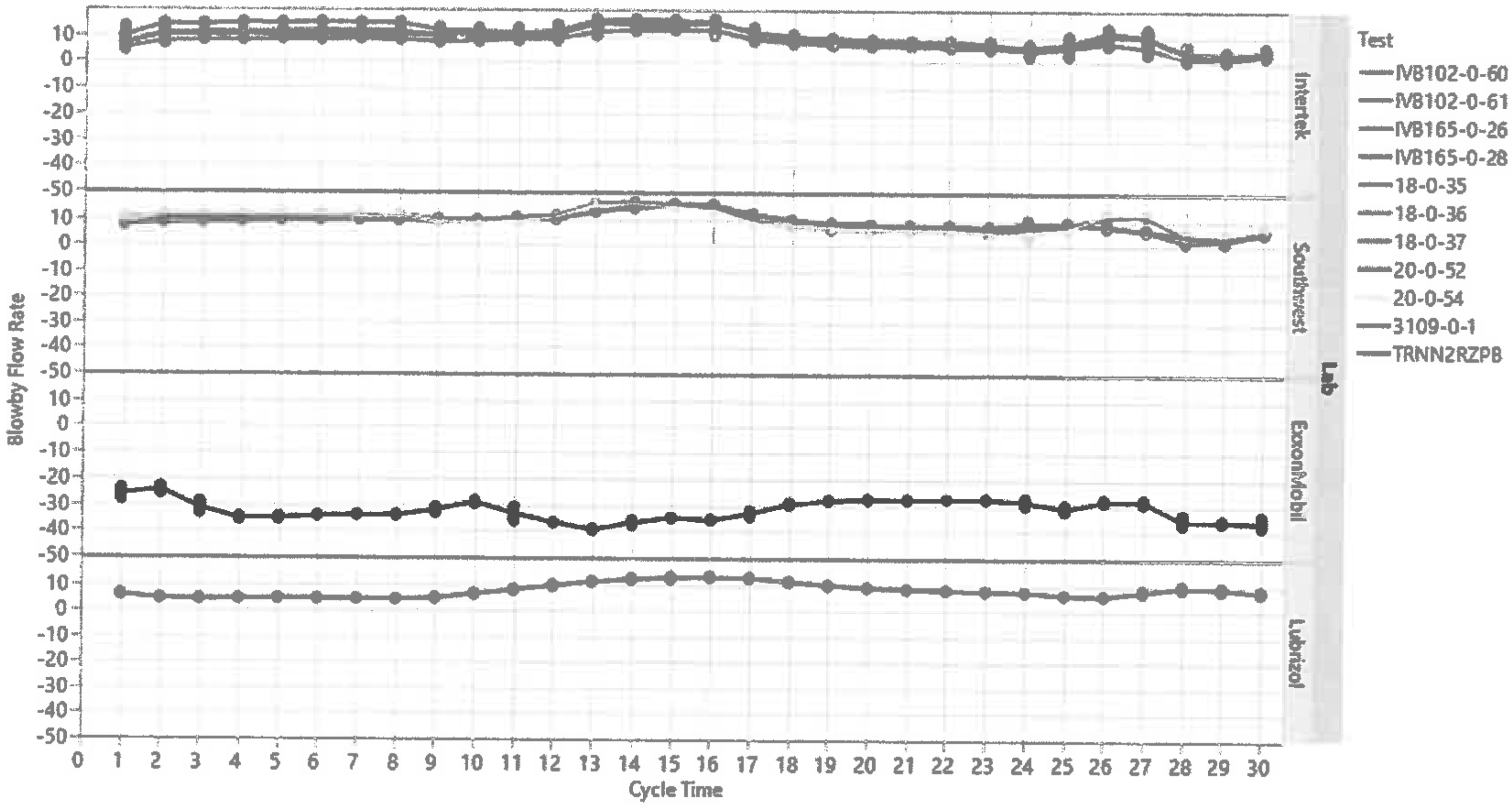

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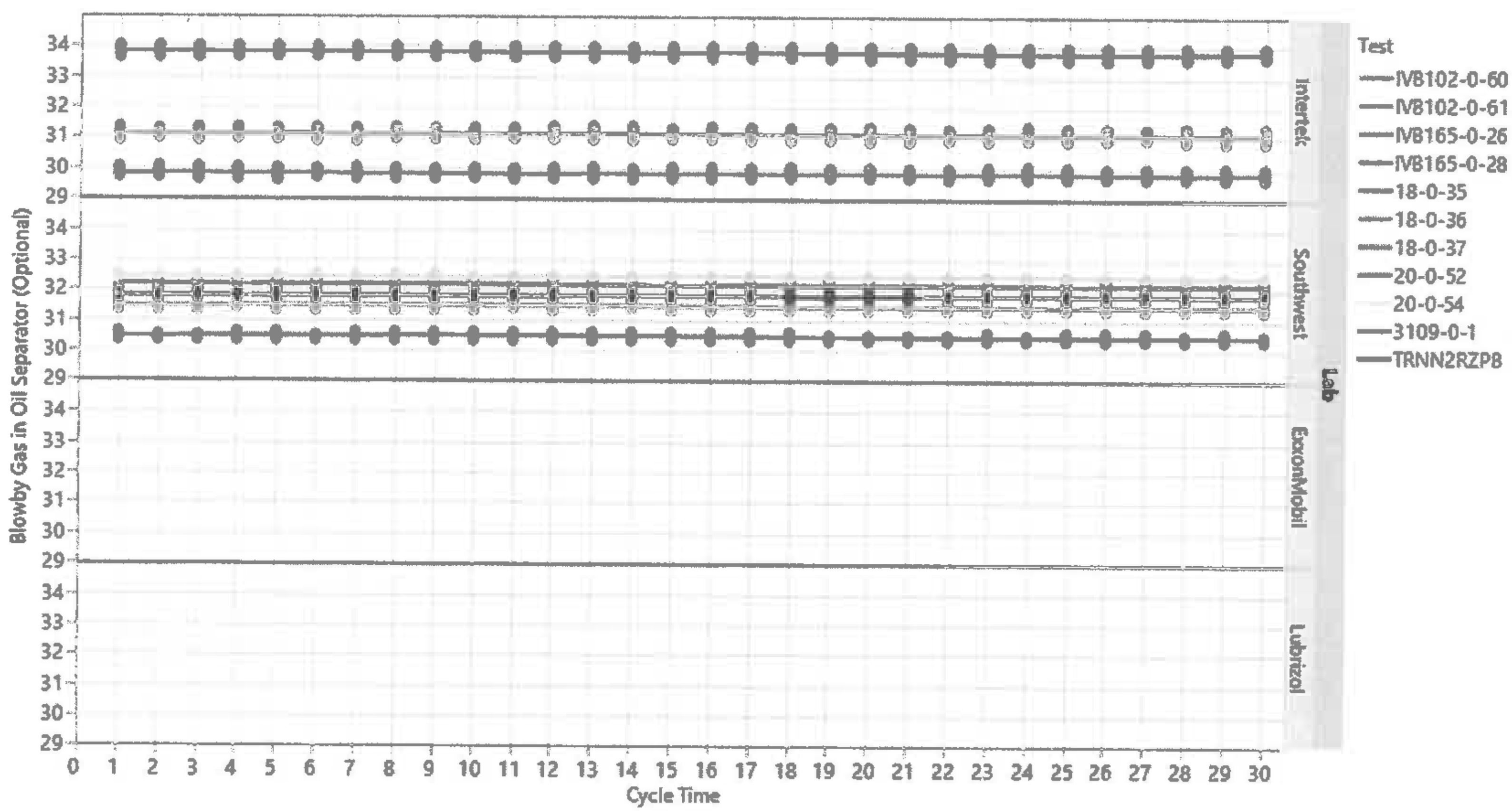

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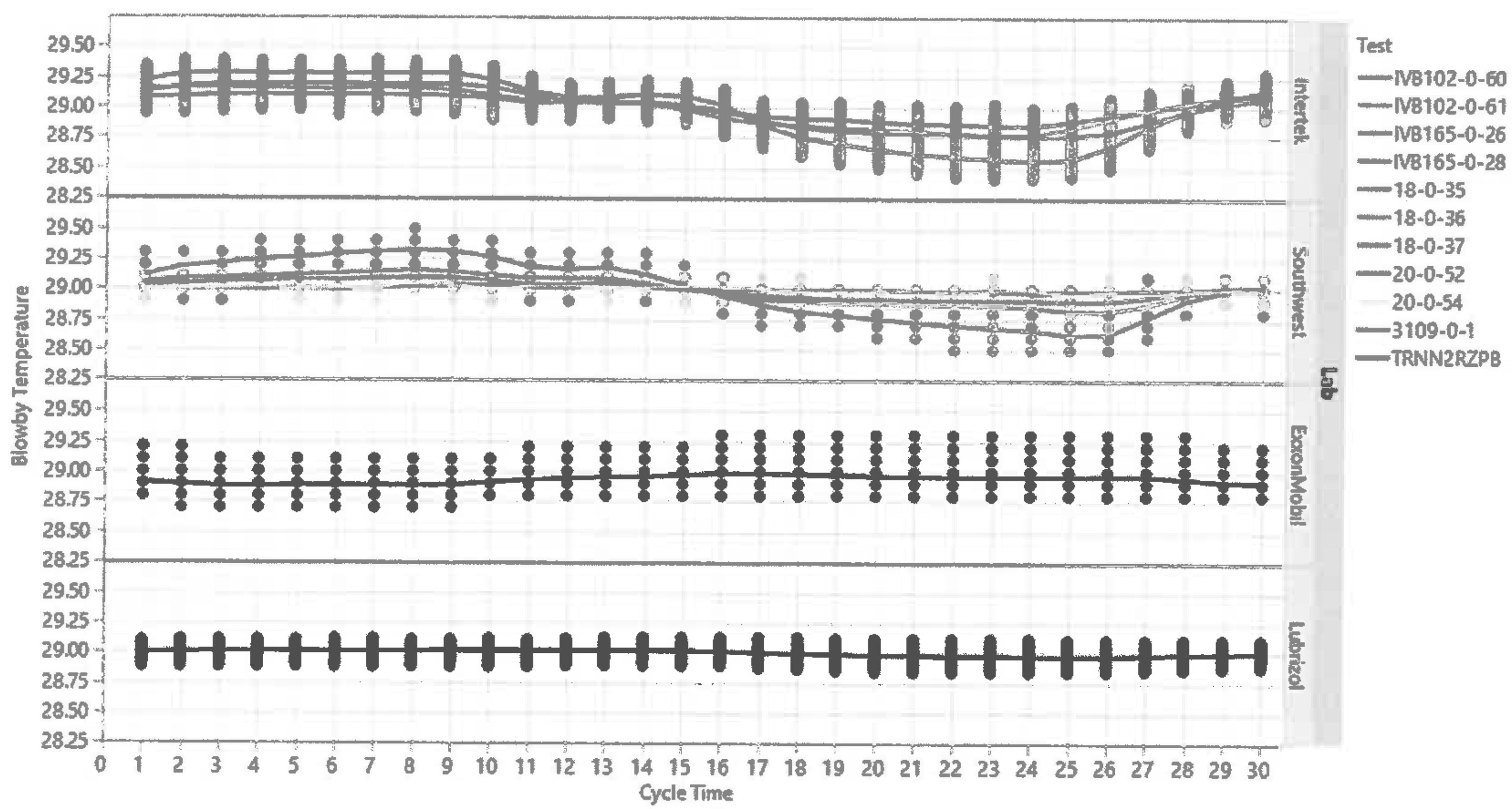

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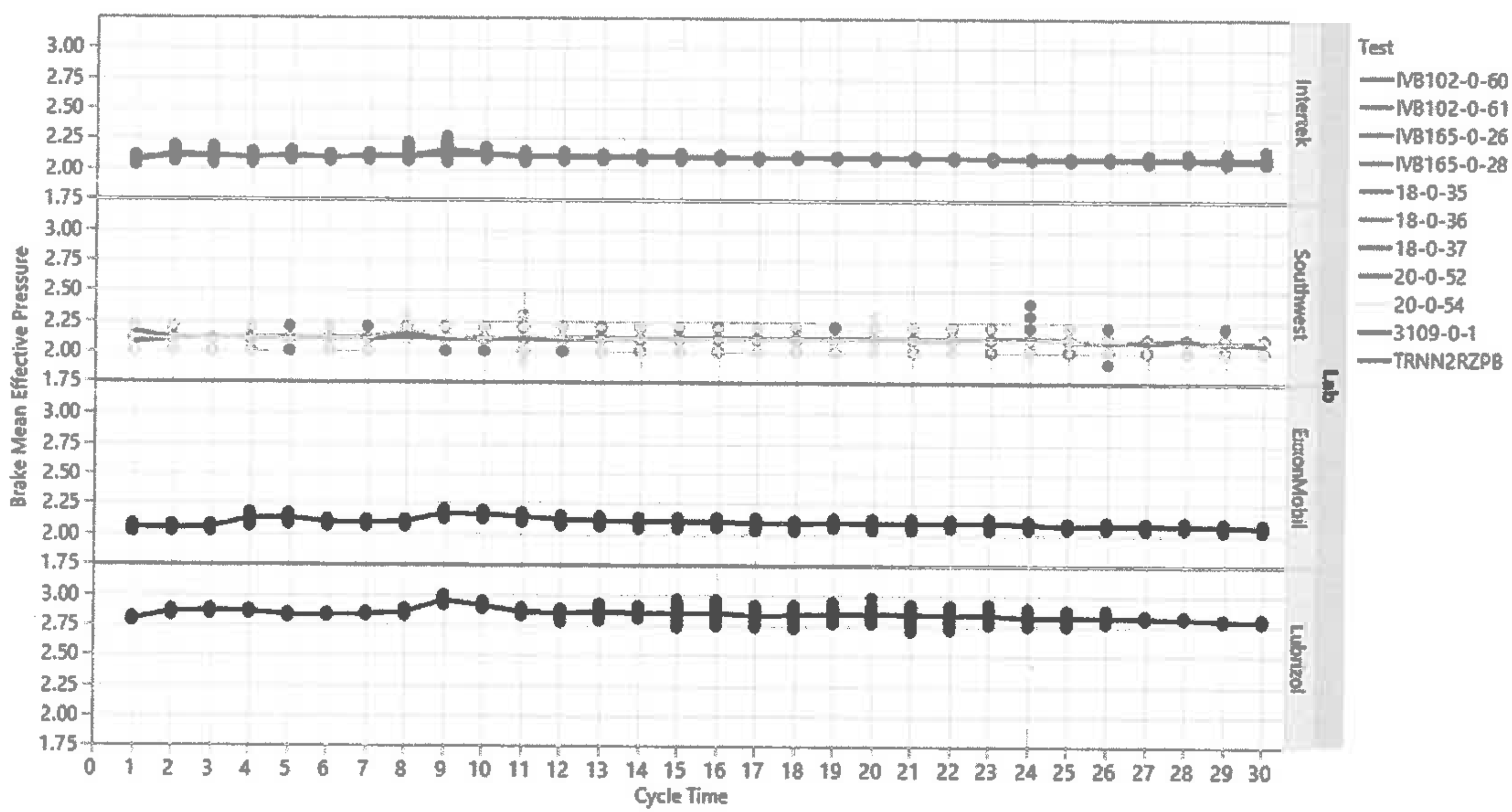

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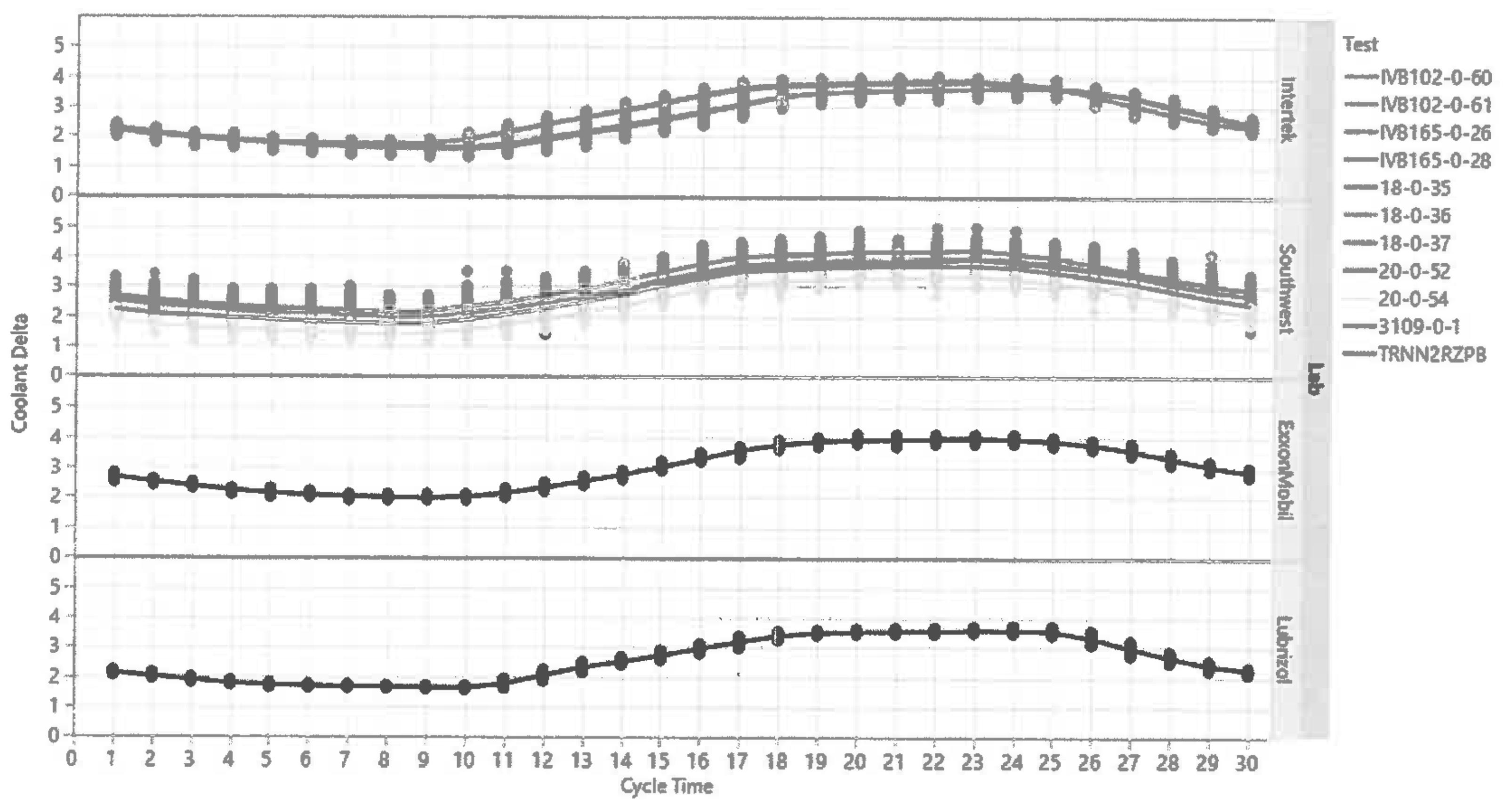

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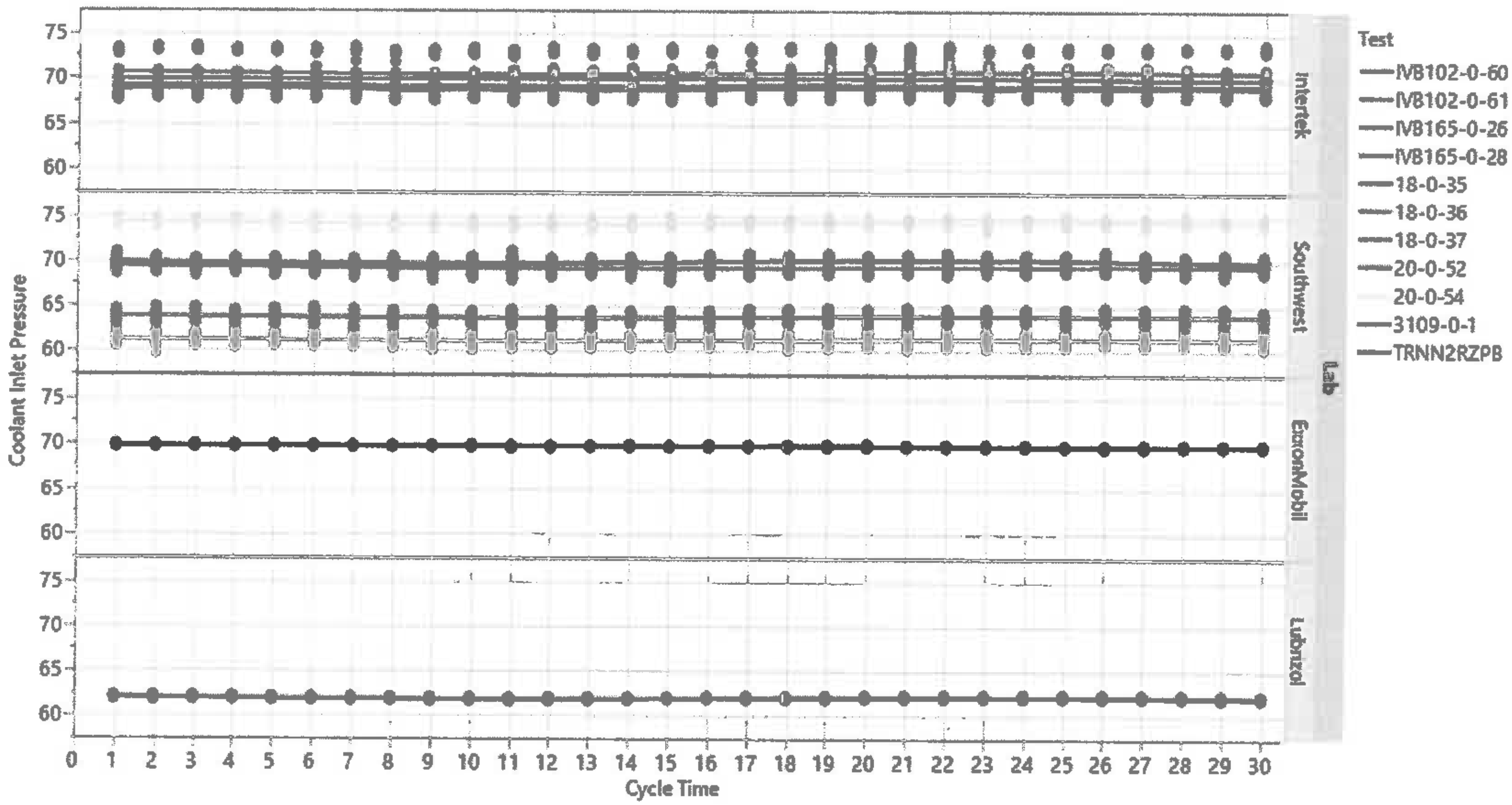

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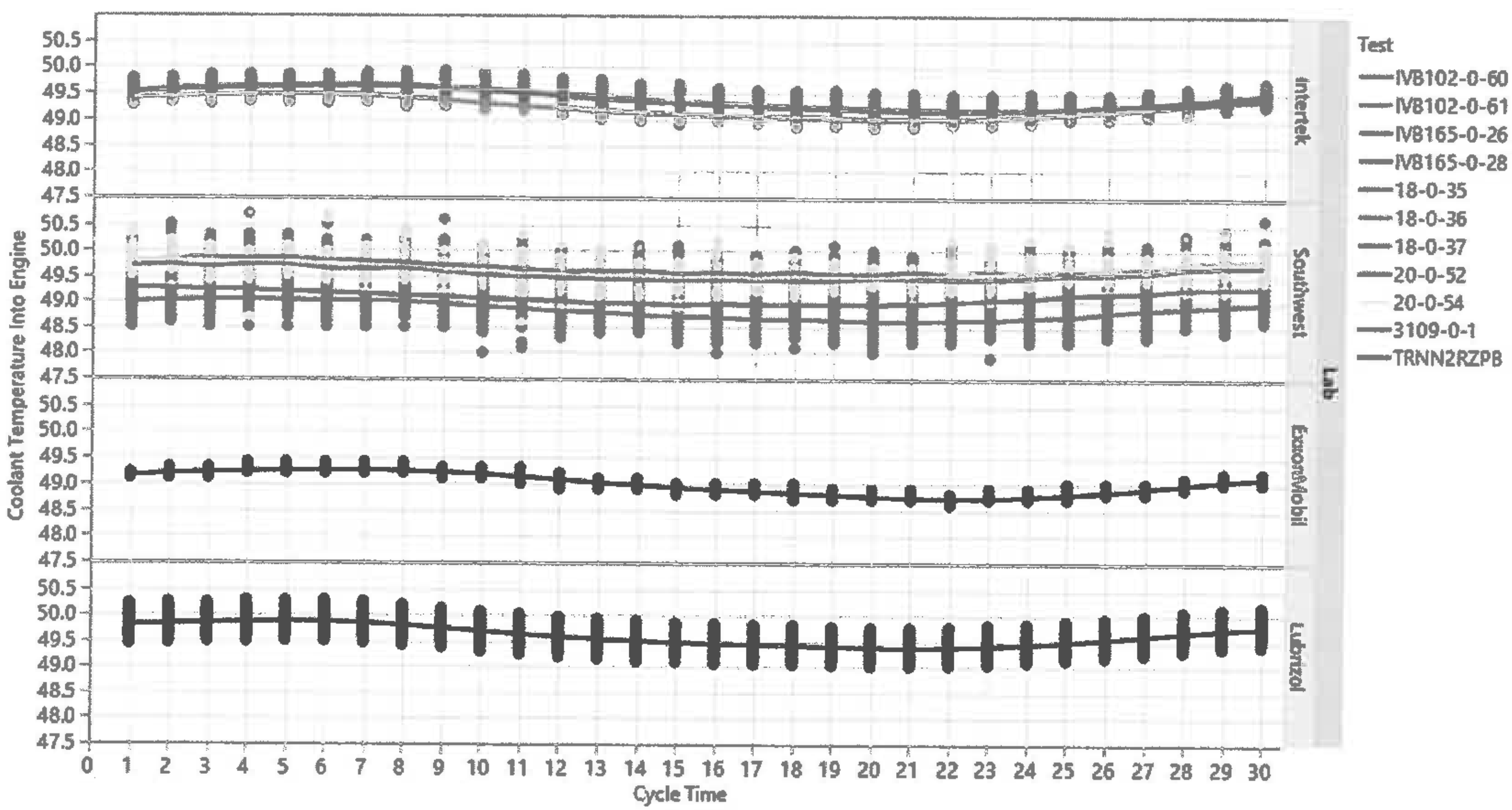

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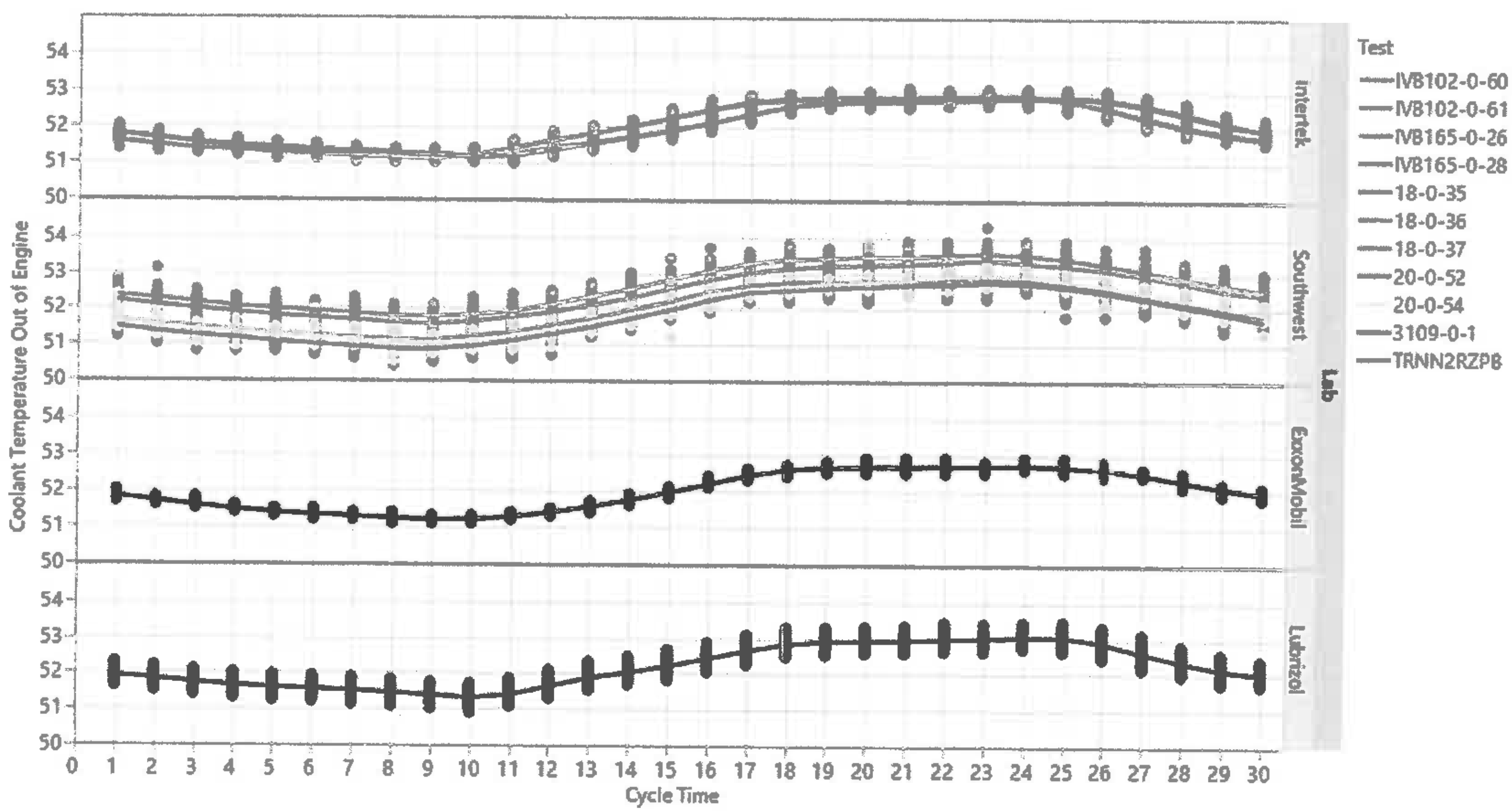

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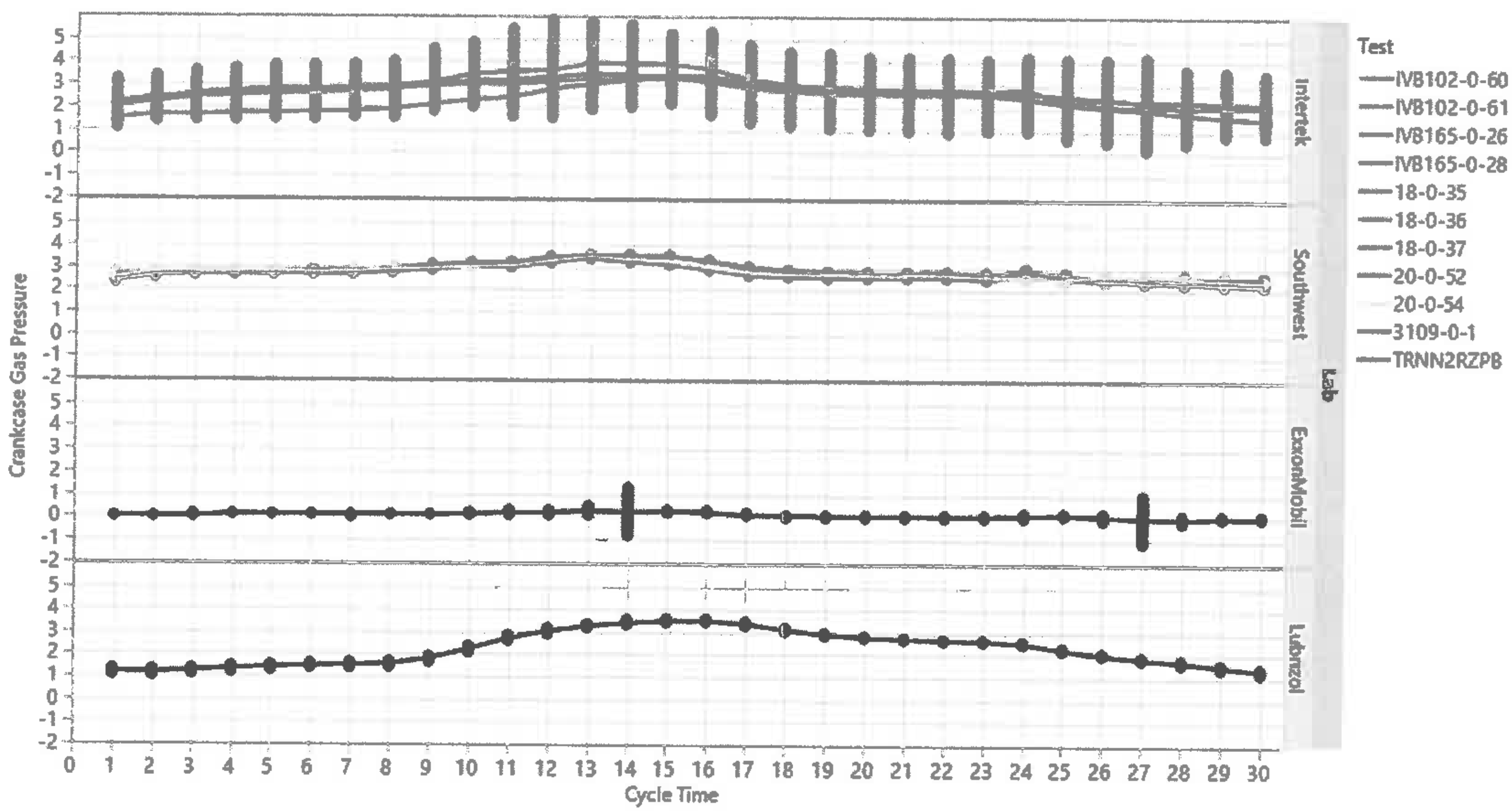

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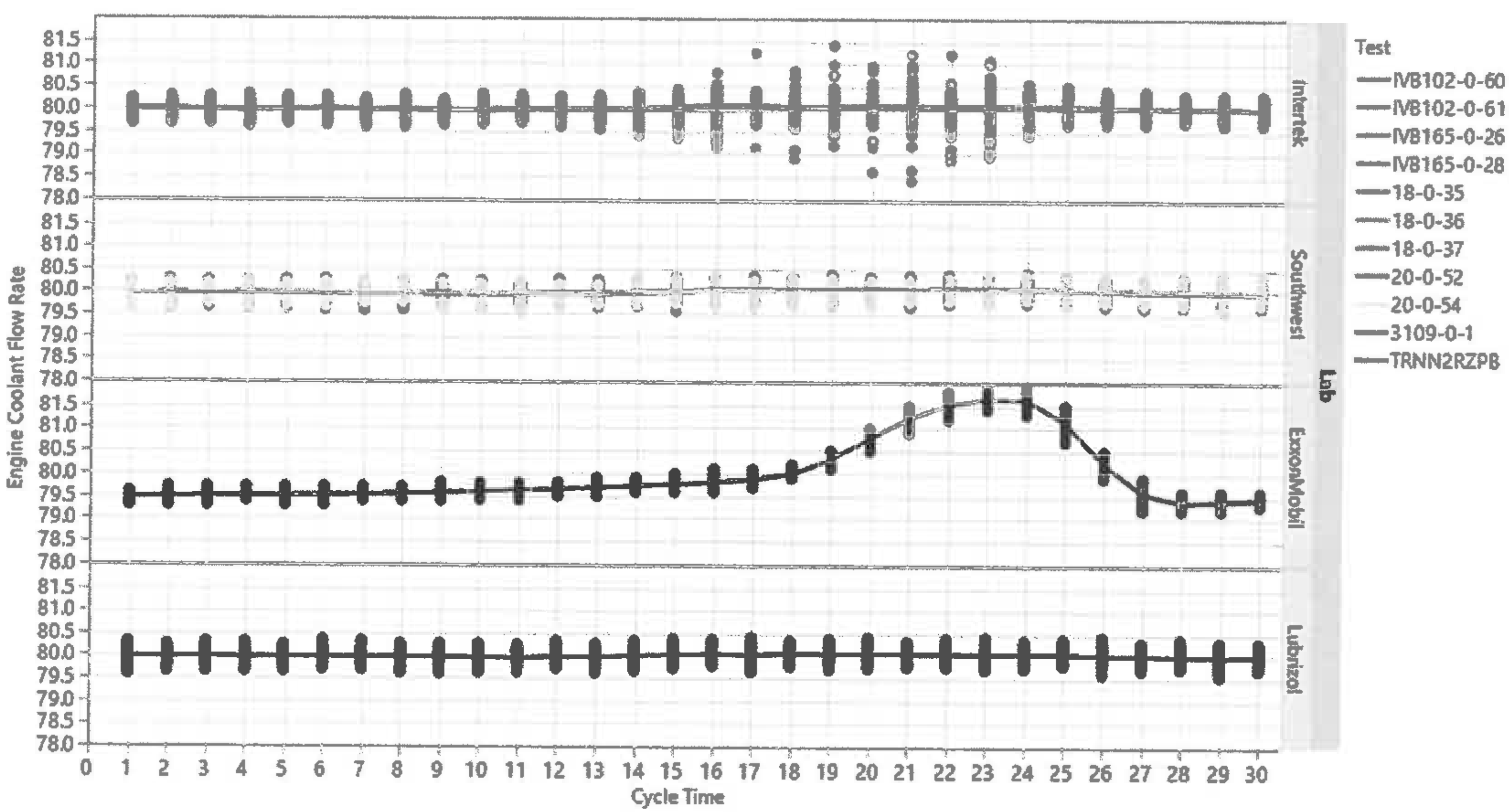

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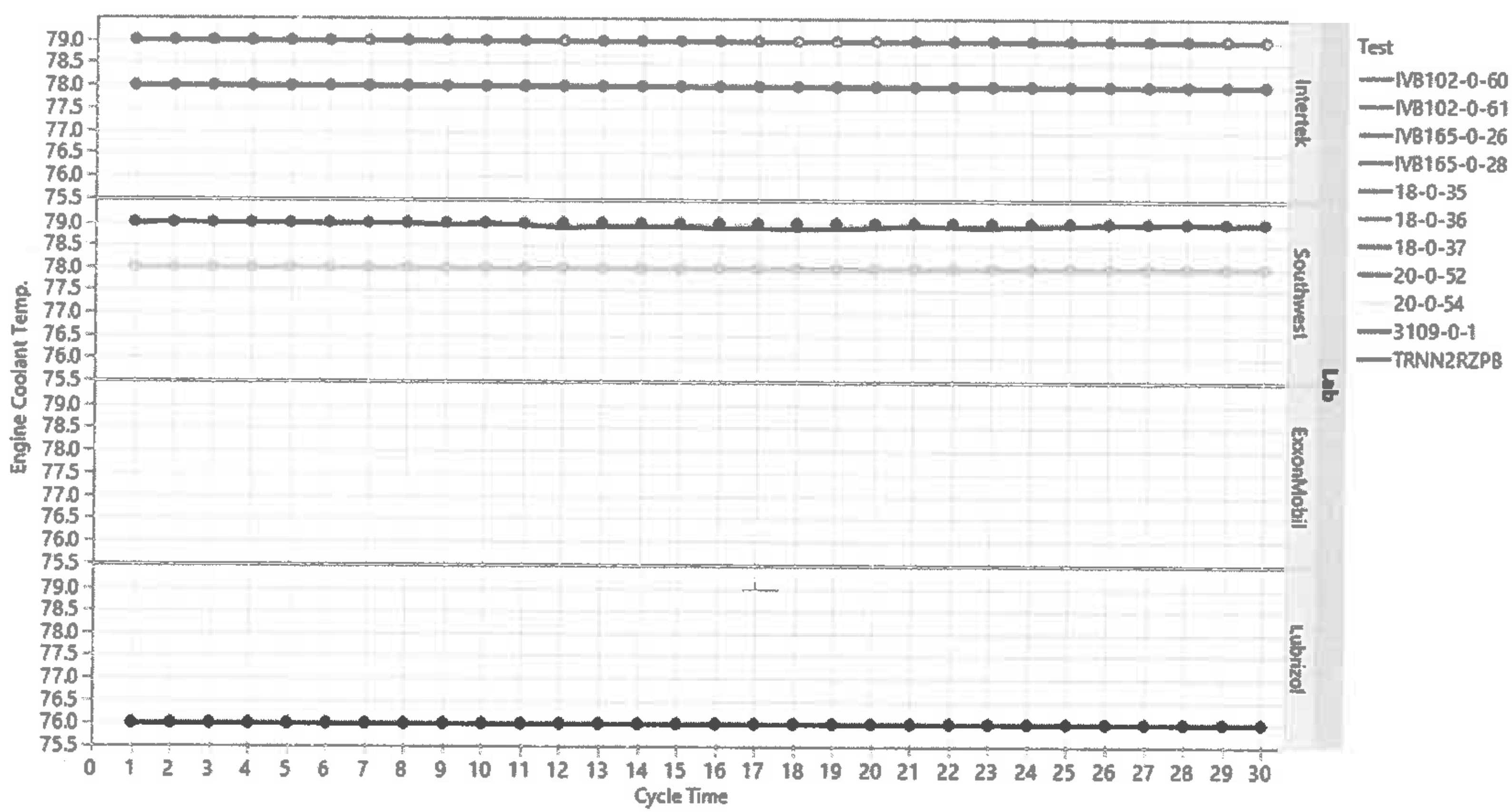

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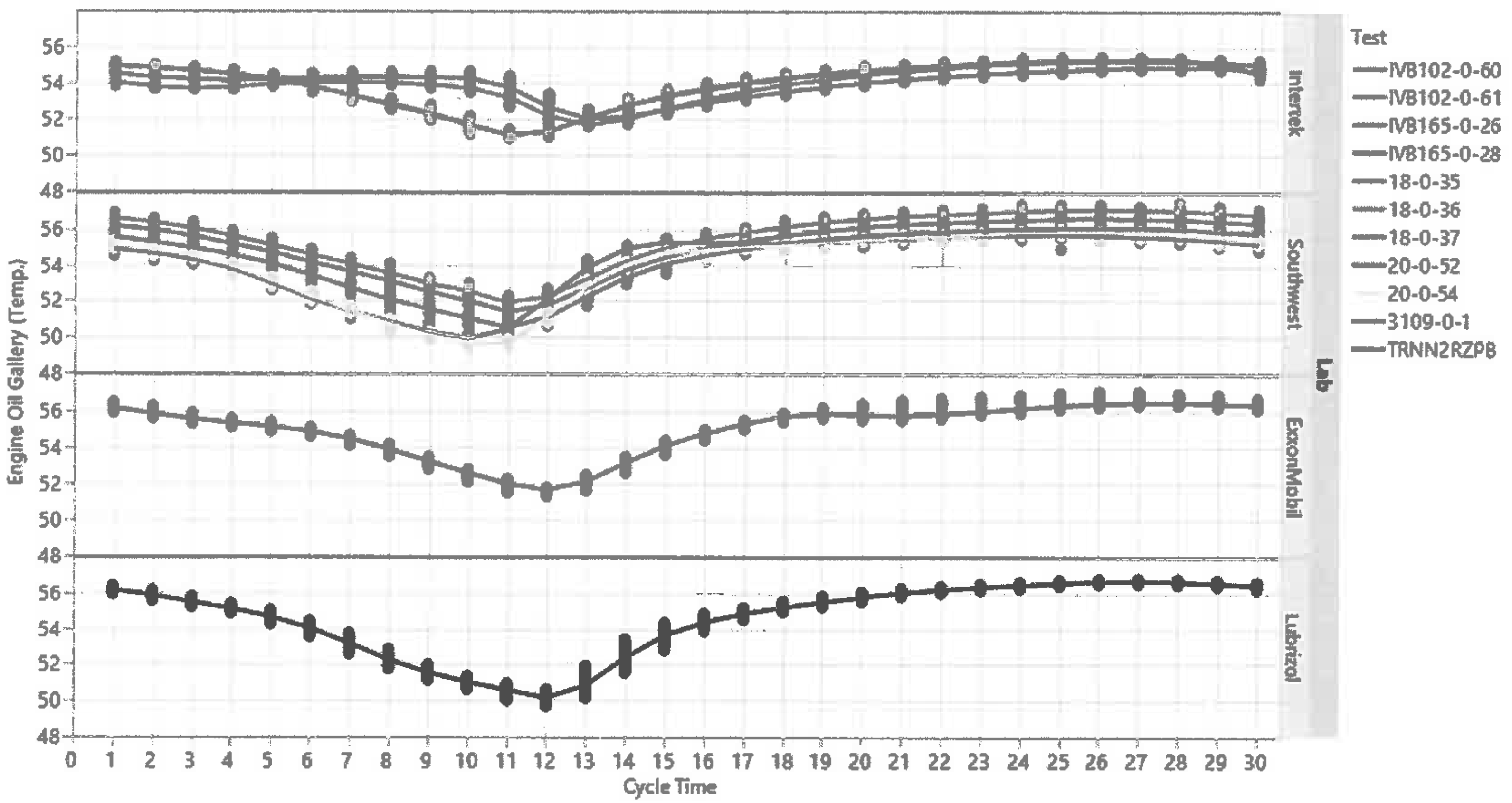

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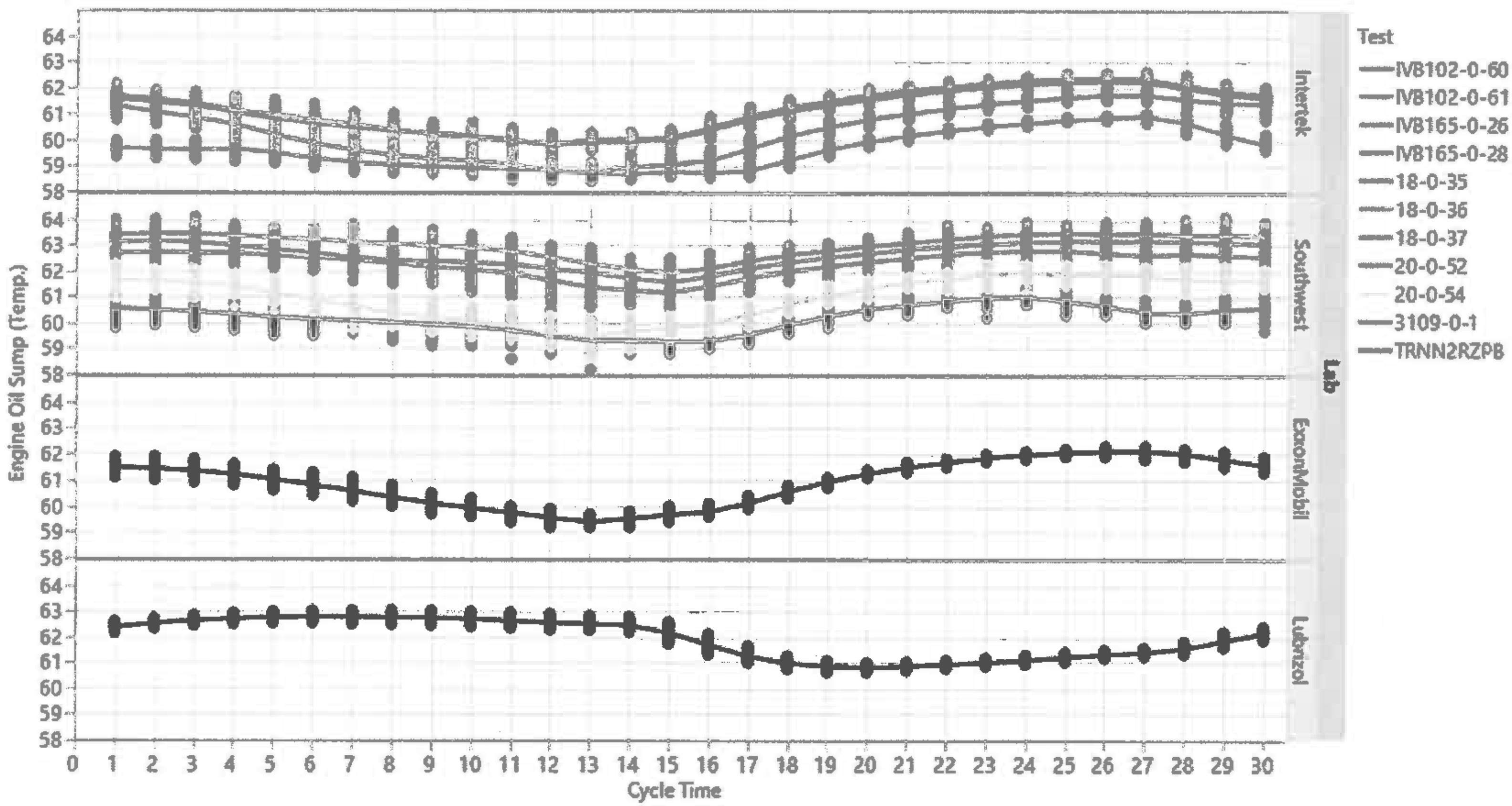

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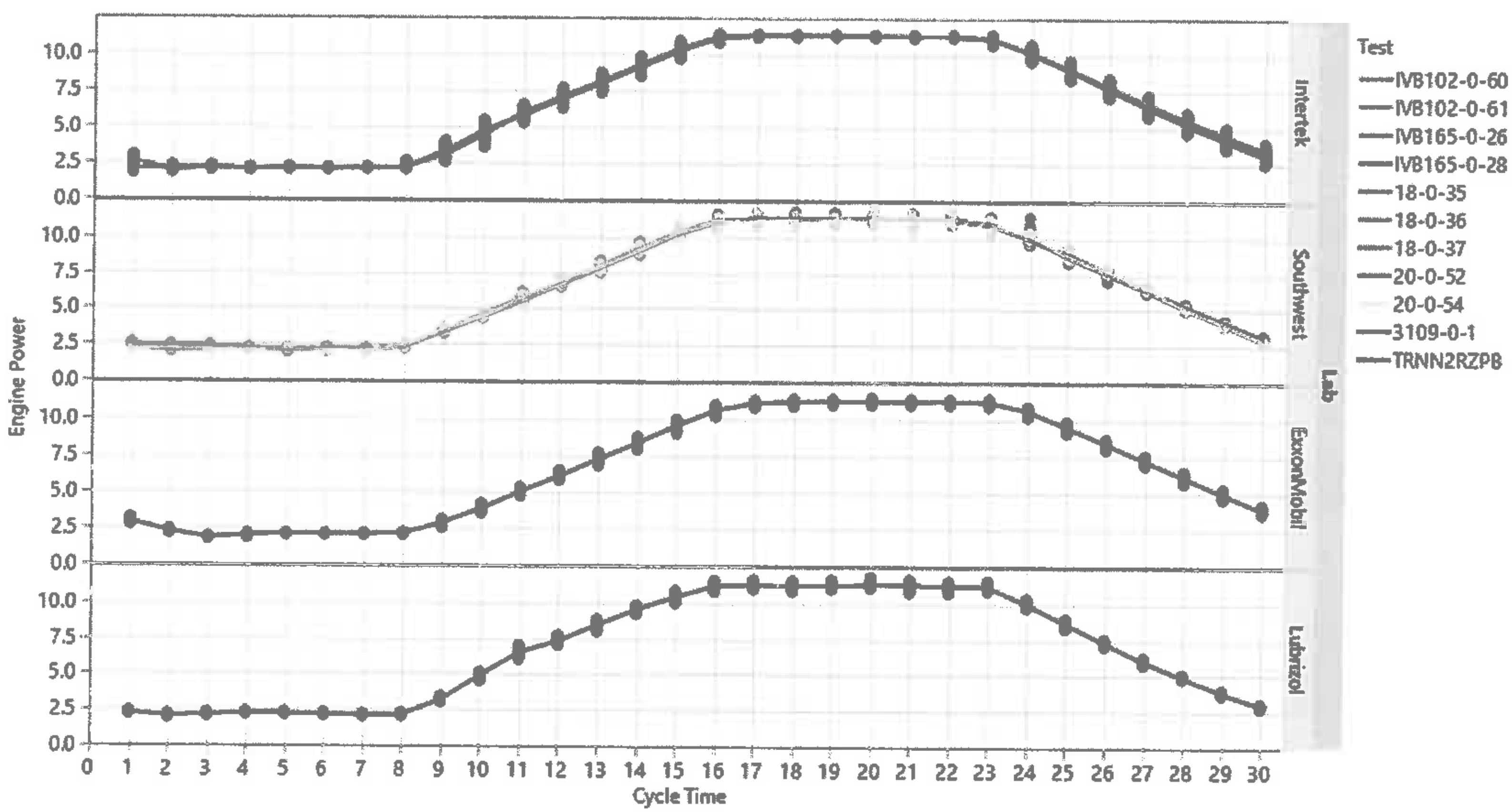

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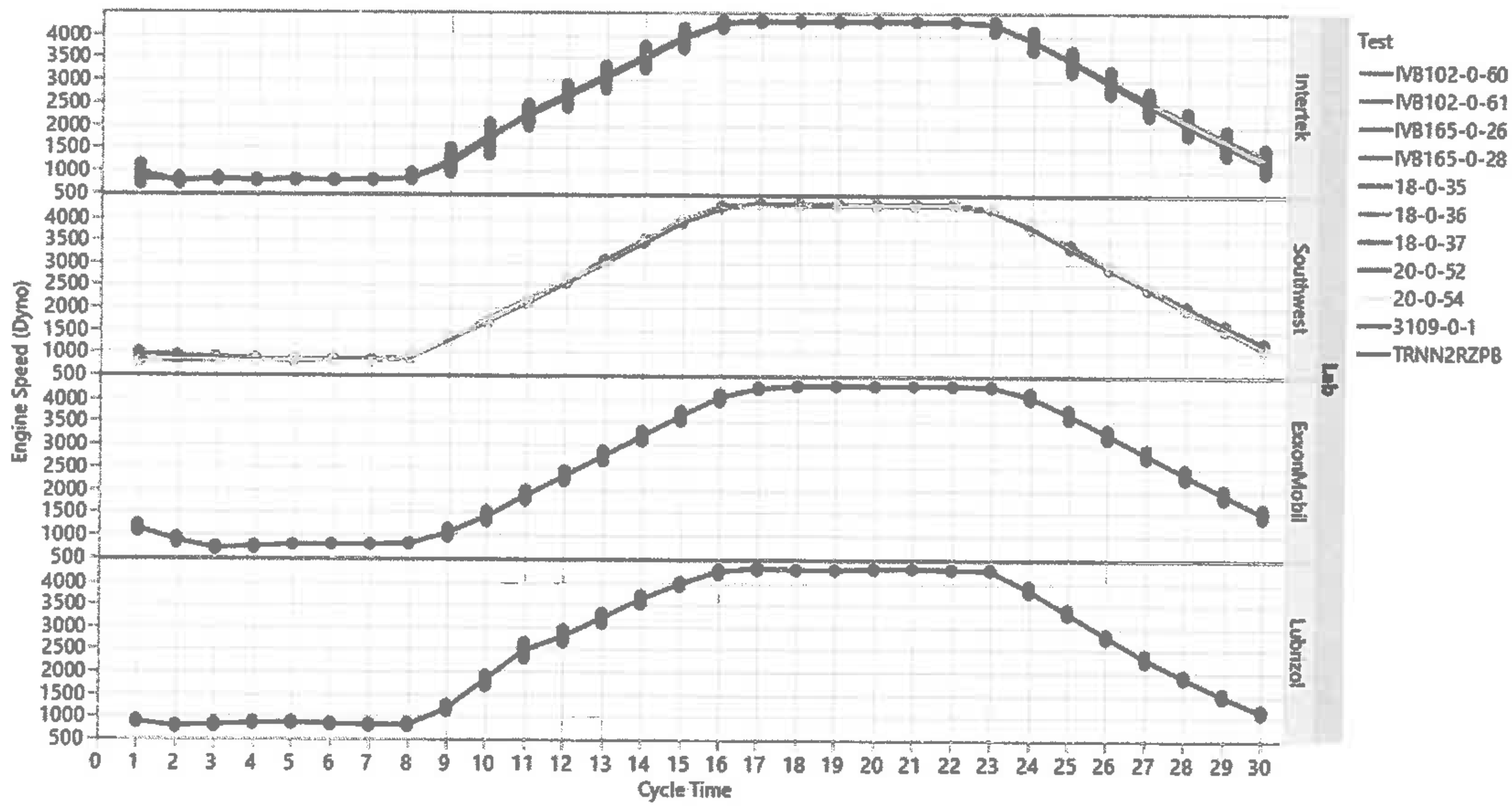

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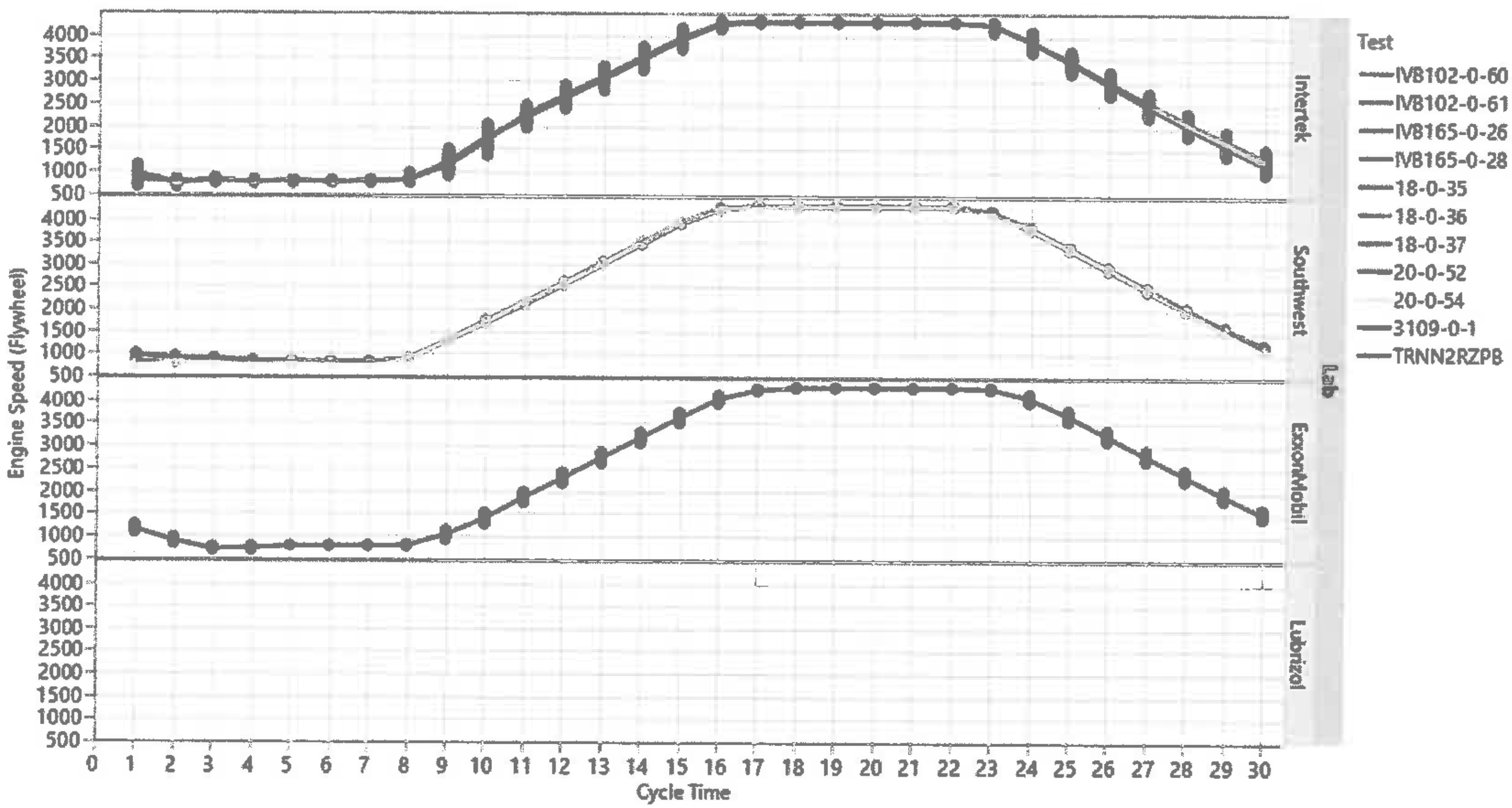

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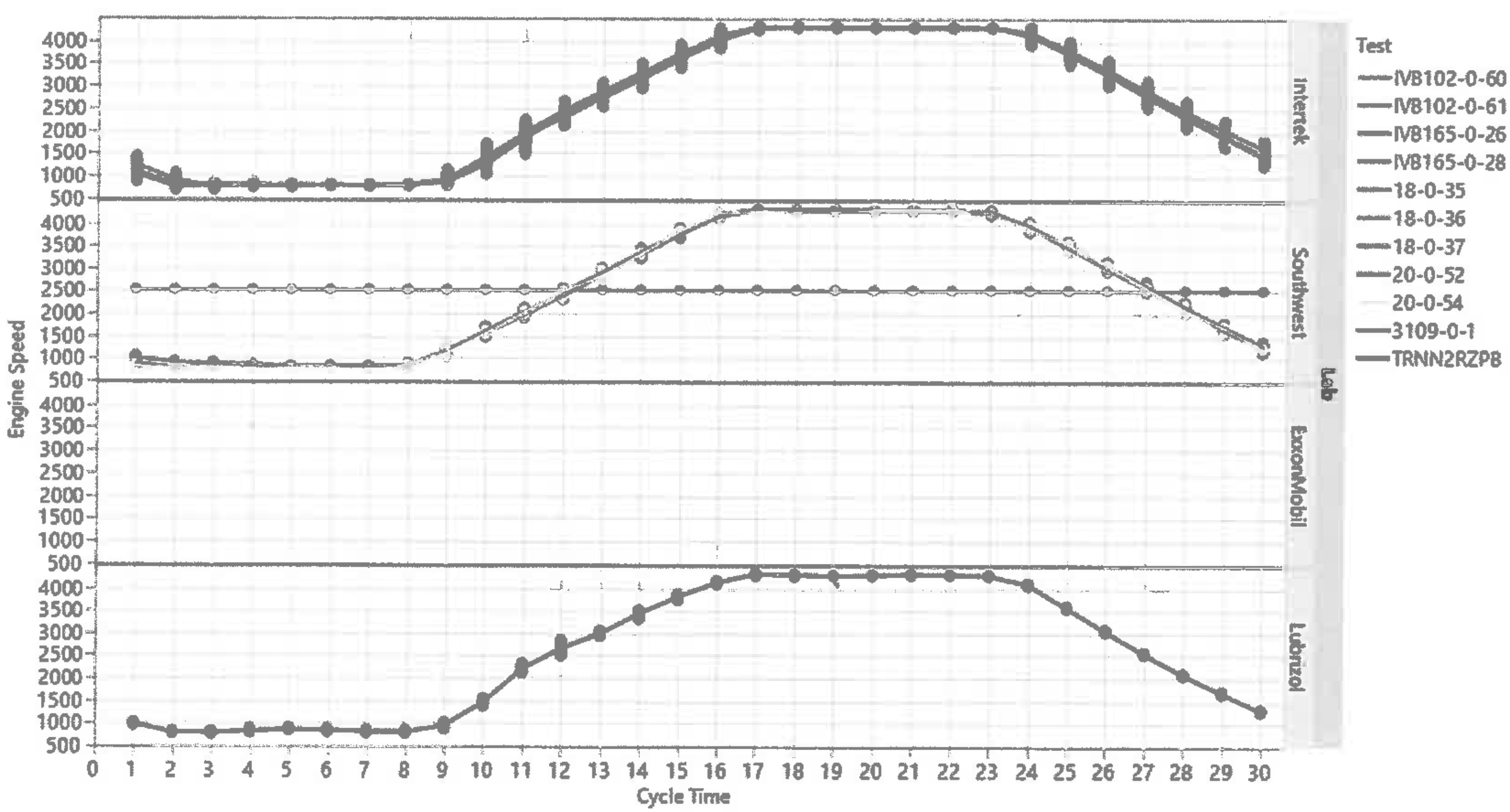

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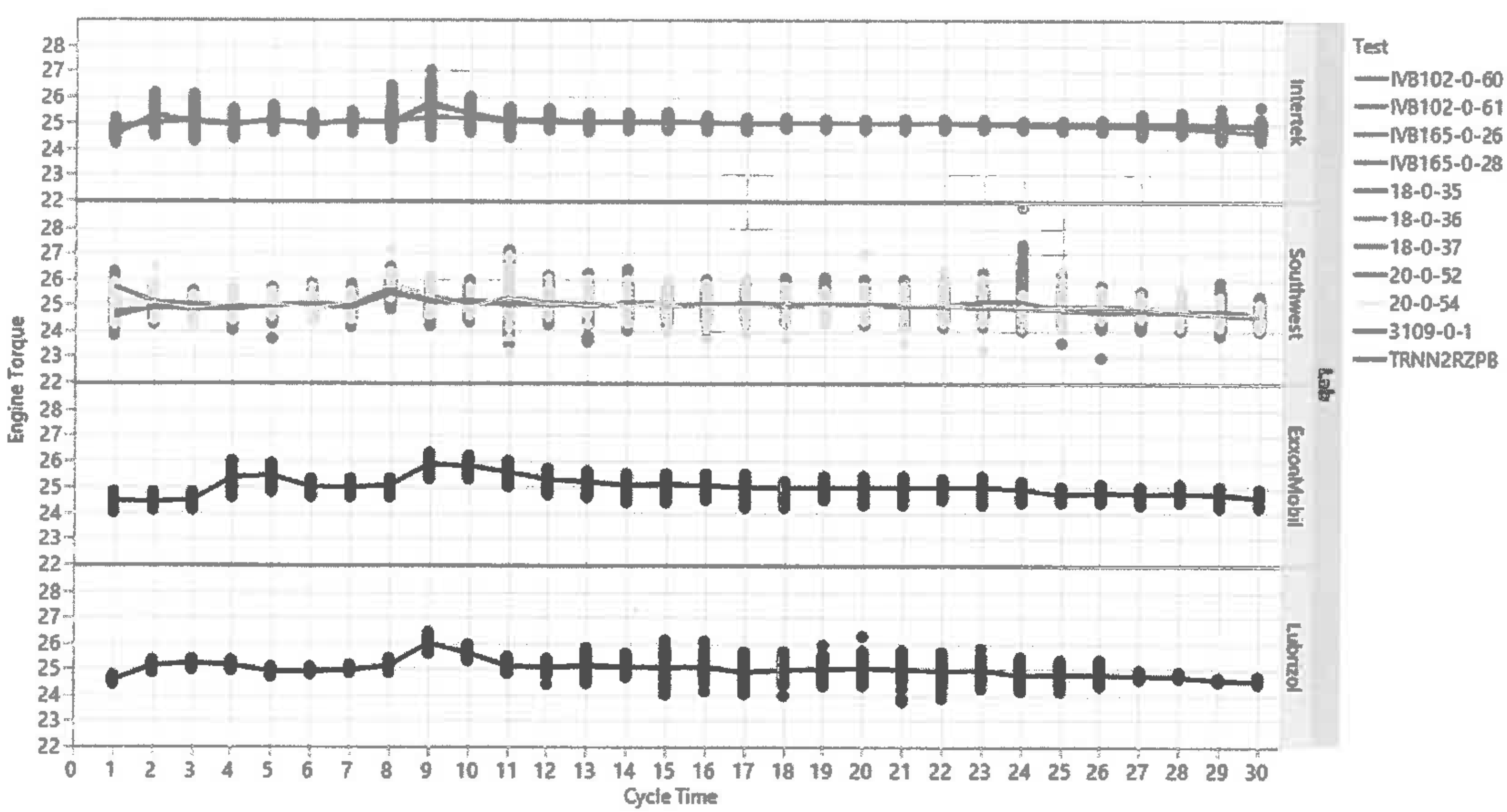

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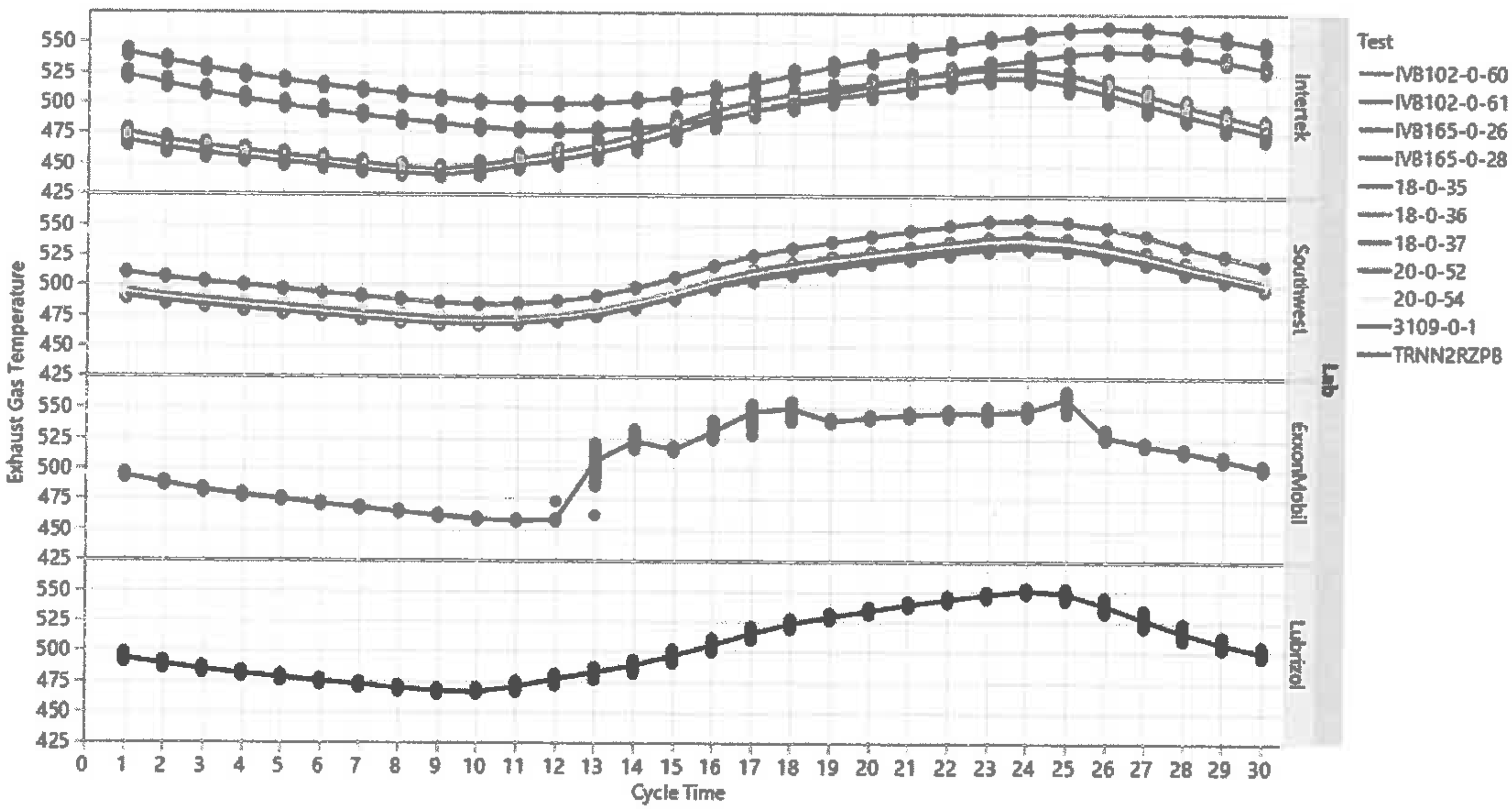

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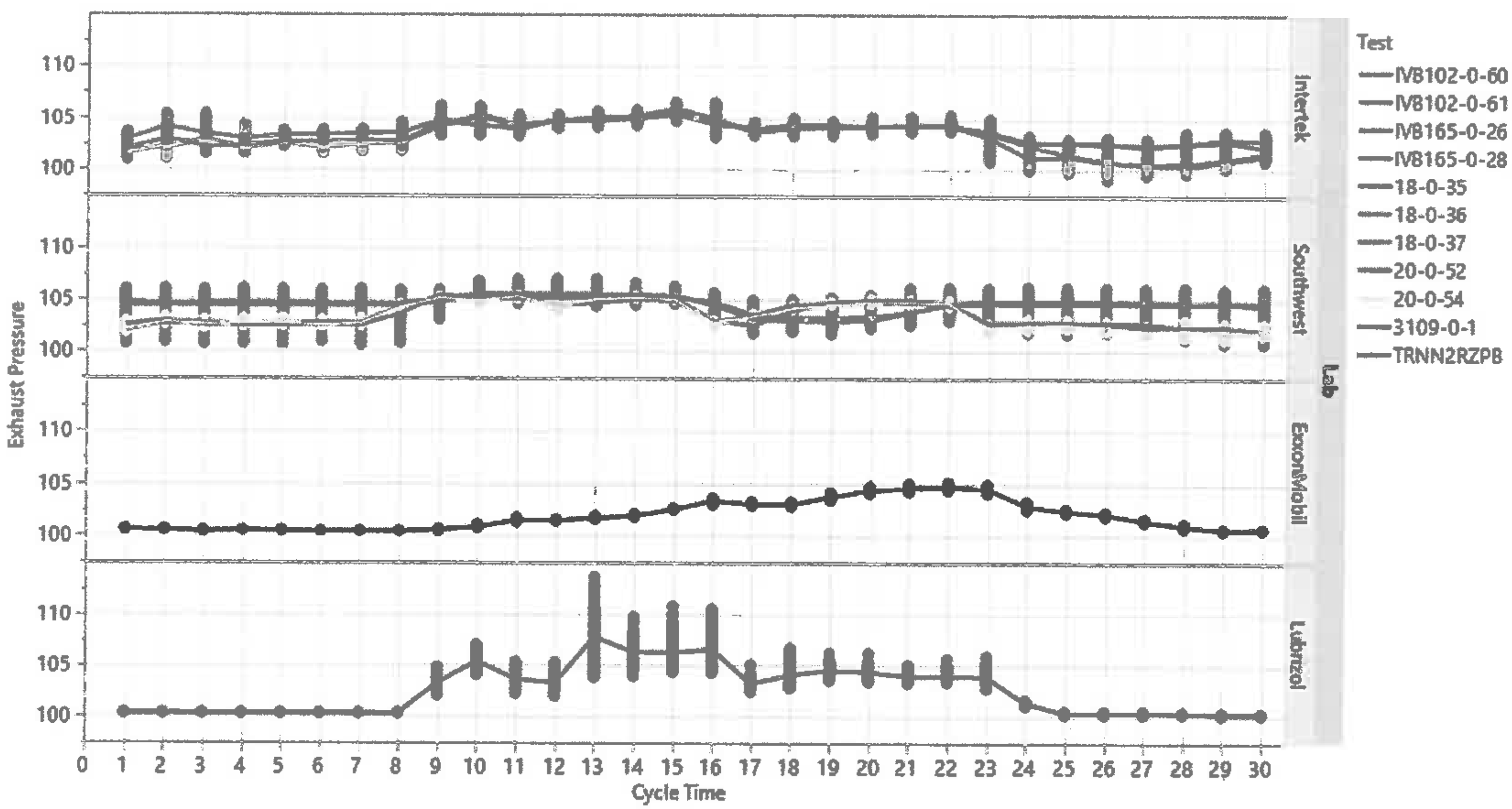

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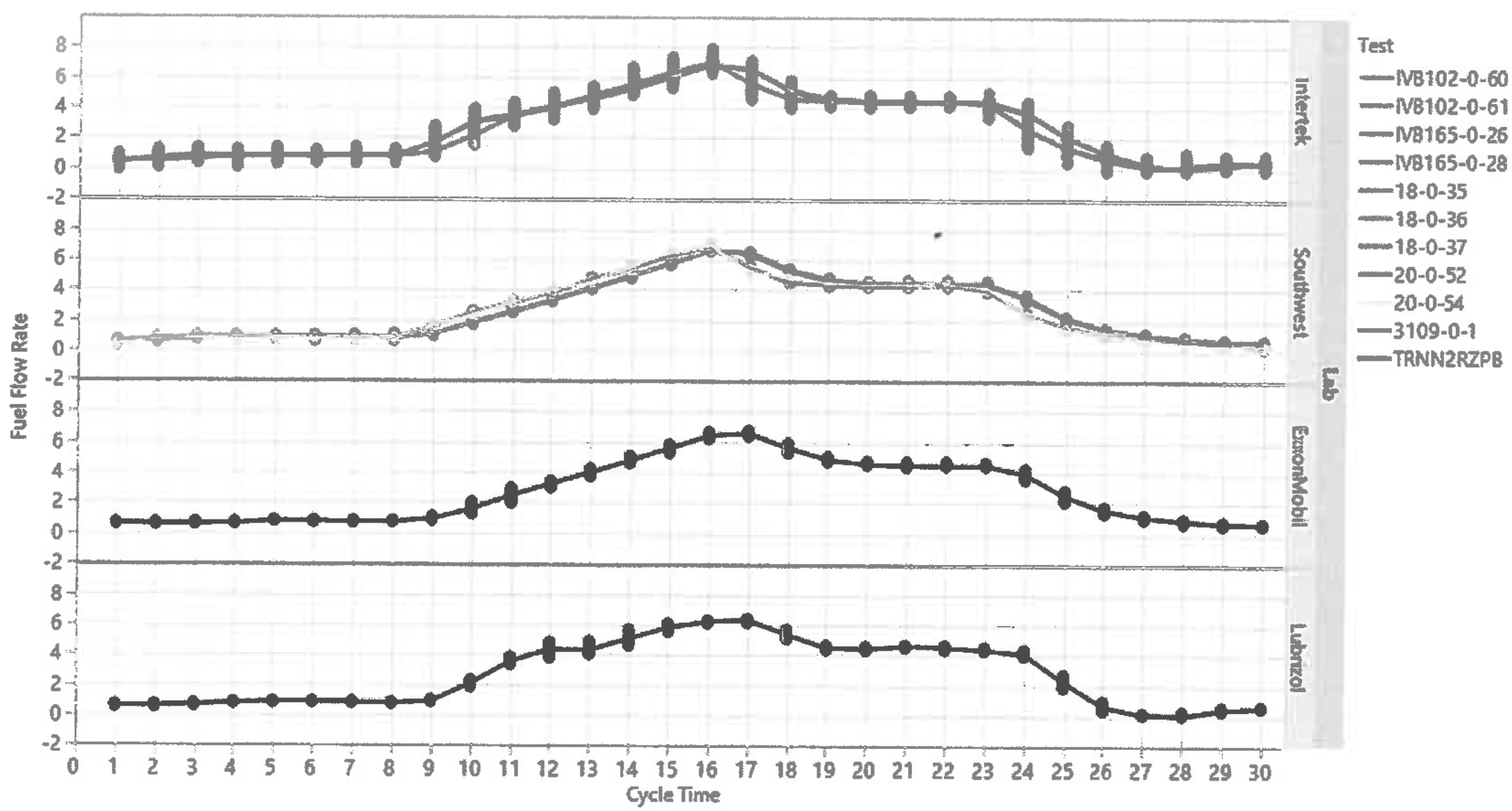

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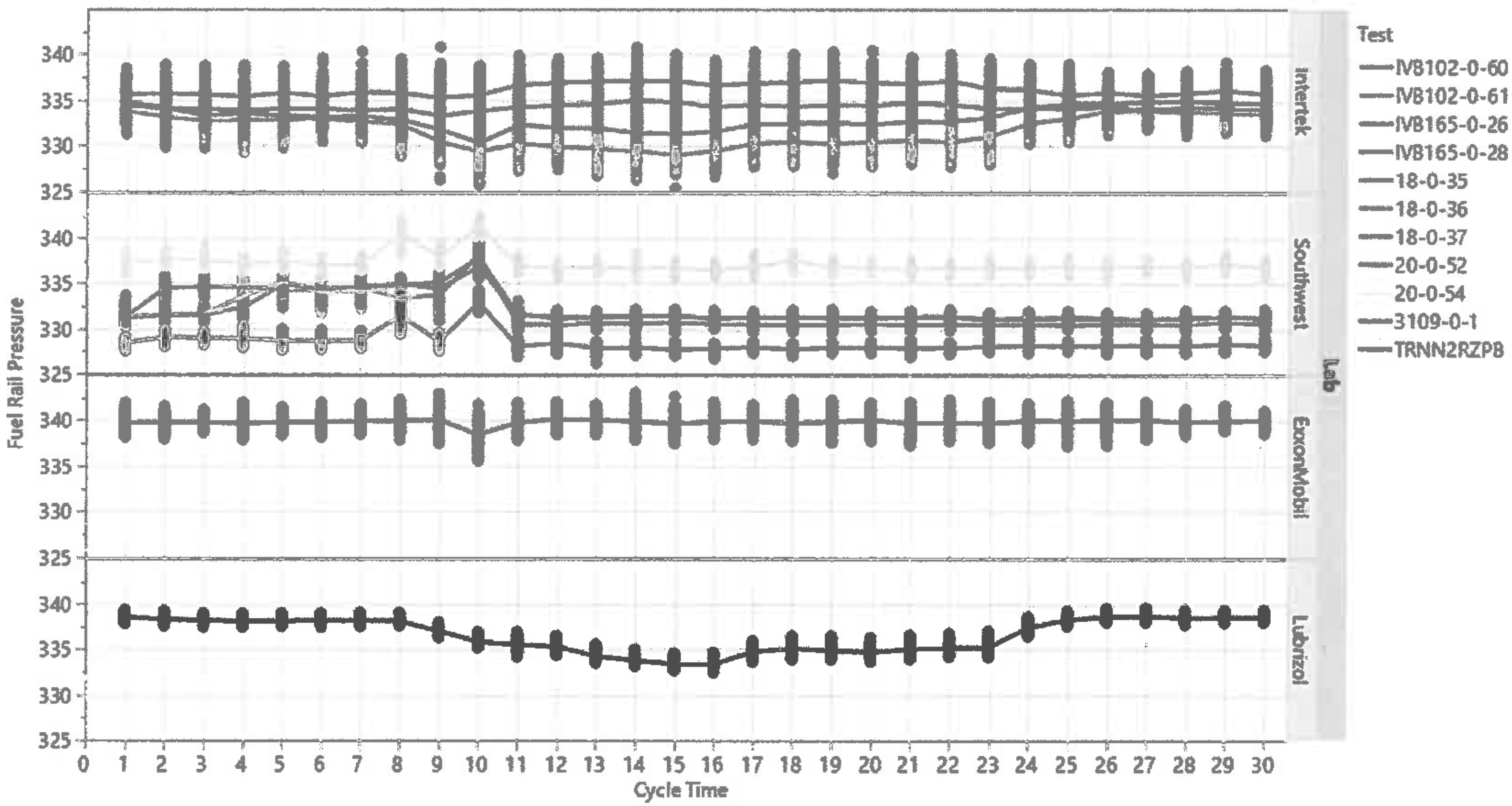

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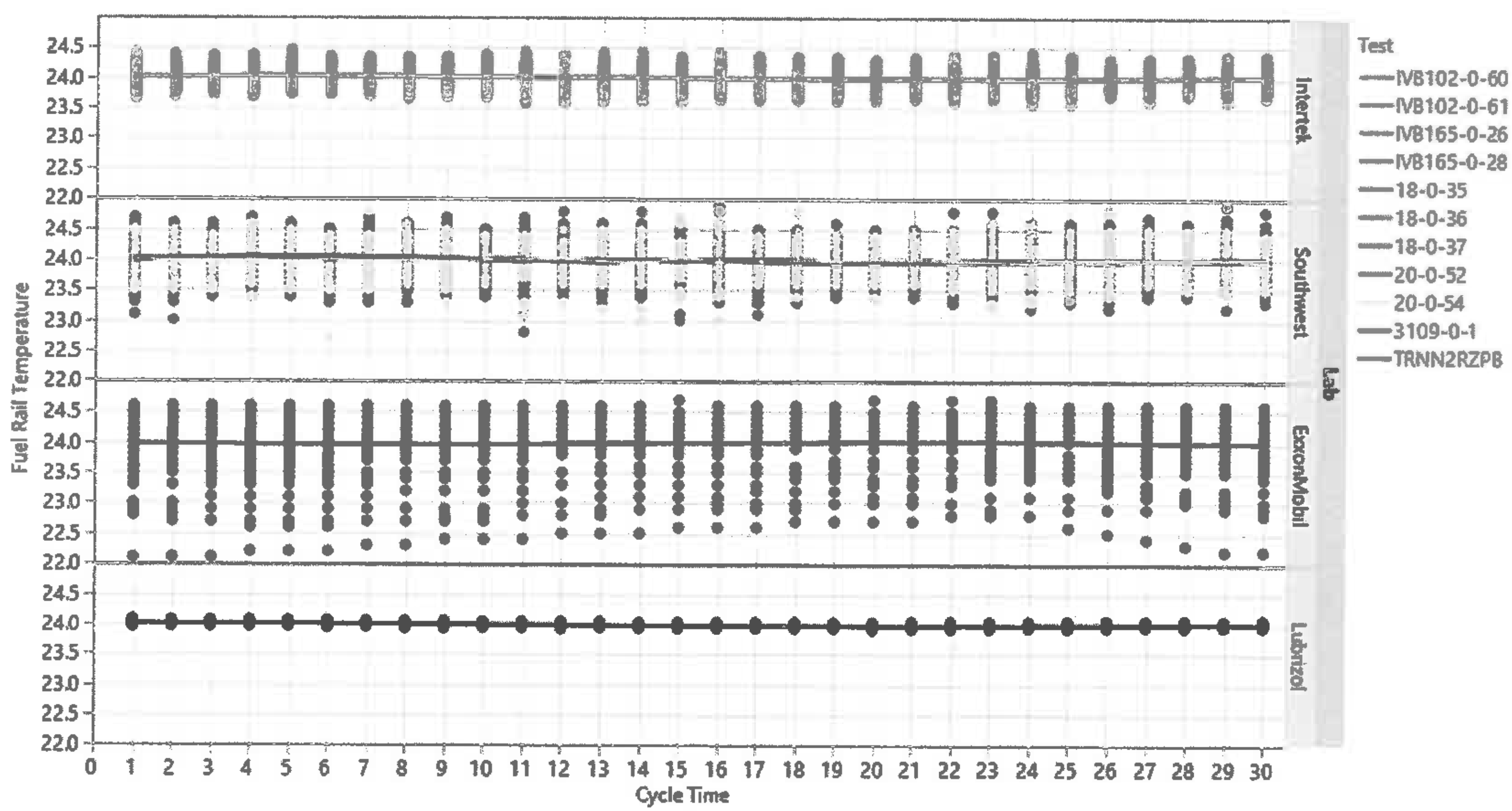

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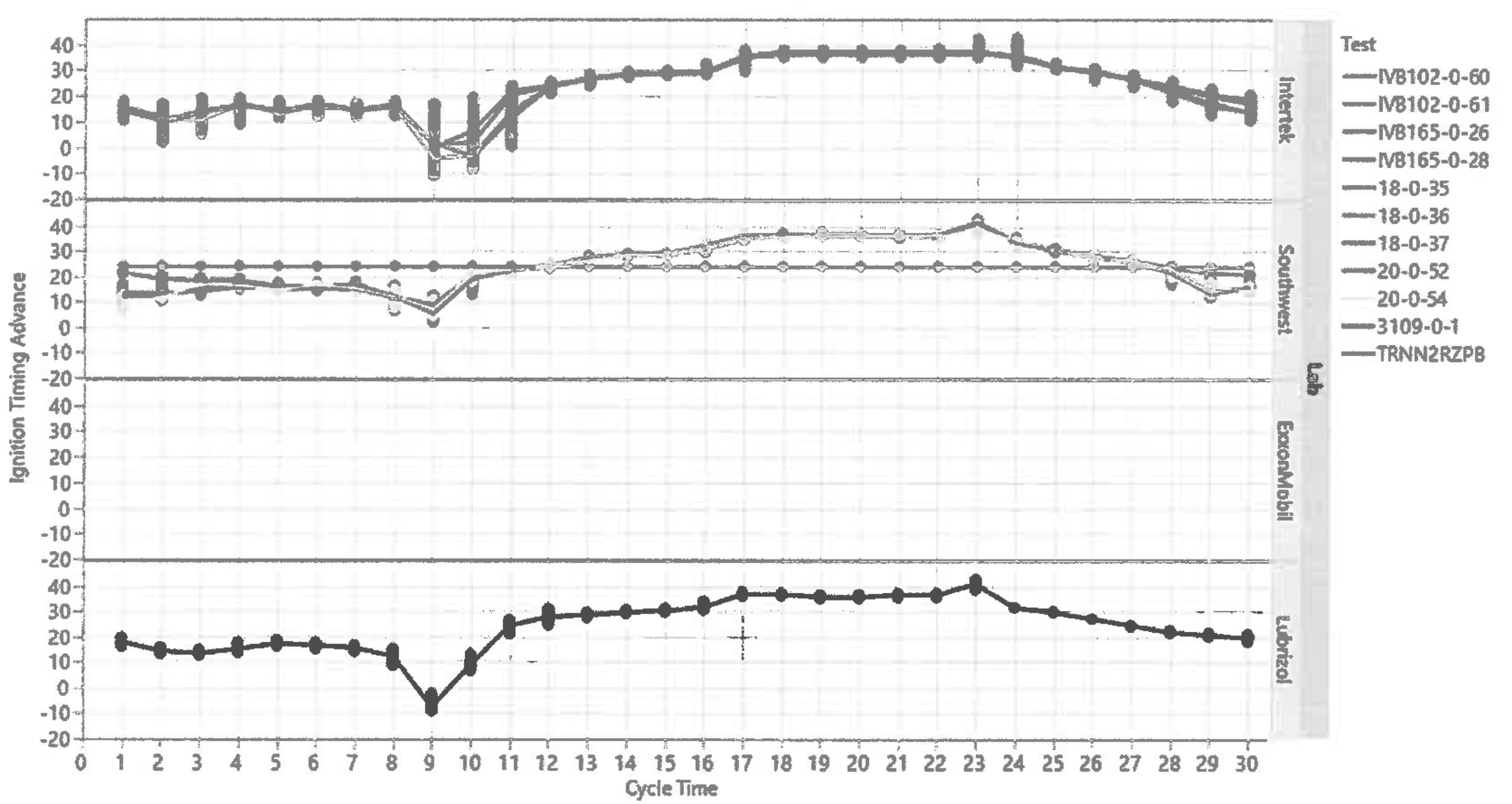

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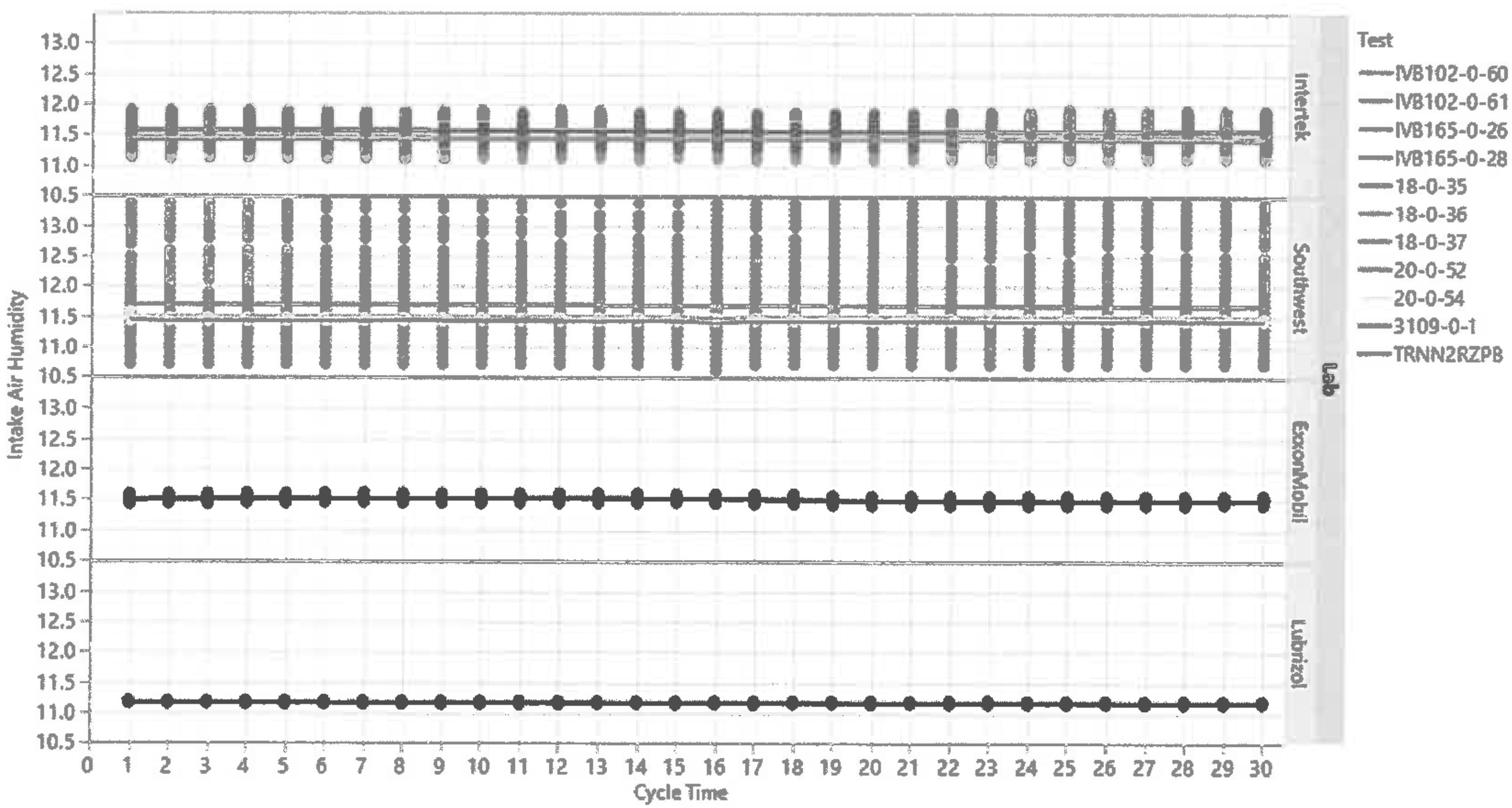

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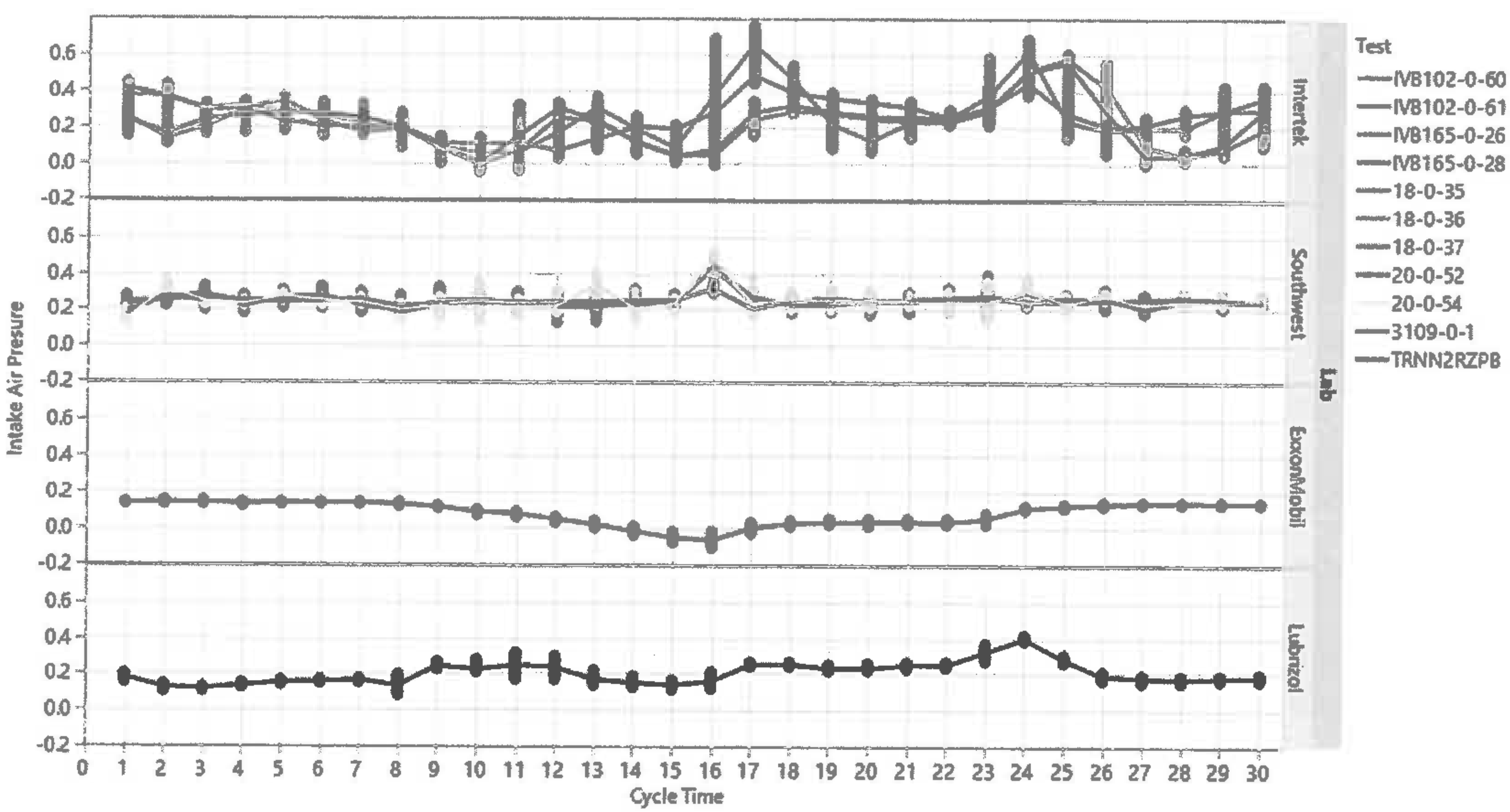

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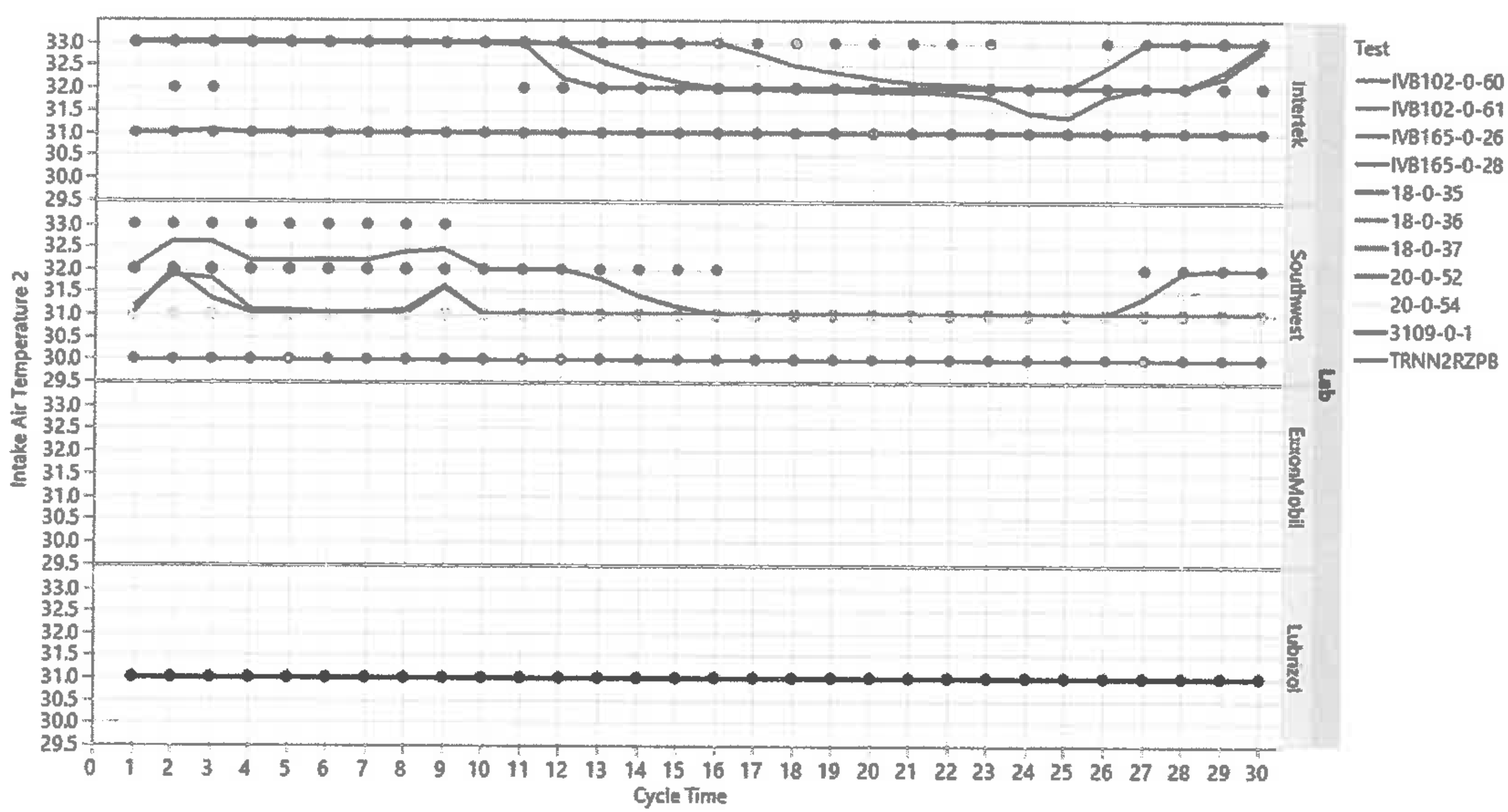

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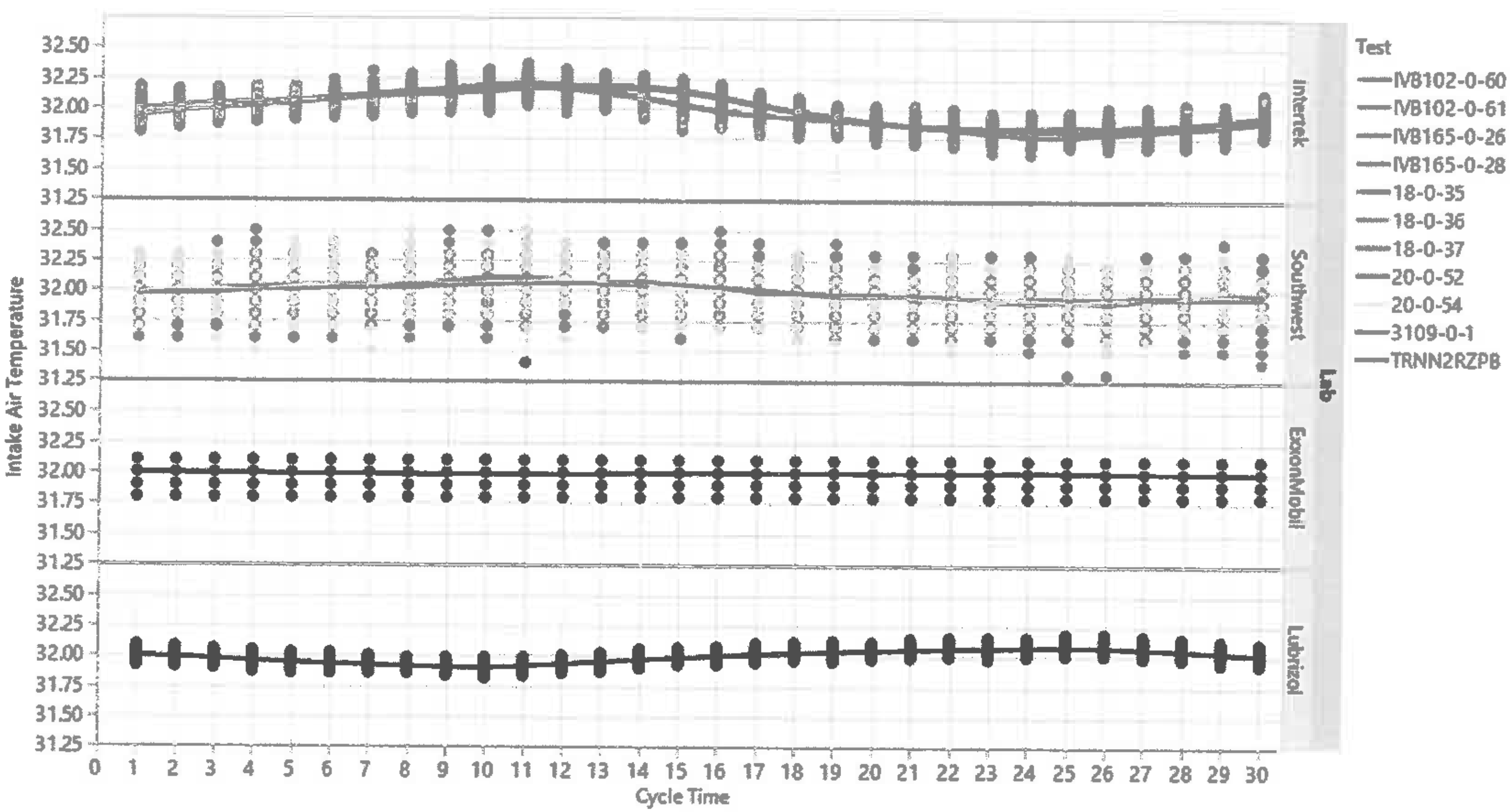

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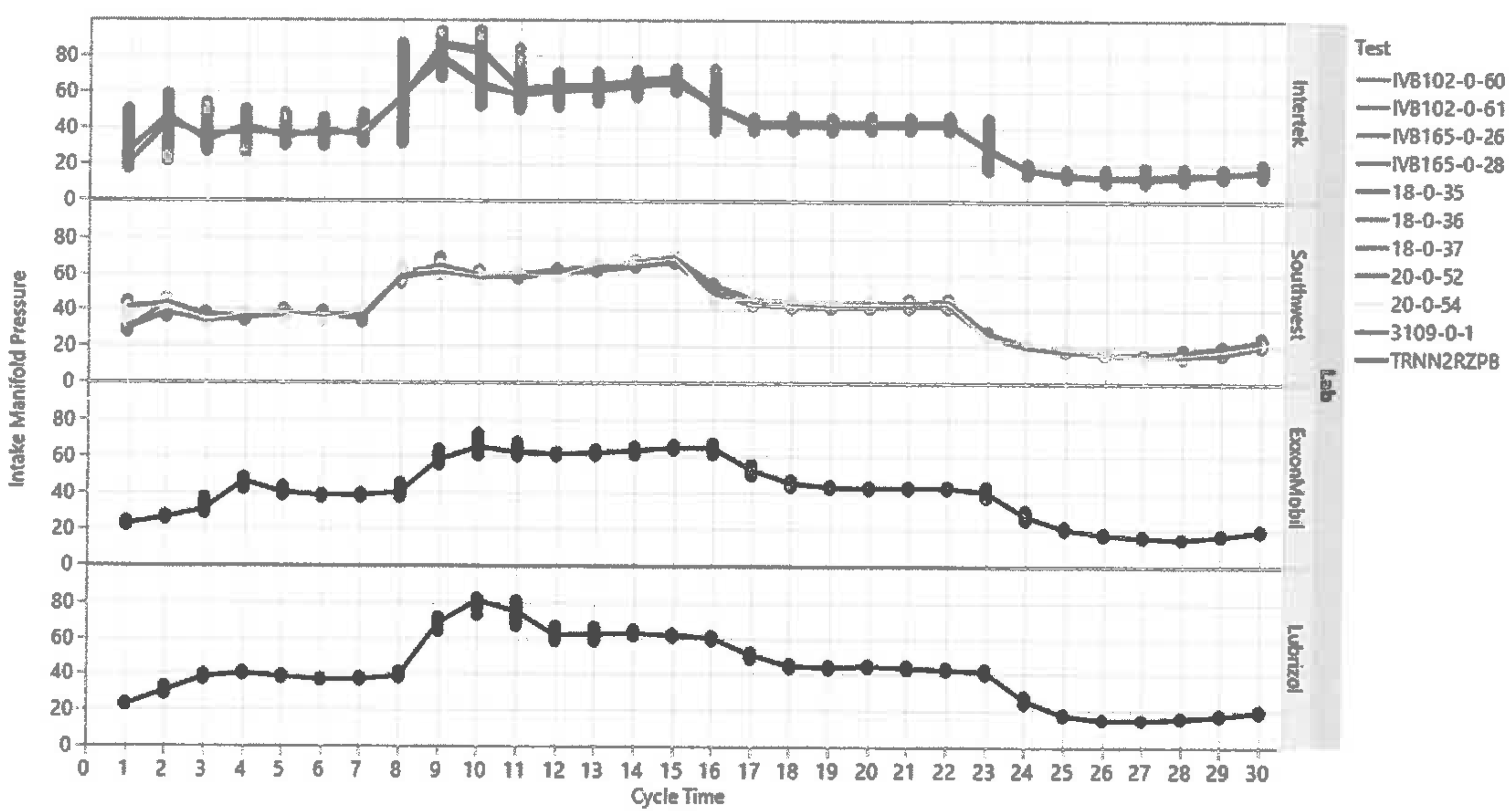

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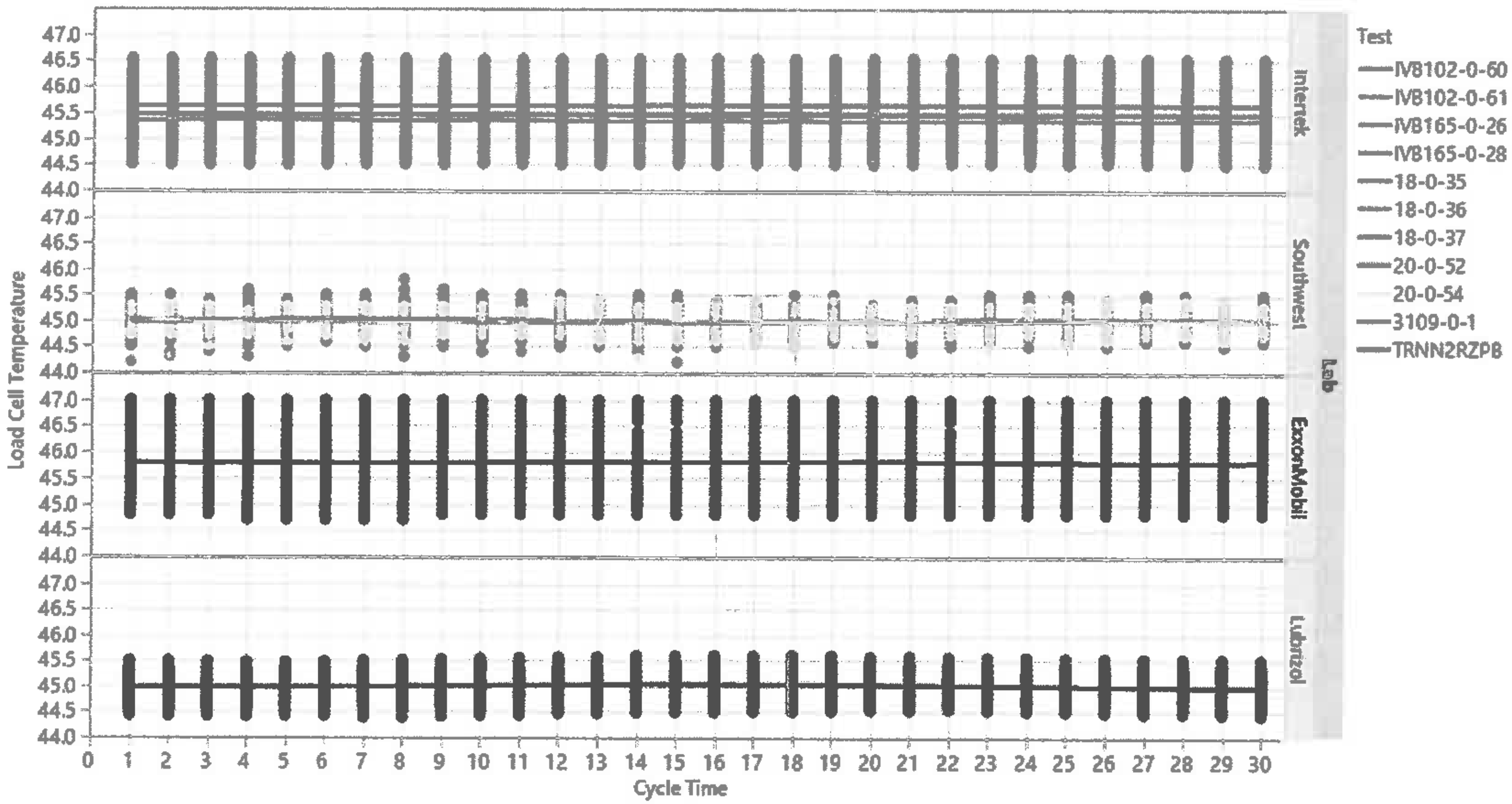

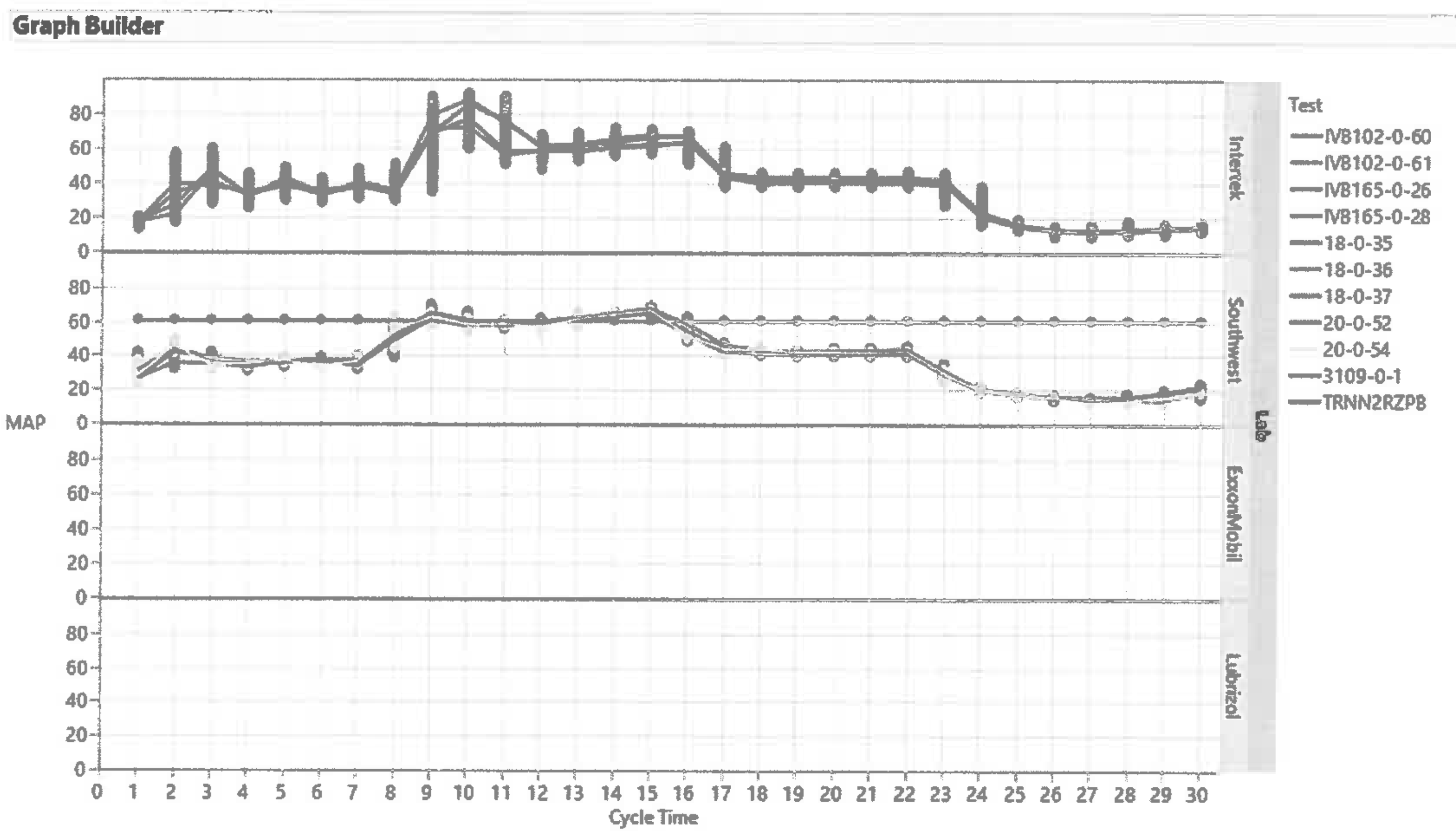
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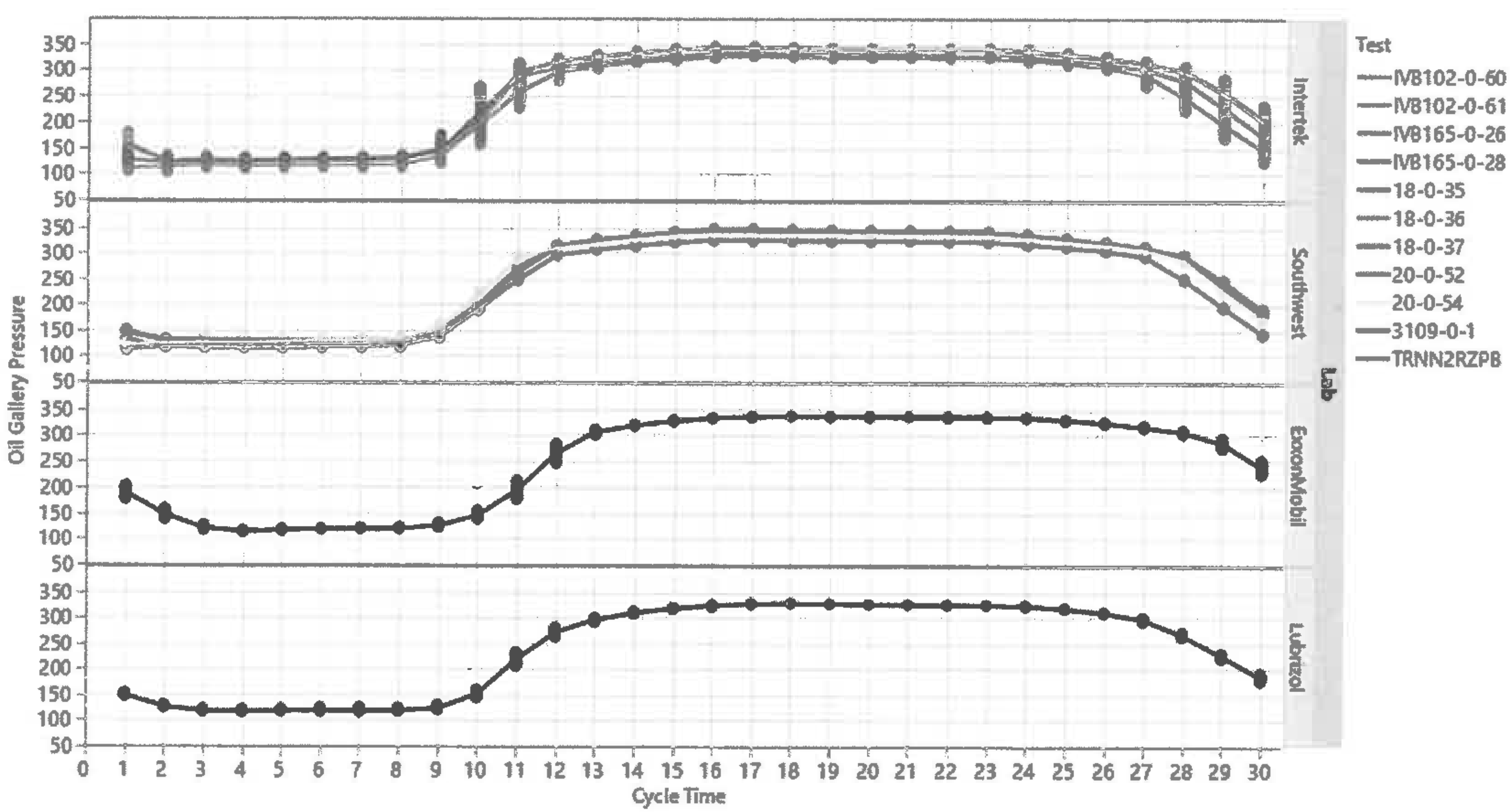

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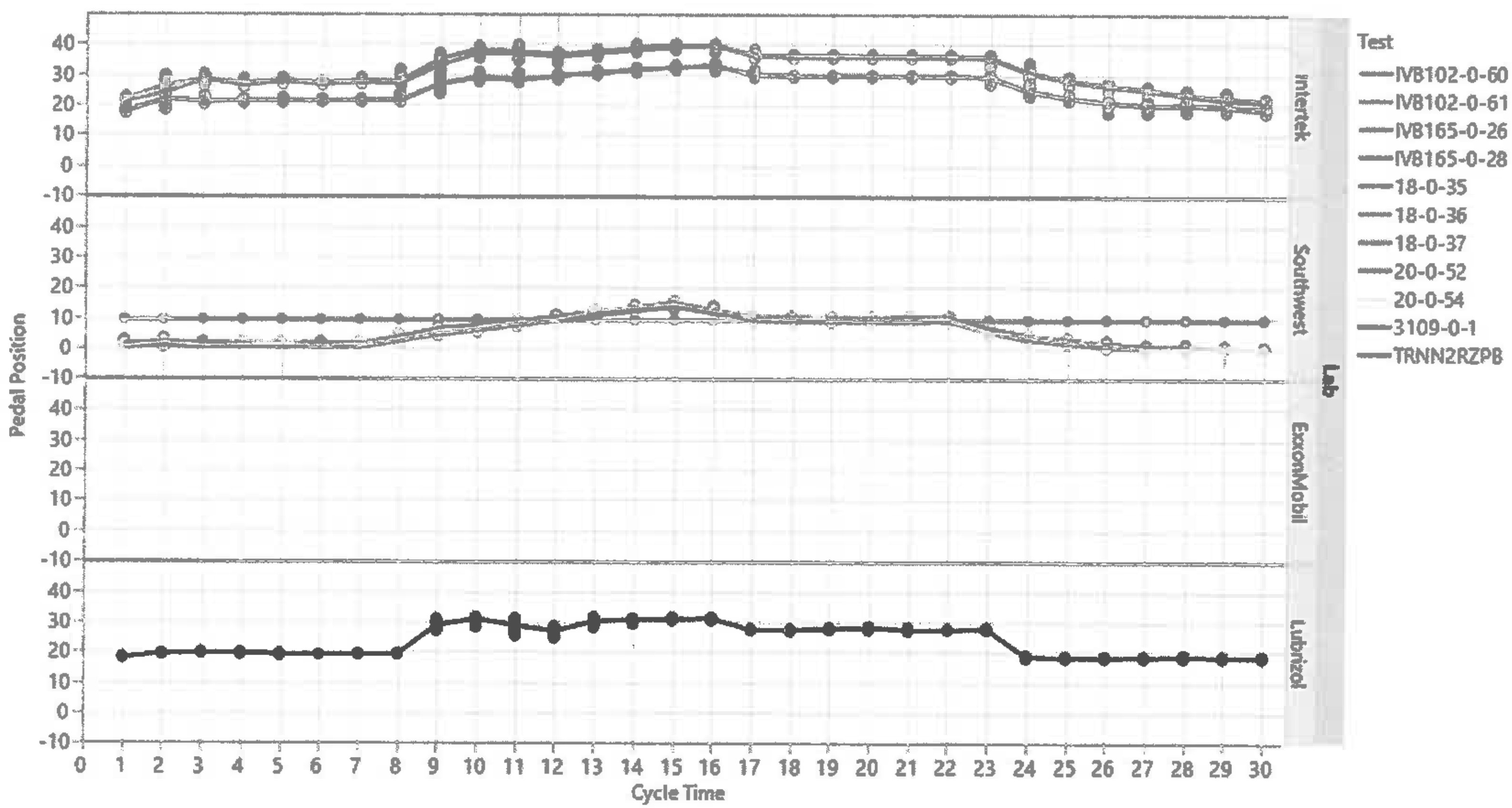

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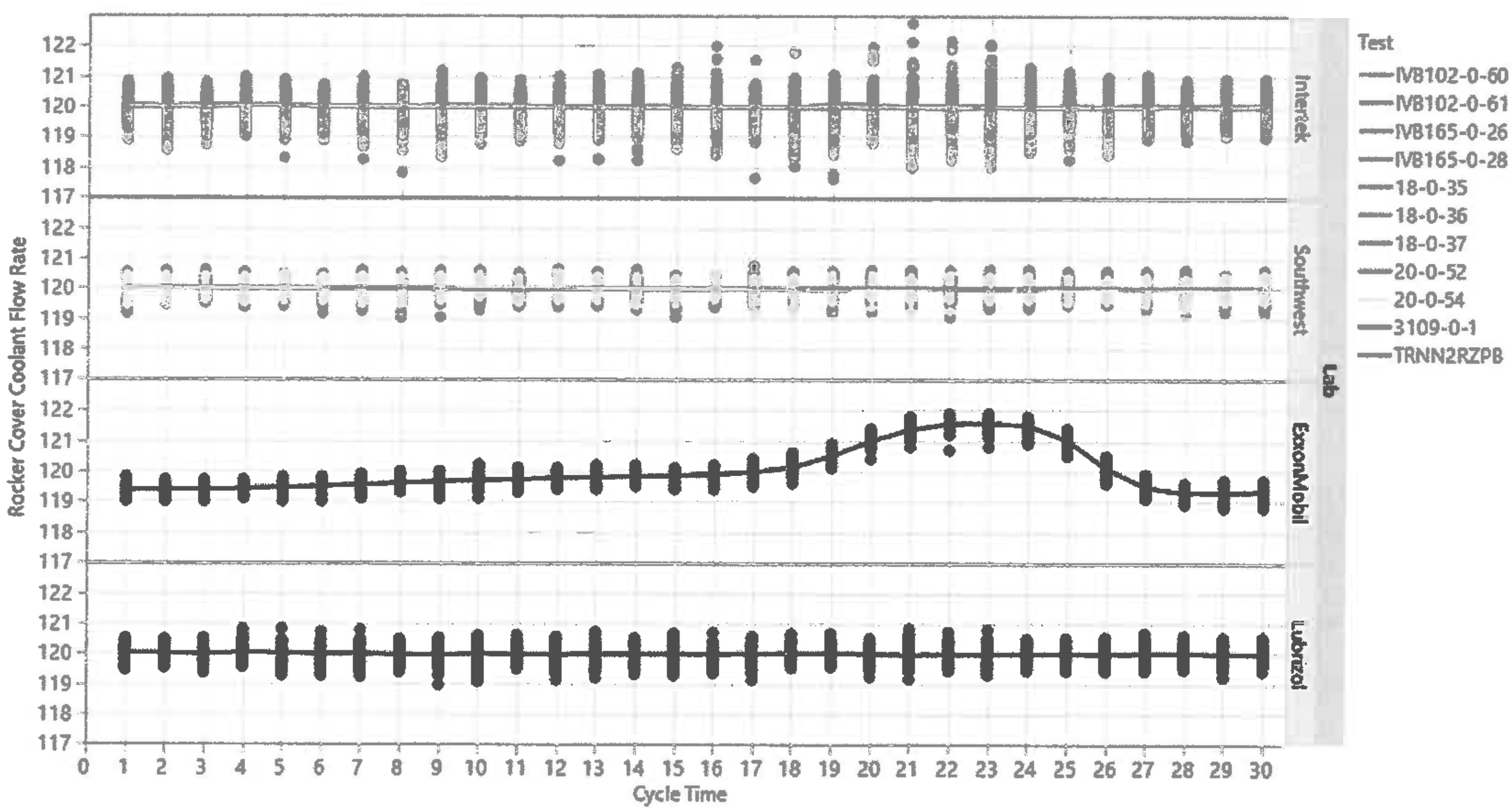

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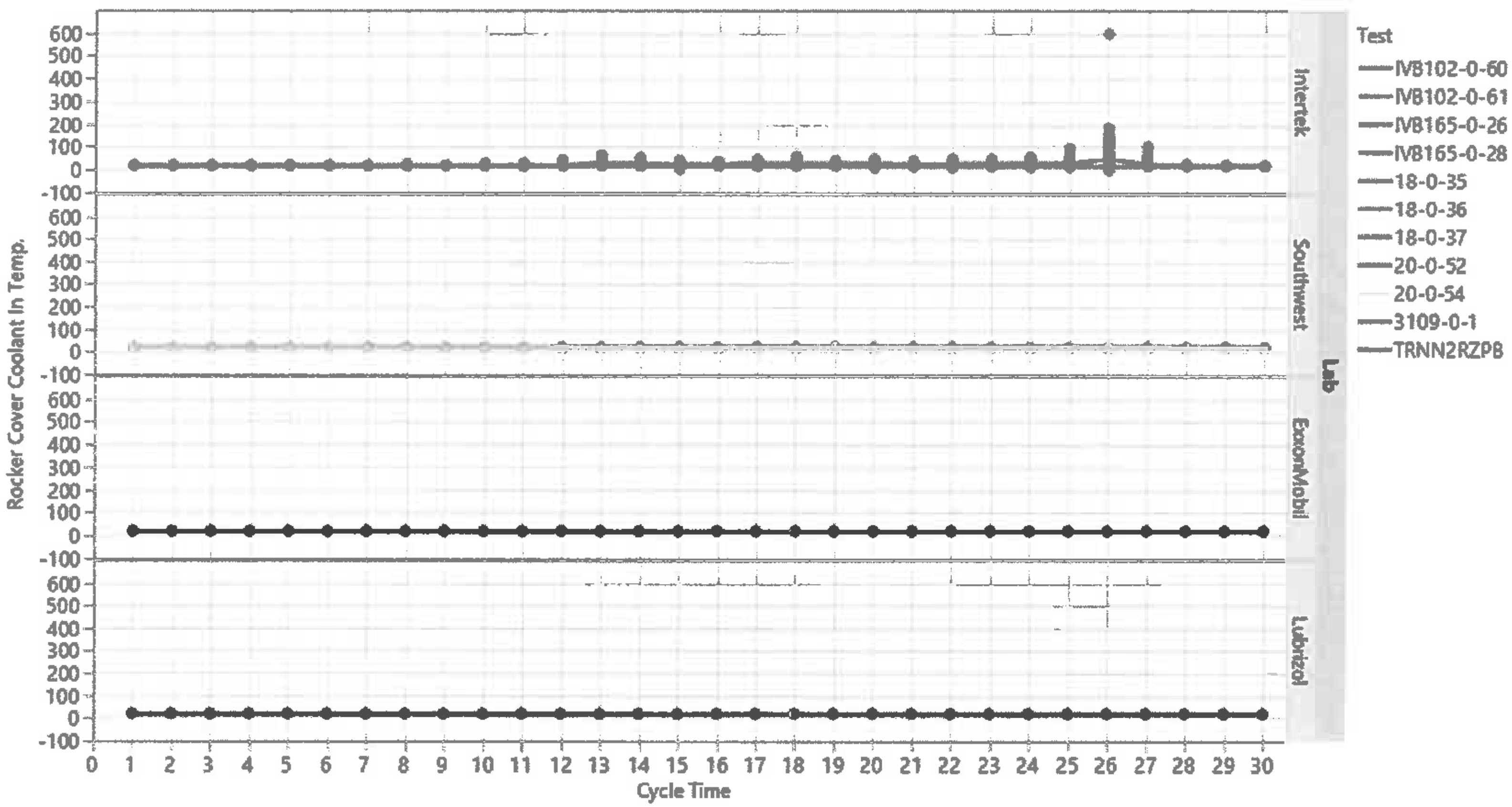

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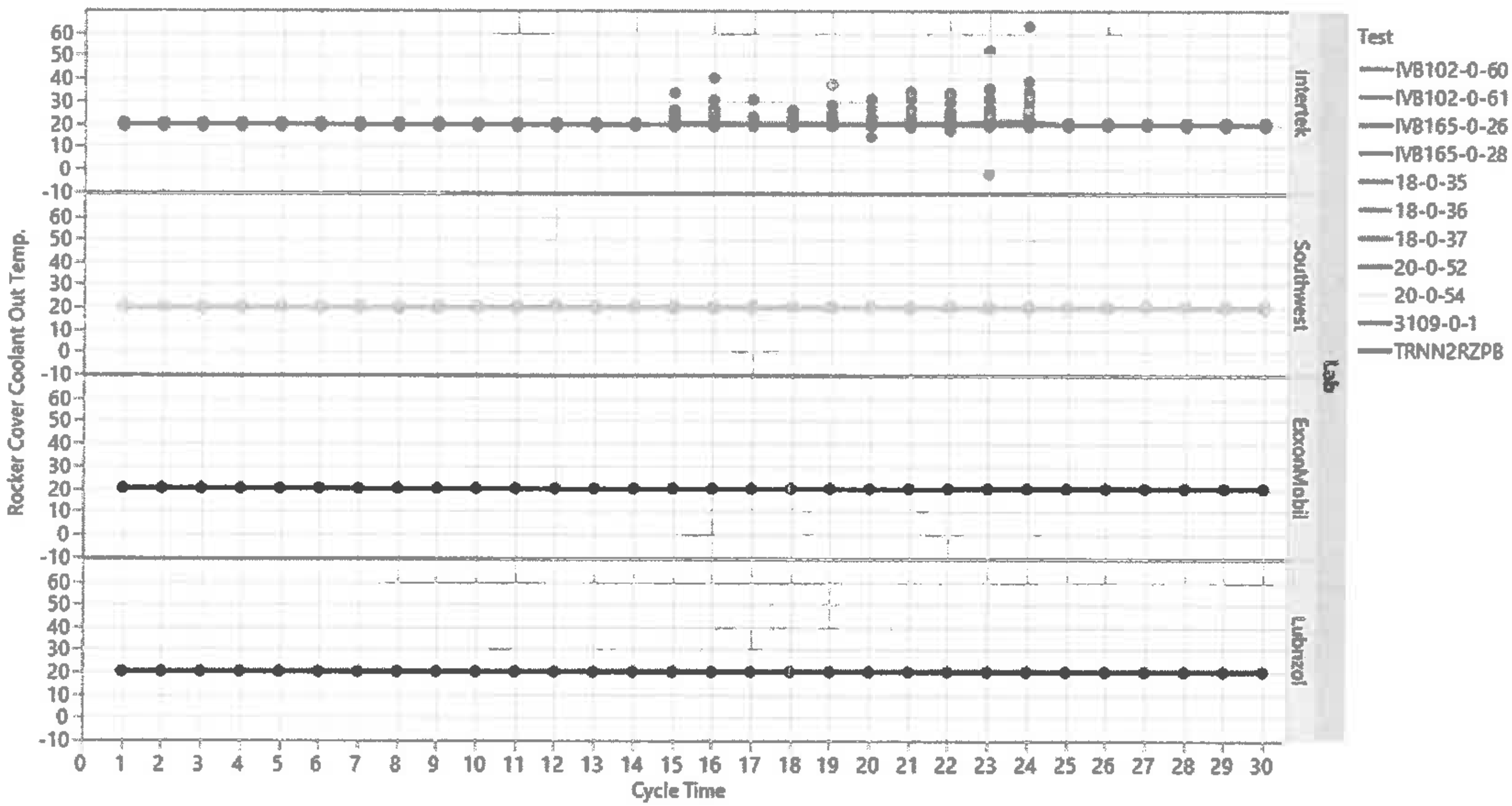

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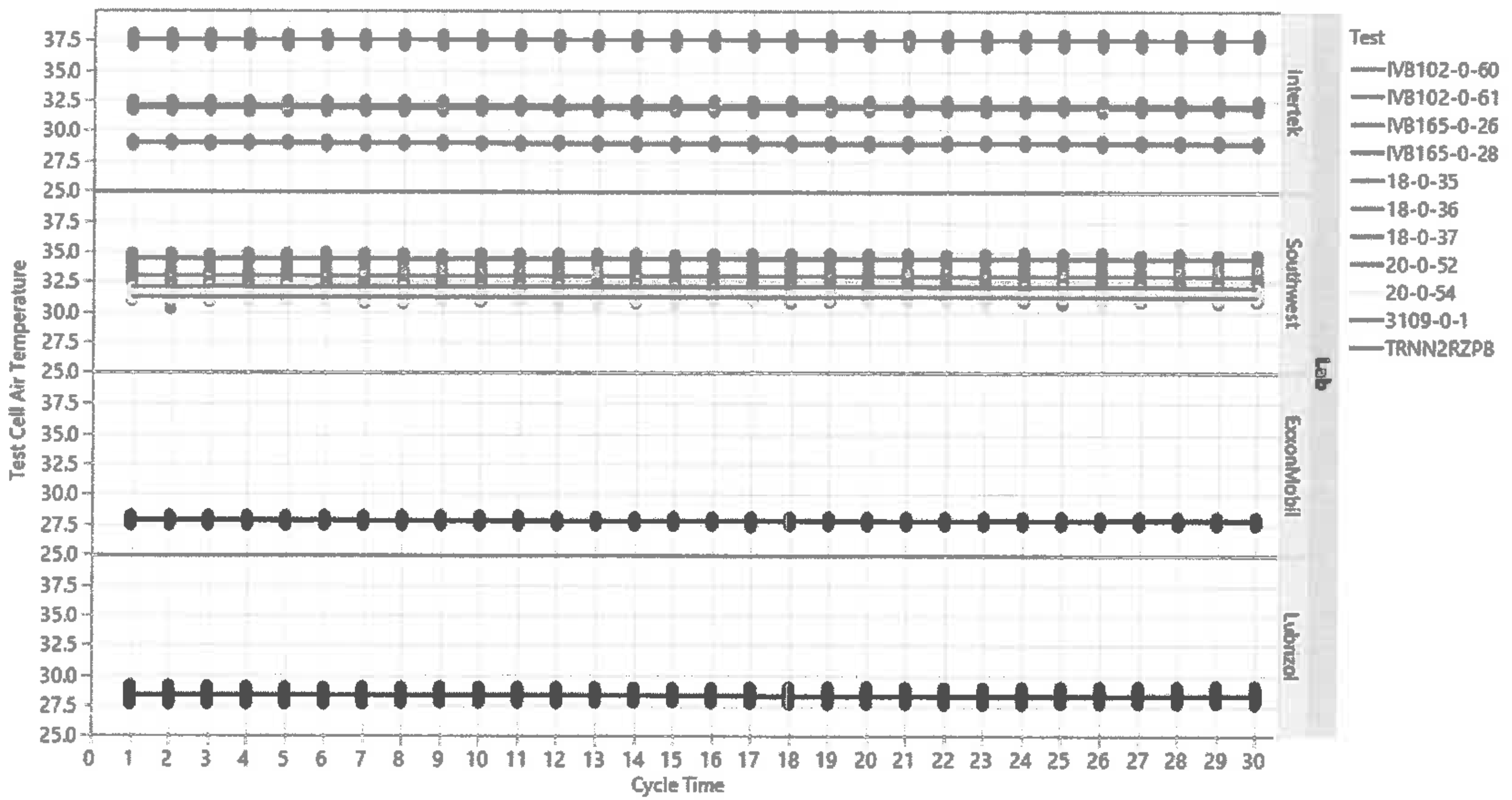

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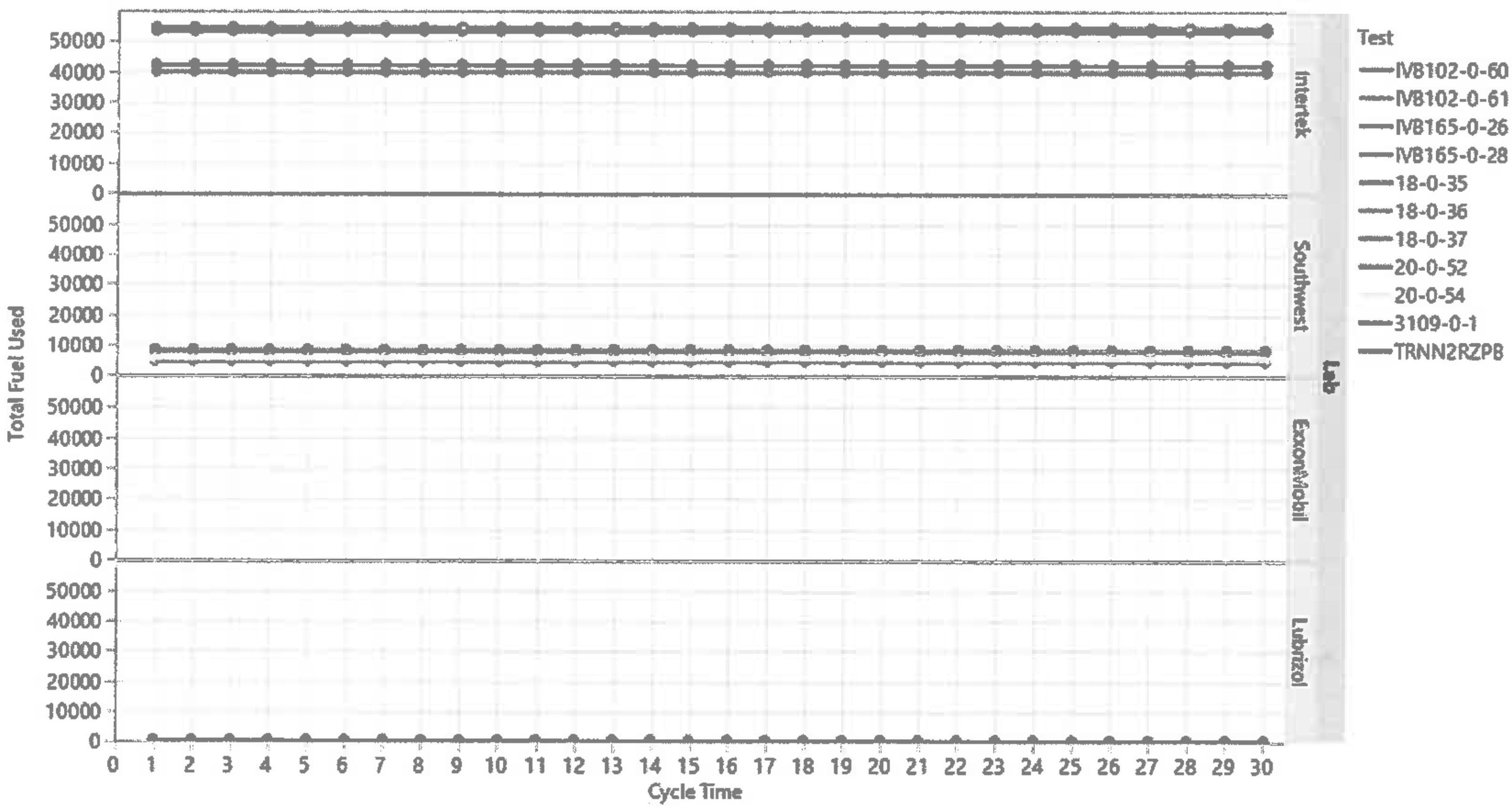

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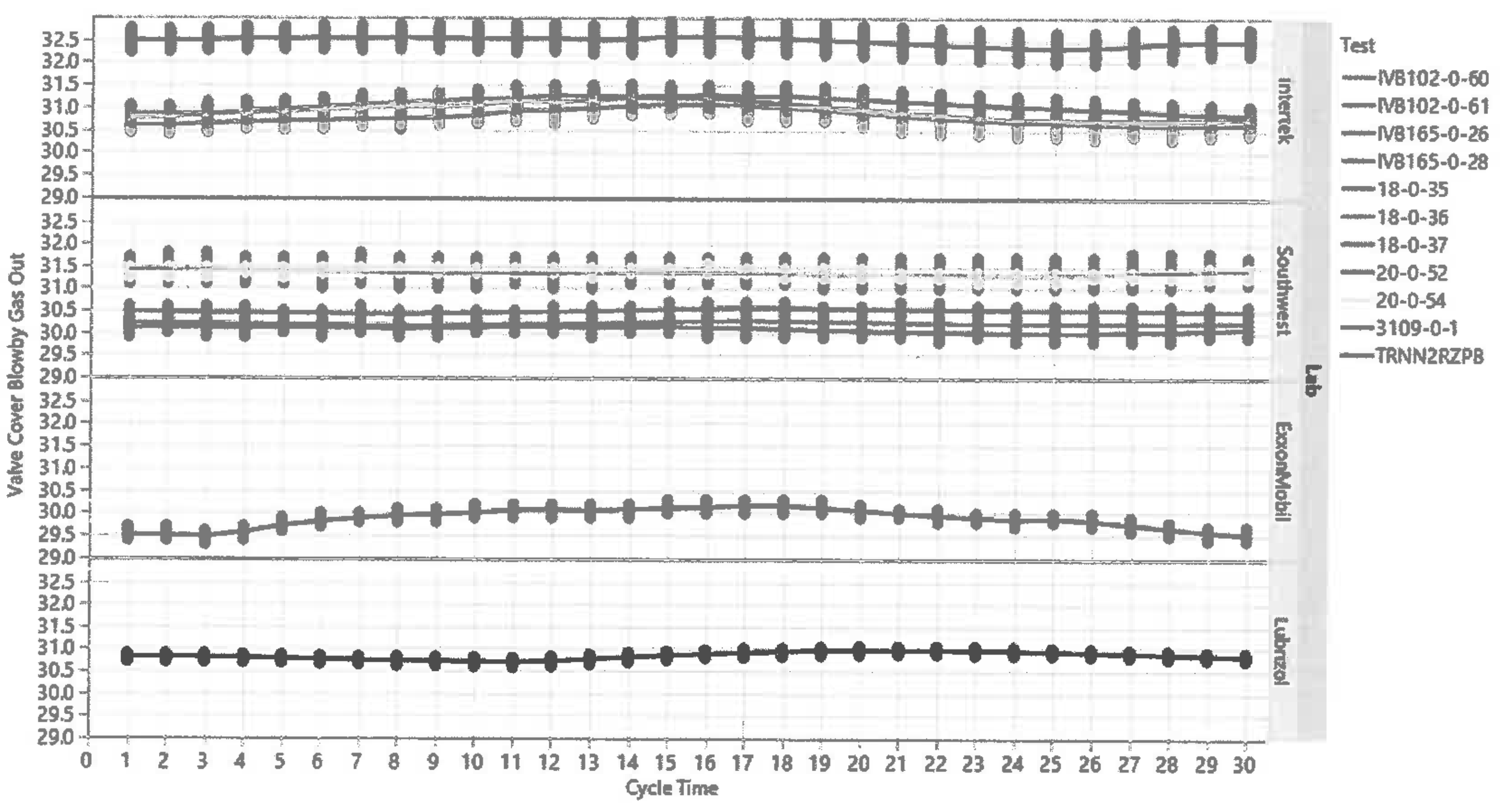

From: Bill Buscher Intertek
To: Alfonso Lopez Intertek; "Lang, Patrick M."; "Clark, Sidney L."; "SATOSHI HIRANO"; "Teri Kowalski (TEMA TTC)"; "lindenjim@jlindenconsulting.com"; "t-sagawa@mail.nissan.co.jp"; "stephen.fields@nissan-usa.com"; "Romano, Ron (R.)"; "Tang Haiying (FCA) (haiying.tang@fcagroup.com)"; "Jeff Betz"; "Mark Sutherland"; "Dan Lanctot"; "dhbowden@ohtech.com"; "Jason Bowden (jhbowden@OHTech.com)"; "Matthew Bowden"; "fmf@astmtmc.cmu.edu"; "jac@astmtmc.cmu.edu"; "Rich Grundza"; "Rieth, Ryan"; "Ritchie, Andrew"; "Farnsworth, Gordon"; "Kaustav <Kaustav. Sinha@chevron. com> Sinha"; "Ed.Altman@aftonchemical.com"; "Bob.Campbell@aftonchemical.com"; "Brys, Jerome"; "tlcaudill@valvoline.com"; "Scott.Lindholm@shell.com"; "Jeff Hsu"; "Hapithom@aol.com"; "BuschWA@aol.com"; "Mike McMillan"; "Chris Castanien (Chris.Castanien@nesteoil.com)"; "Amol Savant"; "Kevin.OMalley@lubrizol.com"; "ray.selz@infineum.com"; Martin Chadwick Intertek; "Dvorak, Todd"; "Martinez, Jo G. (jogm)"; "Doyle Boese"; "Affinito, Ricardo E"; "Lochte, Michael D."; "Stockwell, Robert T"; "Mileti, Christopher"; "Meryn.hopp@gm.com"; "Timothy Cushing"; John Glaser Intertek; "Mourhatch, Ramoun"; "Kostan, Travis G."; "Rais, Khaled"; "Karin.Haumann@shell.com"; "Mark Adams"; "Salvesen, Clifford R"; "James Matasic"; "Hosseini, Seyedeh Mahboobeh"; "Tarry, Preston"; "Pecinovsky, Katerina"; "Charlie"; "Thom Smith (TRSmith@Valvoline.com)"; "Calcut, Brent"; Carlton Coker Intertek; "Collins, Chet A."; "arthur.t.andrews@exxonmobil.com"; "Overaker, Mark"; "ptumati@jhaltermann.com"; "Meier, Adam Robert"
Subject: IVB Precision Degradation and What Could be the Primary Influence
Date: Wednesday, October 11, 2017 5:56:00 PM
Attachments: IVB Lifter Rejection Criteria Old vs New.docx

Sequence IV Surveillance Panel,

So I have been racking my brain trying to understand what change that we have implemented between the original precision matrix and the latest prove-out testing has had such a significant impact on the degradation of our test's precision. I think that I might have identified something to consider. I am listing all of the changes below and what I think the expected influence each one would have on precision and severity:

1. **Change in initial oil charge measurement from volume to mass.**
   a. Expected to improve precision because mass measurement was proven to be more accurate than volume measurement.
   b. Not expected to influence severity because this change did not change the overall amount of oil.
2. **Standardization of engine coolant flow direction to into the coolant inlet pipe and out of the rear of the cylinder head, as is the production coolant flow direction for the Toyota 2NR-FE engine.**
   a. Any improvement in standardization is expected to have a possible improvement in precision.
   b. Not expected to influence severity. Two prove-out tests conducted on ASTM REO 1012 at Intertek confirmed no shift in severity.
3. **Change in the coolant temperature control point from coolant in to coolant out (rear of the cylinder head).**
   a. Not expected to influence precision, compared to previous test conditions.
   b. Not expected to influence severity, compared to previous test conditions.
4. **Change in the coolant temperature set-point from 49°C (Coolant In) to 52°C (Coolant Out).**
   a. Not expected to influence precision, compared to previous test conditions.
   b. Not expected to influence severity, compared to previous test conditions.
5. **Change from 185 ppm Sulfur content KA24E Green fuel to 124 ppm Sulfur content KA24E Green fuel.**
   a. This specific change is not necessarily expected to improve precision, but the test

fuel Sulfur spec change from 100 – 400 ppm to 130 ± 10 ppm is expected to improve test precision from fuel batch to fuel batch.

b. Expected to influence severity in the mild direction due to reduction in corrosive wear.
c. Expected to help reduce or eliminate intake camshaft lobe failures due to reduction in corrosive wear.

6. **Change from Batch Code C to Batch Code D Intake camshafts.**
   a. Not expected to influence precision, compared to previous camshaft batches.
   b. Not expected to influence severity, compared to previous camshaft batches.
7. **Change from 2,400 ml (2,100 g) to 3,000 ml (2,600 g) initial oil charge volume.**
   a. Expected to improve precision because this change will help eliminate oil starvation and oil aeration.
   b. Might influence severity in the mild direction due to increased oil volume.
   c. Expected to help reduce or eliminate intake camshaft lobe failures due to a reduction or elimination of oil aeration.
8. **Change from 1 ounce (30 ml) to 2 ounce (60 ml) 25-hour interval oil sample volumes.**
   a. Not expected to influence precision.
   b. Not expected to influence severity.
9. **Elimination of the 3 ml 5-hour interval oil samples at 105, 110, 115, 120, 130, 135, 140 ,145, 155, 160, 165, 170, 180, 185, 190 and 195 hours.**
   a. Not expected to influence precision.
   b. Not expected to influence severity.
10. **Change to OHT modified oil pan with additional modifications to the oil pick-up tube.**
    a. Expected to improve precision because this change will help eliminate oil aeration.
11. **Addition of insulation to the oil separator and blowby stack plumbing.**
    a. Expected to improve precision because this change will help eliminate ambient effect.
    b. Not expected to influence severity.
12. **Change to performing all Keyence volume loss measurements with the new Keyence software (version G2), new Keyence template and settings (as per 8/15/17 Sequence IVB Metrology Workshop) and Talc powder.**
    a. Expected to improve precision by improving the precision of the wear measurement technique.
    b. Not expected to influence severity. A couple of the Intertek prove-out tests had Keyence volume loss measurements performed with both the old and new software, templates and settings and the severity shift was 0.00 to 0.02 mm^3.
13. **Change in lifter rejection criteria for intake lifters (as per 8/15/17 Sequence IVB Metrology Workshop). Dropped lifter crown profile rejection criteria for intake lifters. See attached file for old and new lifter rejection criteria.**
    a. Not expected to influence precision, but MAYBE this is influencing on precision? Facts are as follows:
       i. From the start of test development at SwRI in 2012, the same intake lifter crown profile rejection criteria was utilized for all testing at all participating development labs in North America (SwRI, Intertek and Lubrizol).
       ii. The latest prove-out testing from late August 2017 to present are the only

tests that have been conducted without utilizing the intake lifter crown profile rejection criteria.

iii. The prove-out testing prior to the original precision matrix and the original precision matrix, both exhibited better precision than the latest prove-out testing.

iv. The lifter crown profile rejection criteria has never been utilized for the exhaust lifters and the exhaust lifter wear has historically had poorer precision compared to the intake lifter wear.

b. Not expected to influence severity, but maybe certain lifter crown profiles wear at different rates?

Would you agree that most of the changes that this surveillance panel or sub-group of the surveillance panel have agreed to implement were designed to improve the precision of the test? Would you agree that most of these changes have sound technical reasoning for enhancing precision?

I think that we potentially made a mistake with **change number 13** and that we made an incorrect assumption, assuming that the lifter crown profile was not a severity and/or precision influence. What do you think? This is some food for thought for tmorrow's surveillance panel conference call.

Regards,

William A. Buscher III
Chairman, Sequence IV Surveillance Panel
Office: 210-647-9489
Cell: 210-240-8990
Email: william.buscher@intertek.com

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SEQUENCE IVB SURVEILLANCE PANEL UPDATE

October 3, 2017

PROVE-OUT TESTING

Run Order	IAR Stand 1	IAR Stand 2	SwRI Stand 1	SwRI Stand 2	Lubrizol	ExxonMobil
	Required	Required	Required	Required	Supplemental	Supplemental
1	300	IVB-LFO-1	1012	IVB-LFO-1	300	300
2	1012		300	IVB-LFO-2	1012	1012
3		300	300	300		

= Completed

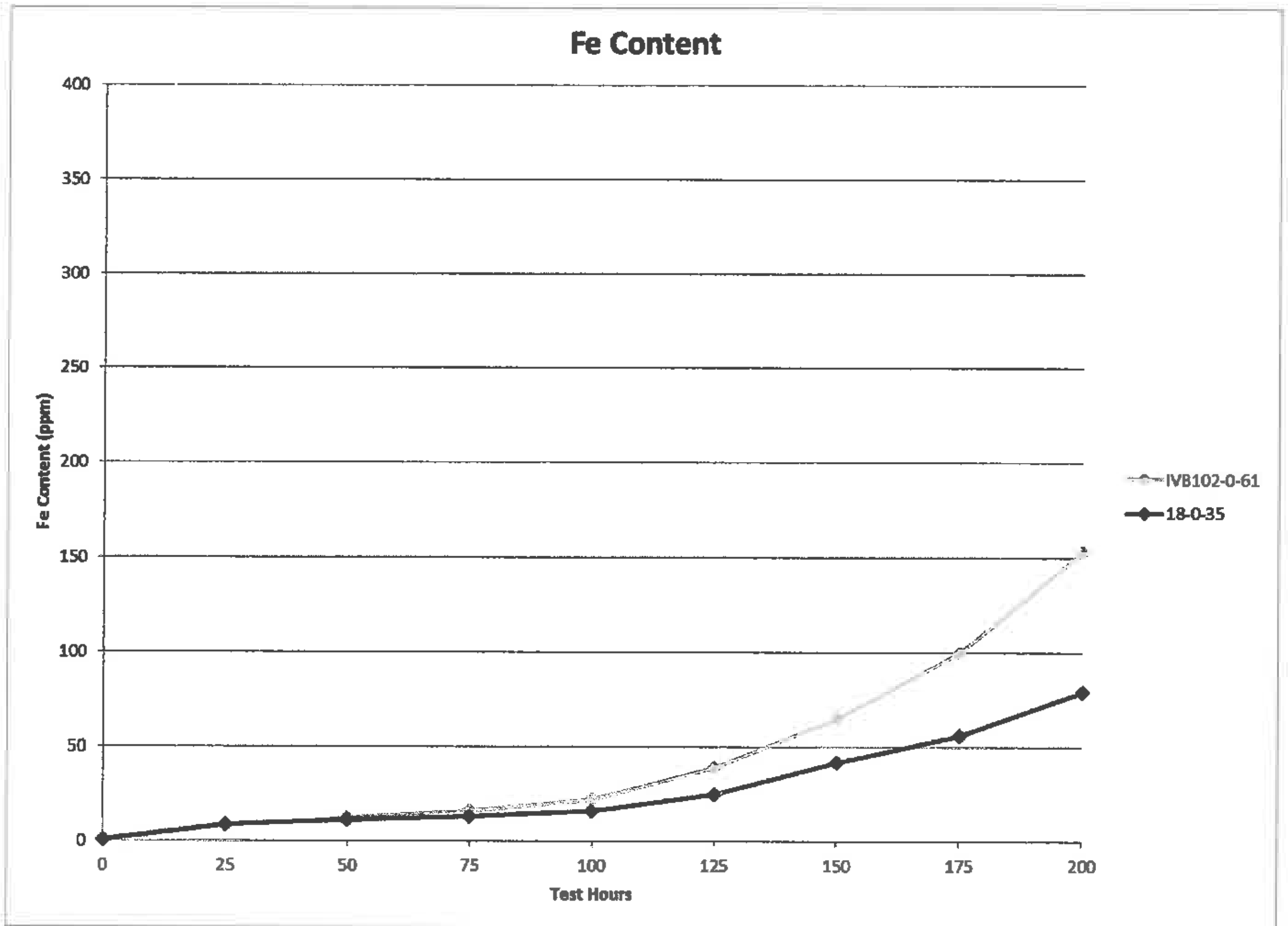
= Running

- Row 1, 2 and 3 of the required testing has completed
- Row 1 of the supplemental testing has completed
- Row 2 of the supplemental testing to start?

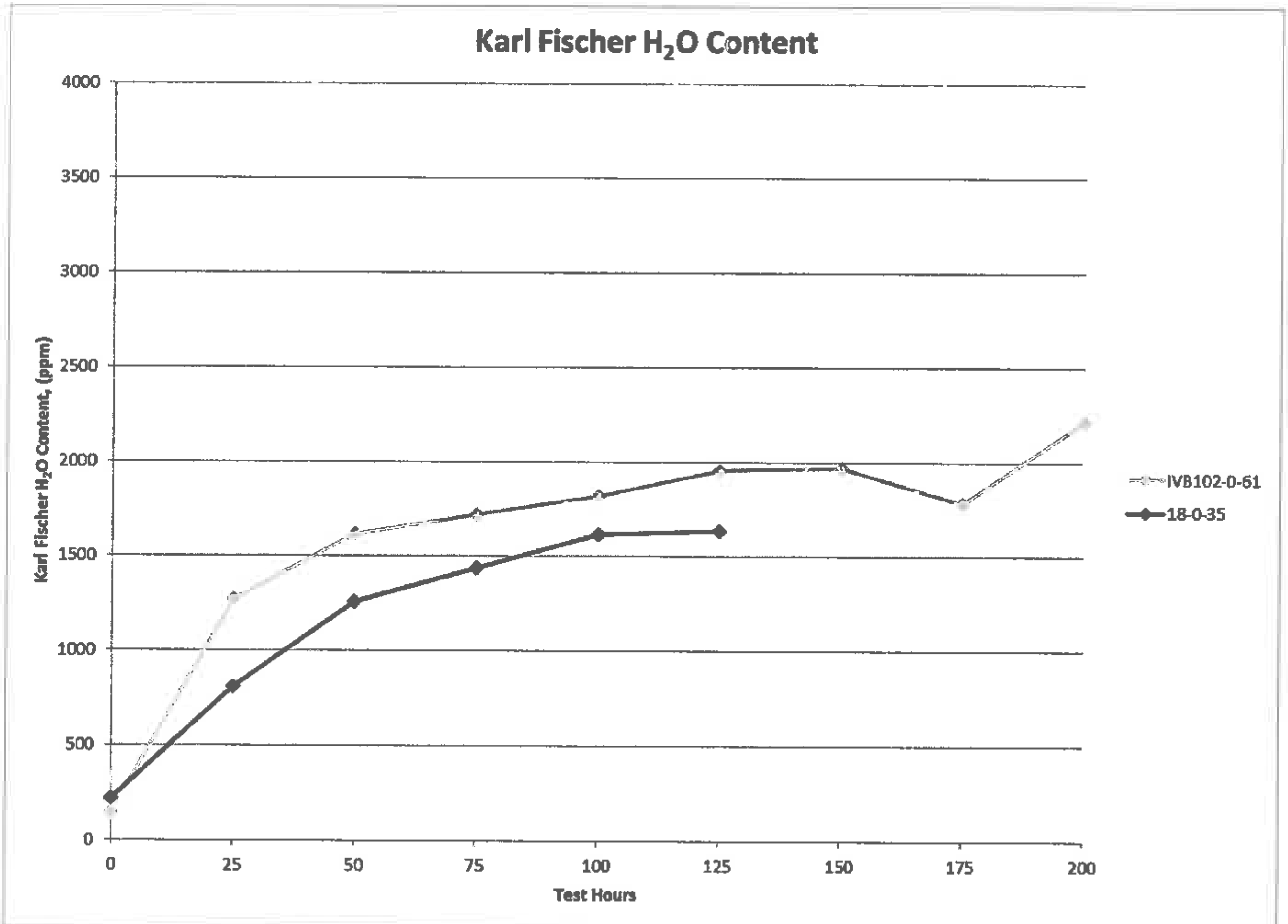
PROVE-OUT TESTING

Lab	Stand	Test Oil	Test Number	Intake Lifter Average Volume Loss mm^3
Intertek	102	ASTM REO 1012	IVB102-0-61	1.32
SwRI	18	ASTM REO 1012	18-0-35	1.01
Intertek	102	ASTM REO 300	IVB102-0-60	1.79
Intertek	165	ASTM REO 300	IVB165-0-28	2.26
SwRI	18	ASTM REO 300	18-0-36	1.16
SwRI	18	ASTM REO 300	18-0-37	1.15
SwRI	20	ASTM REO 300	20-0-54	1.50
Lubrizol	1	ASTM REO 300	TRNN2RZPB	1.08
ExxonMobil	1	ASTM REO 300	3109-0-1	1.53

PROVE-OUT TESTING: ASTM REO 1012



PROVE-OUT TESTING: ASTM REO 1012



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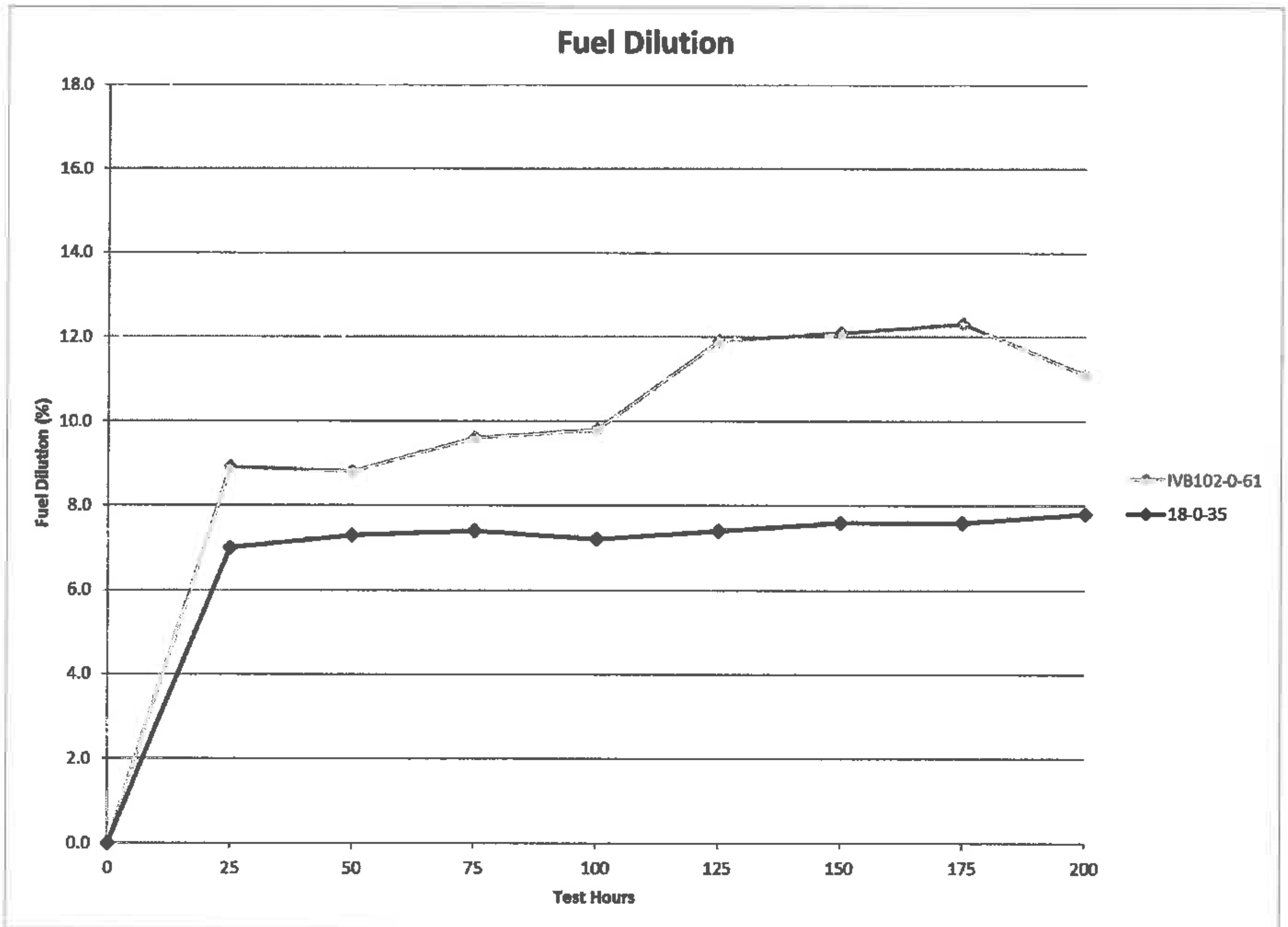

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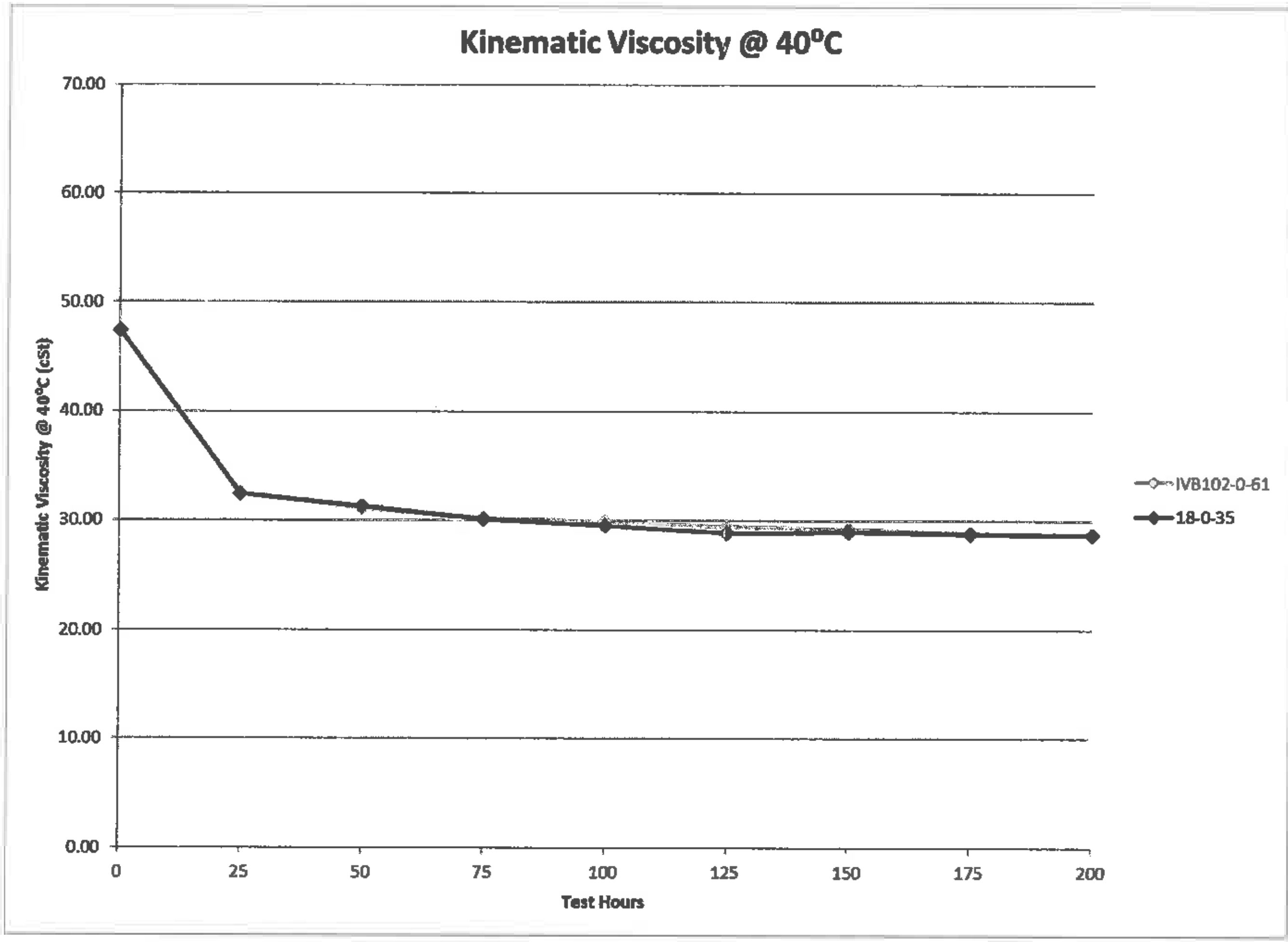

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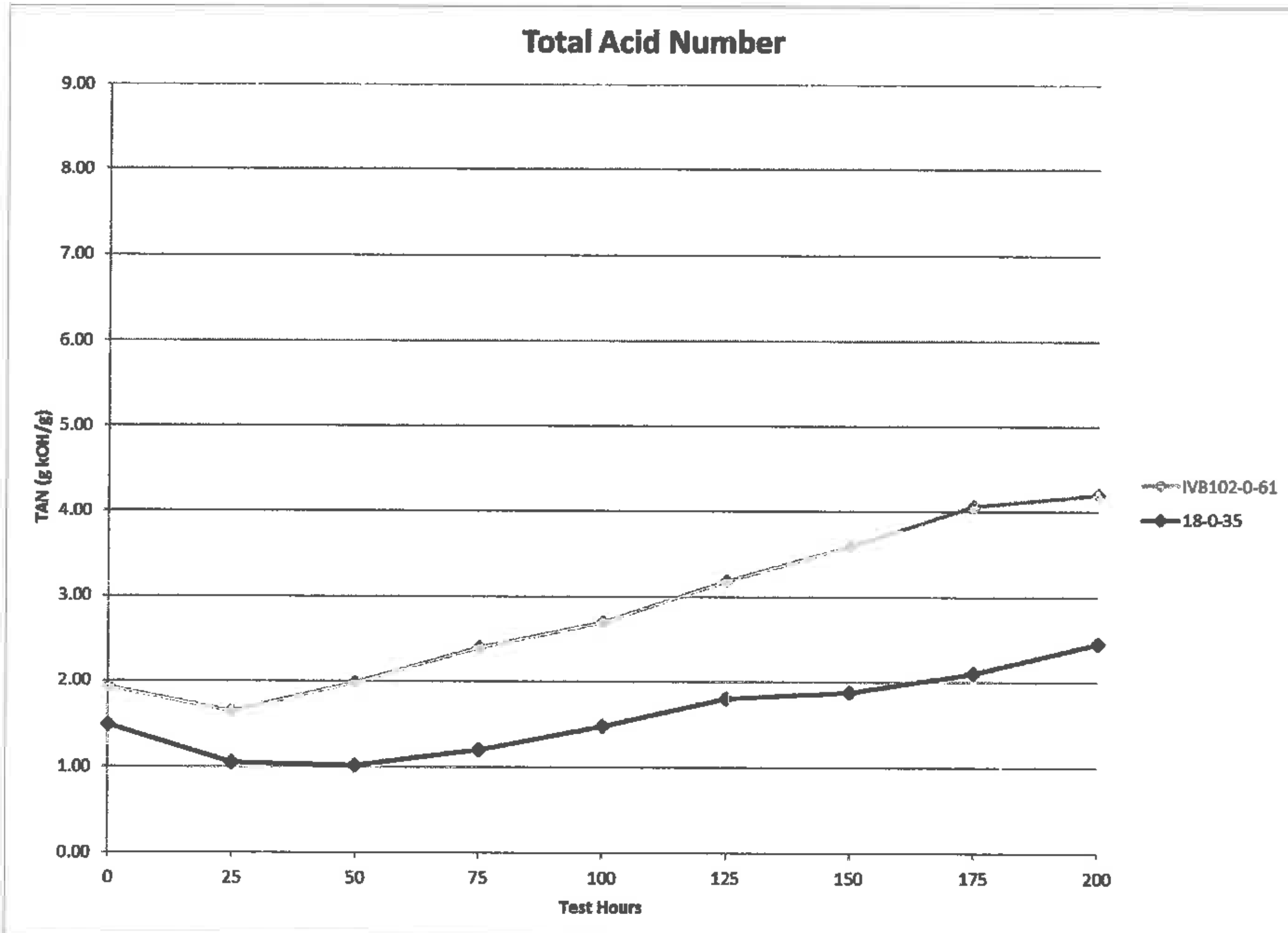

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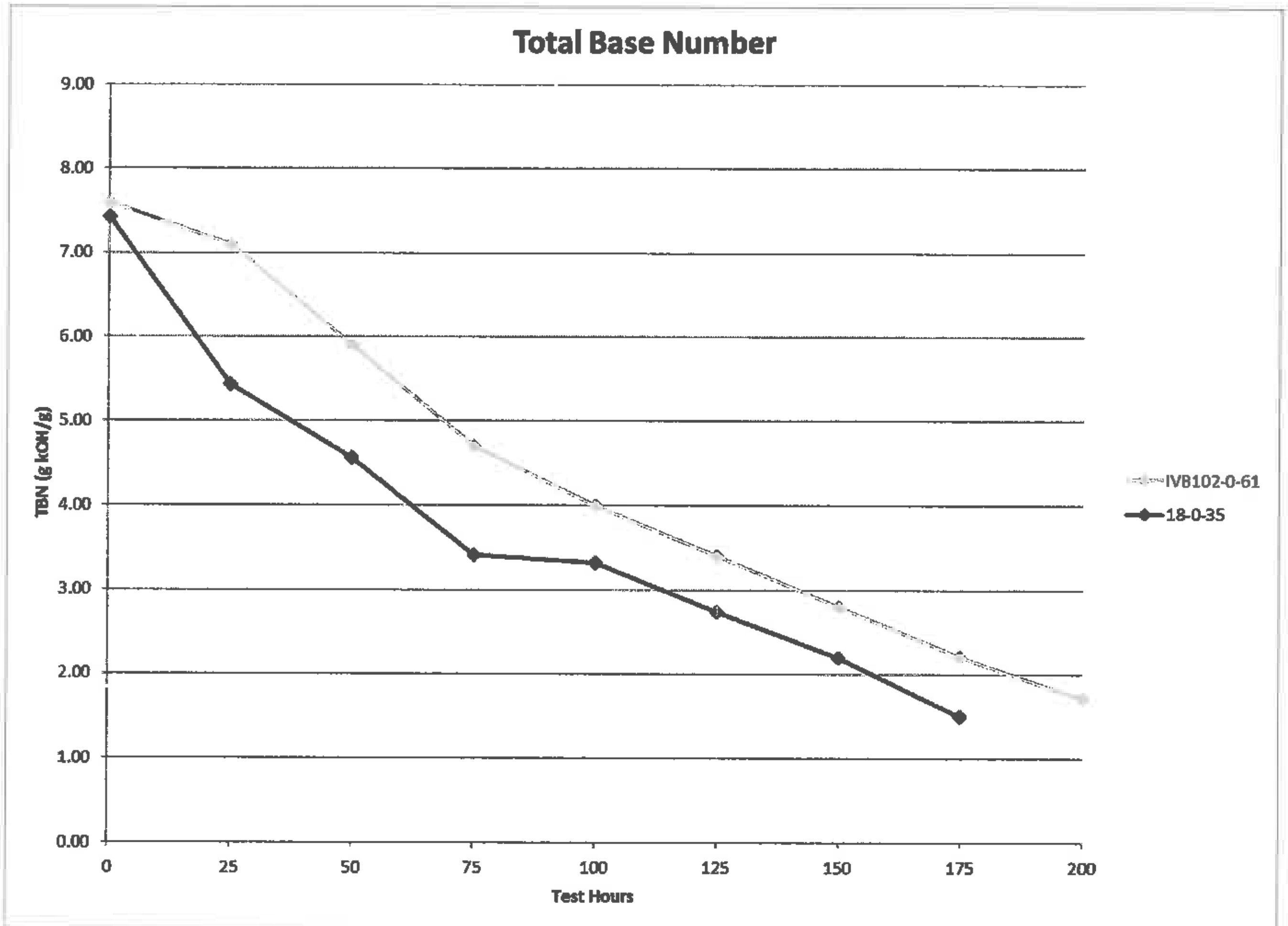

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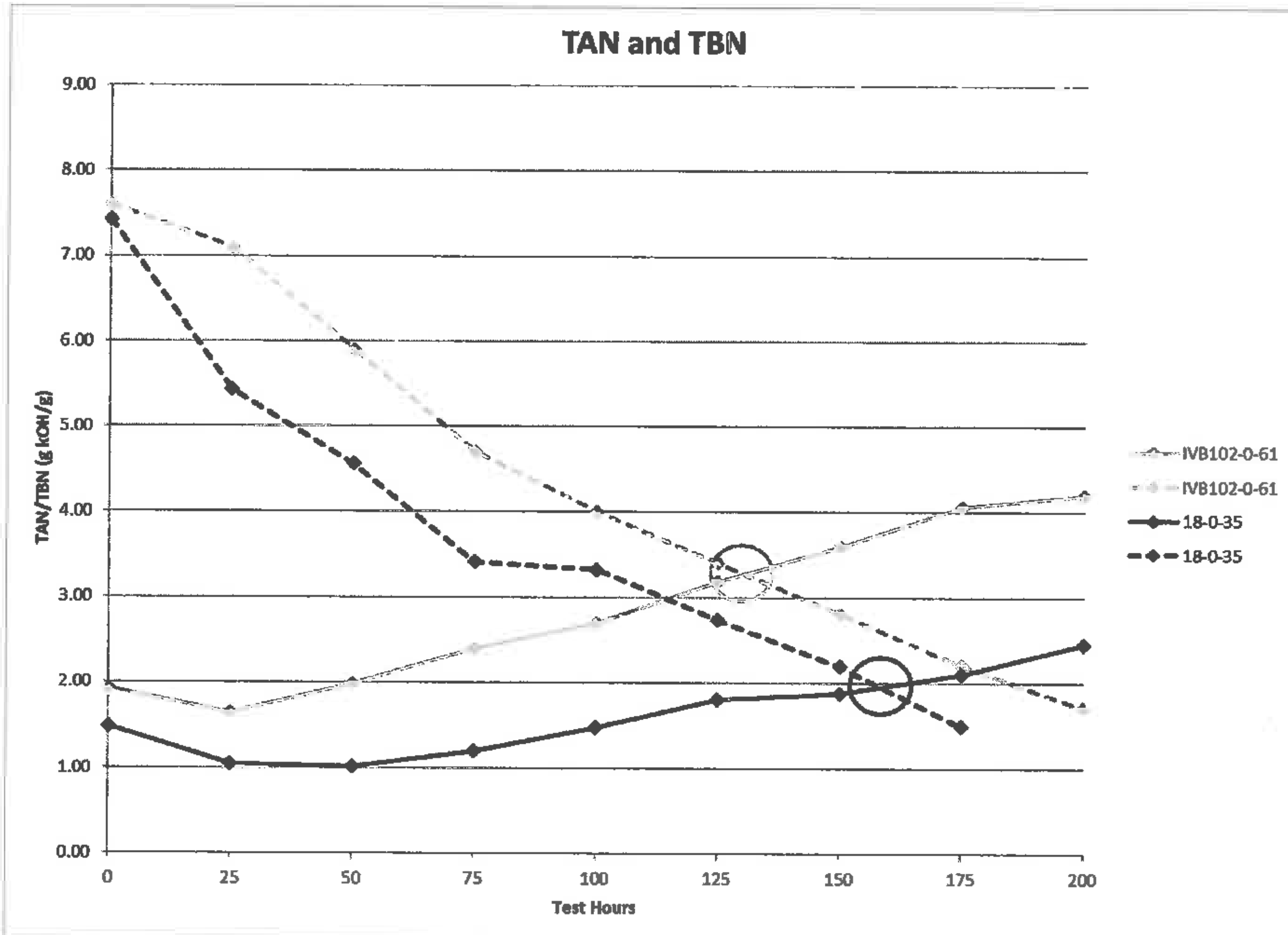

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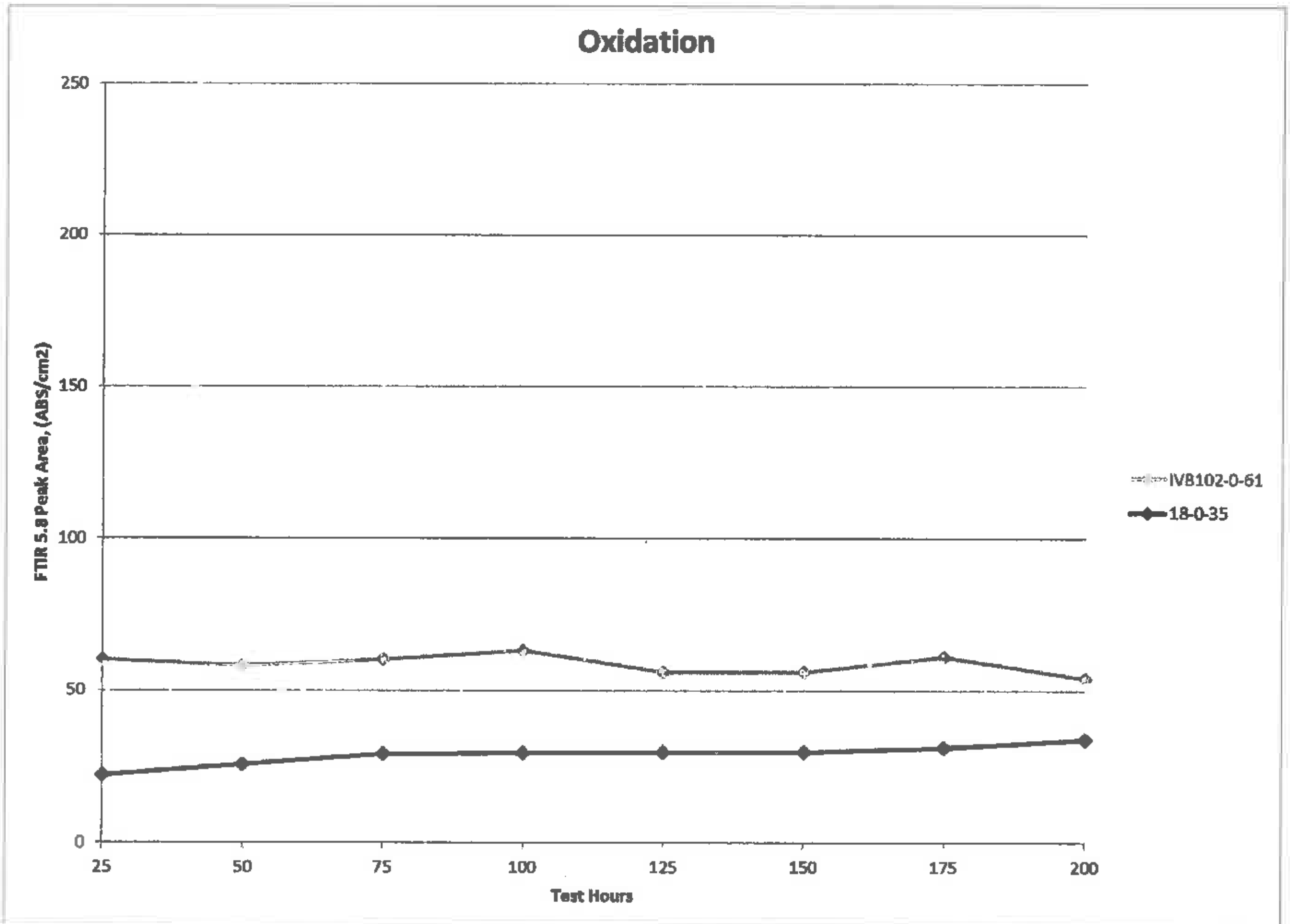

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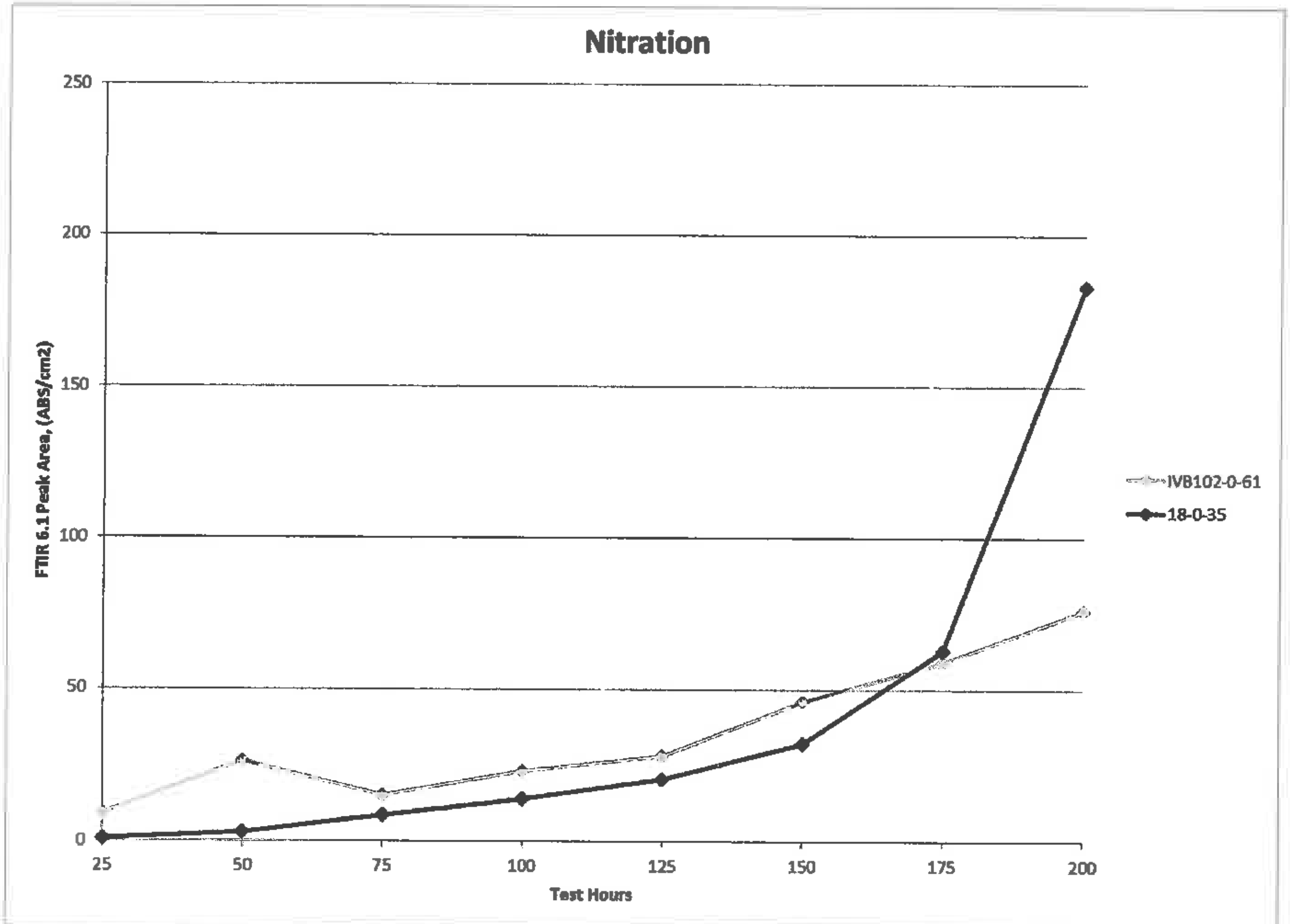

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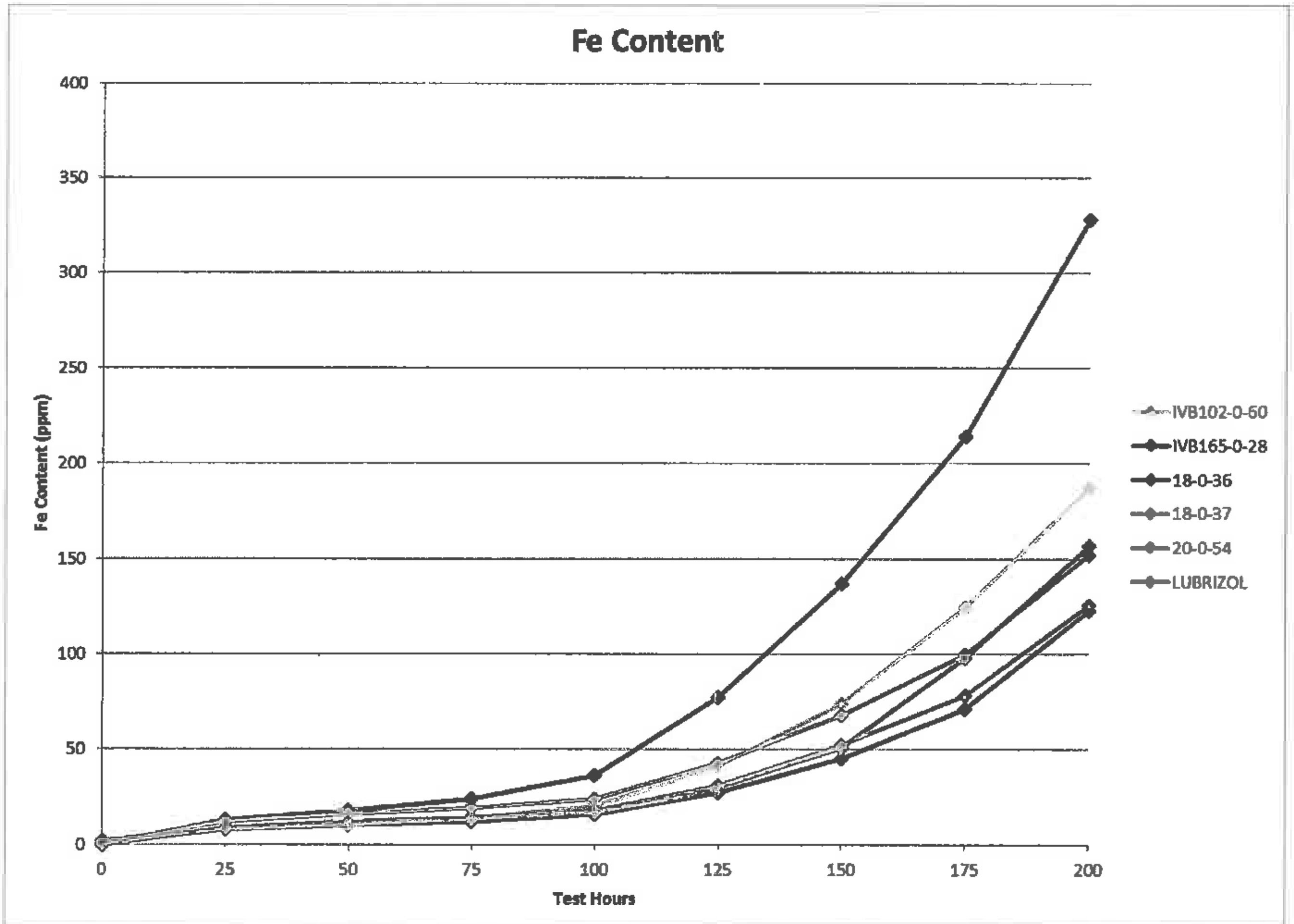

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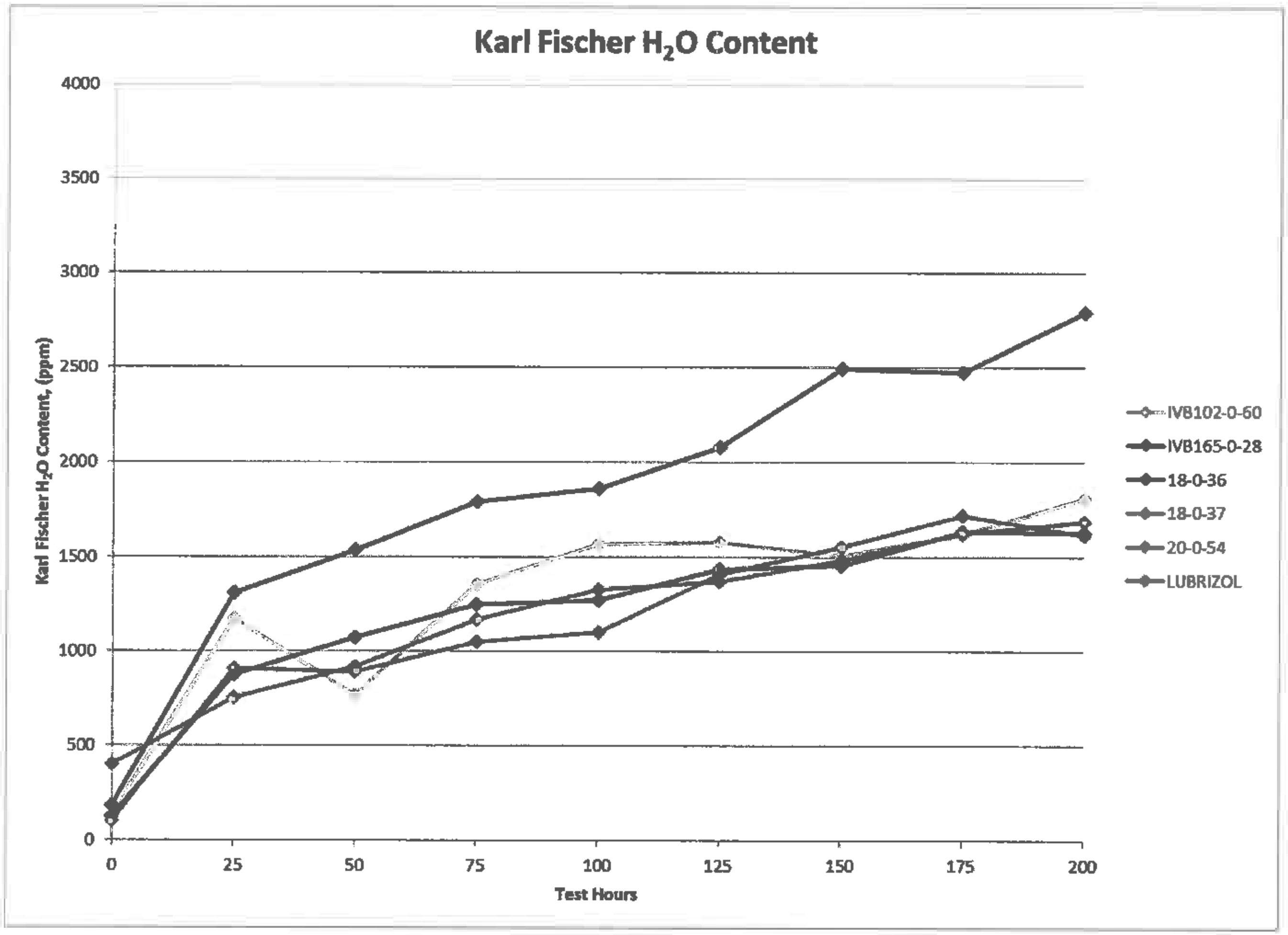

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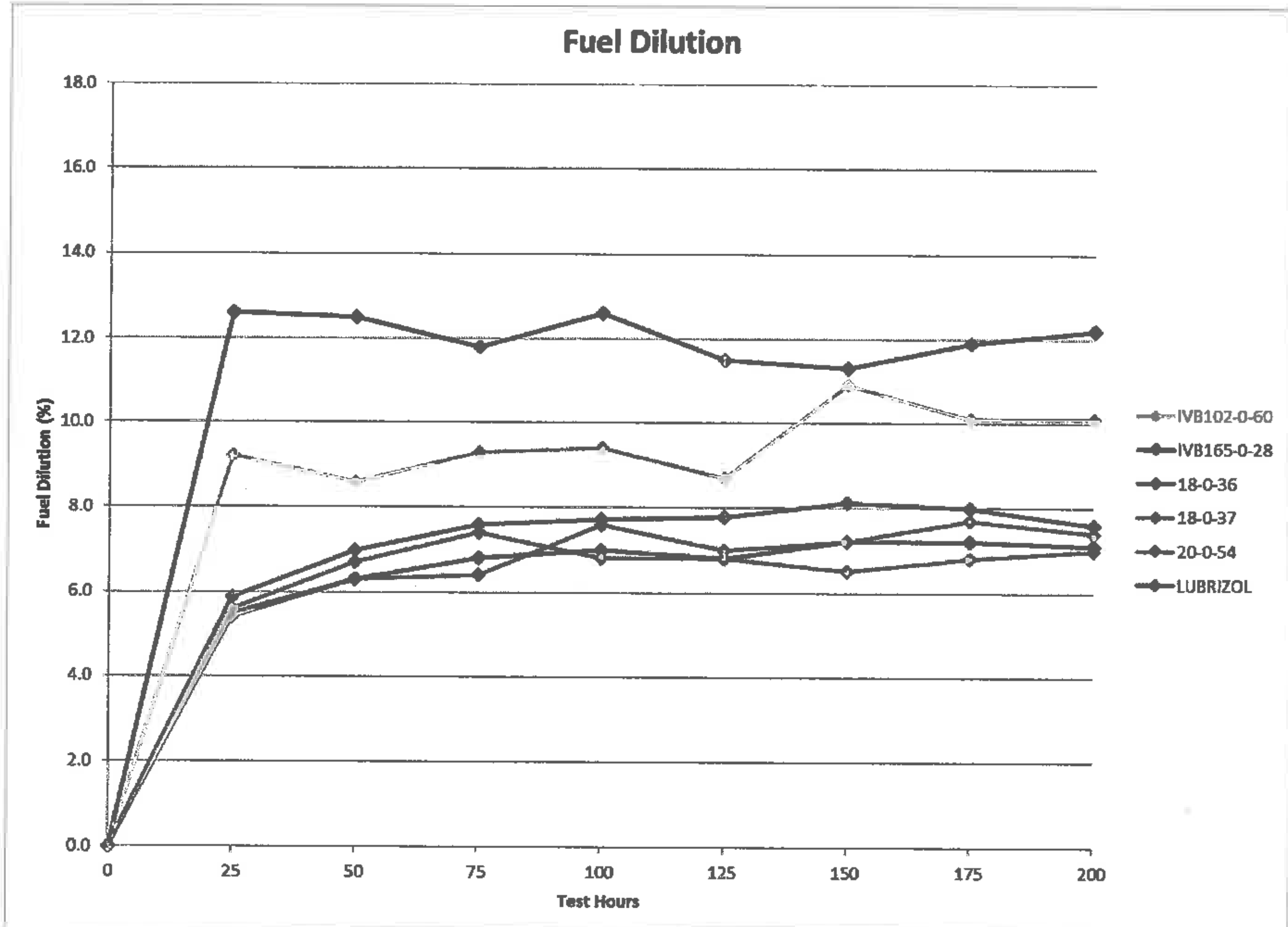

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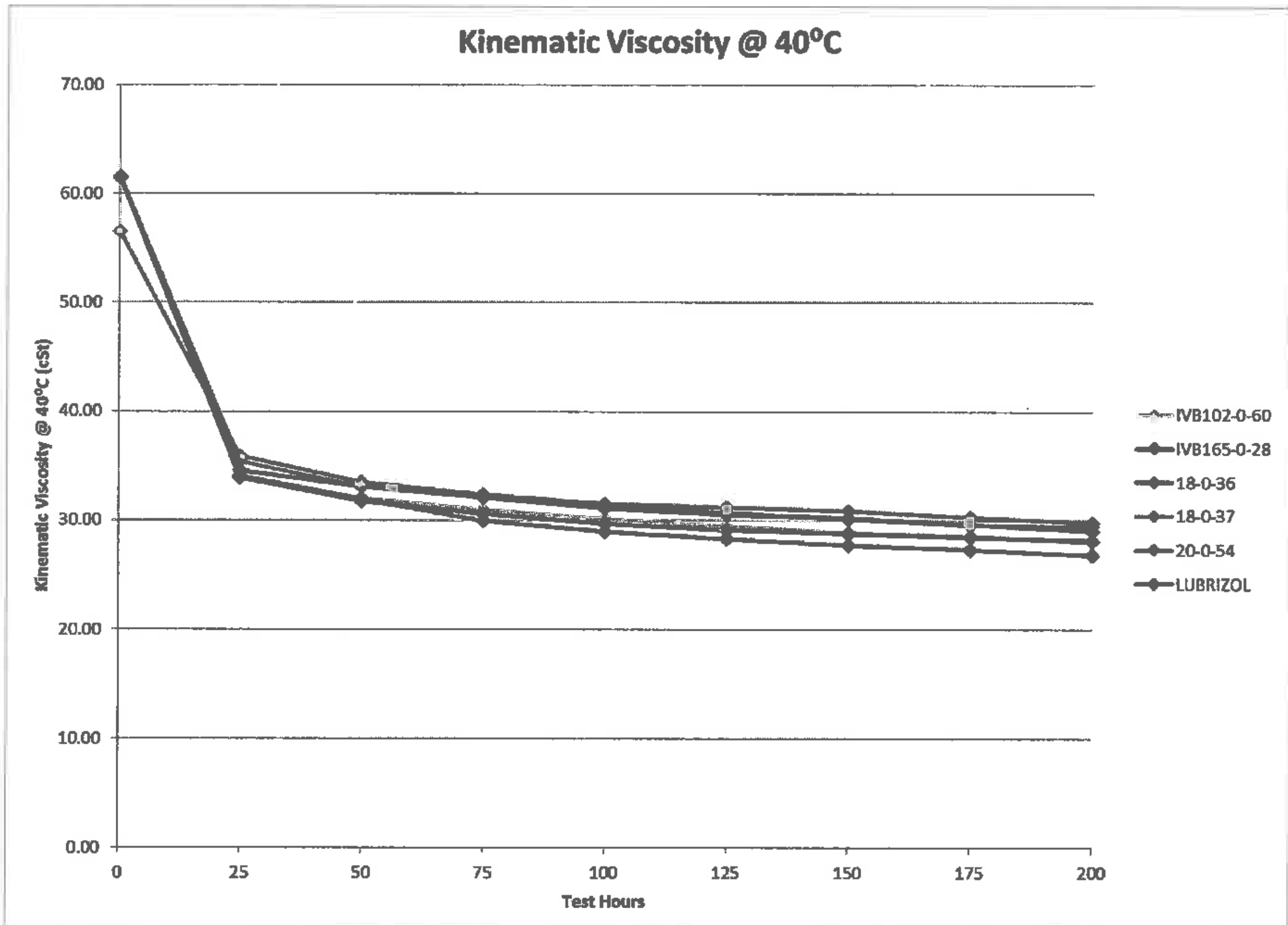

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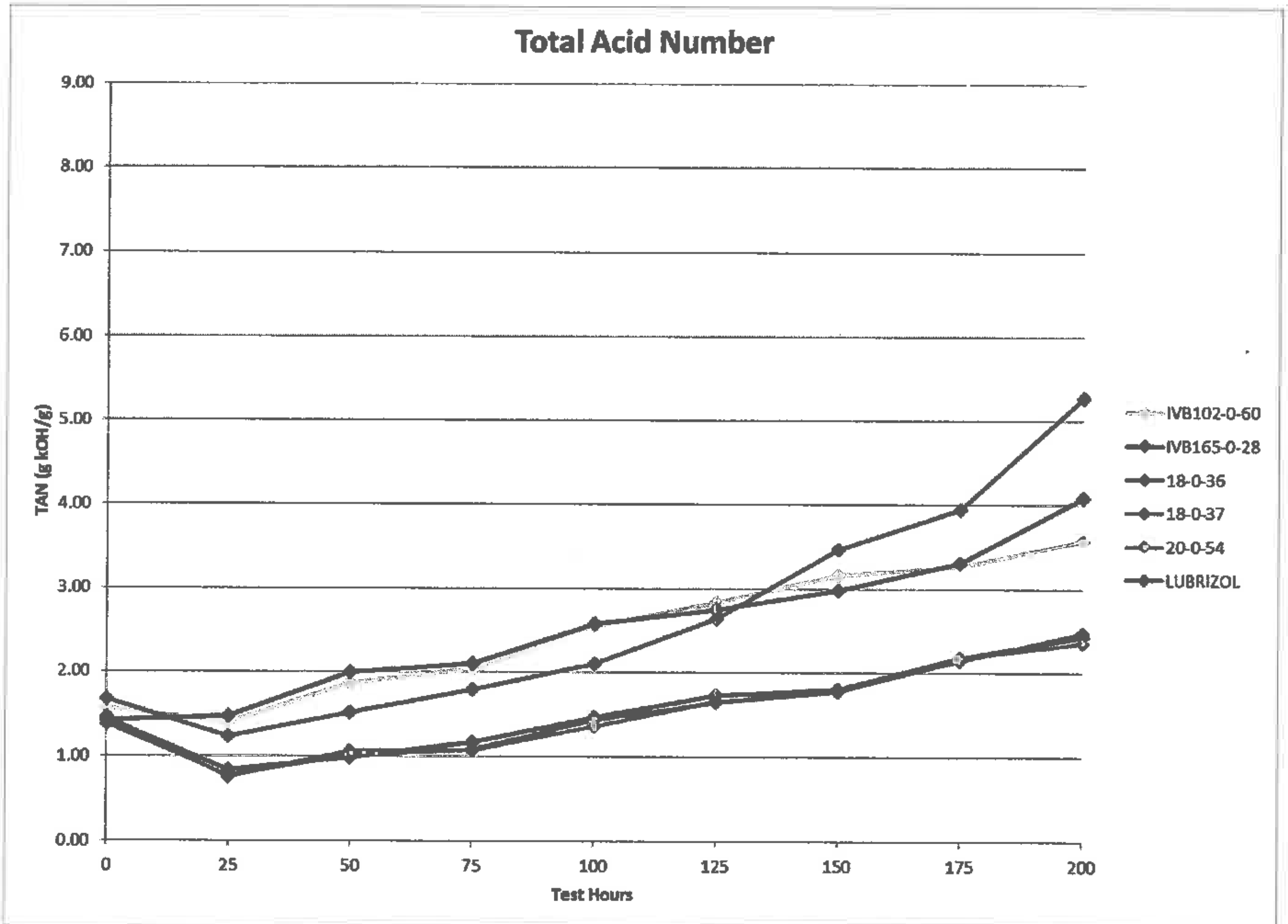

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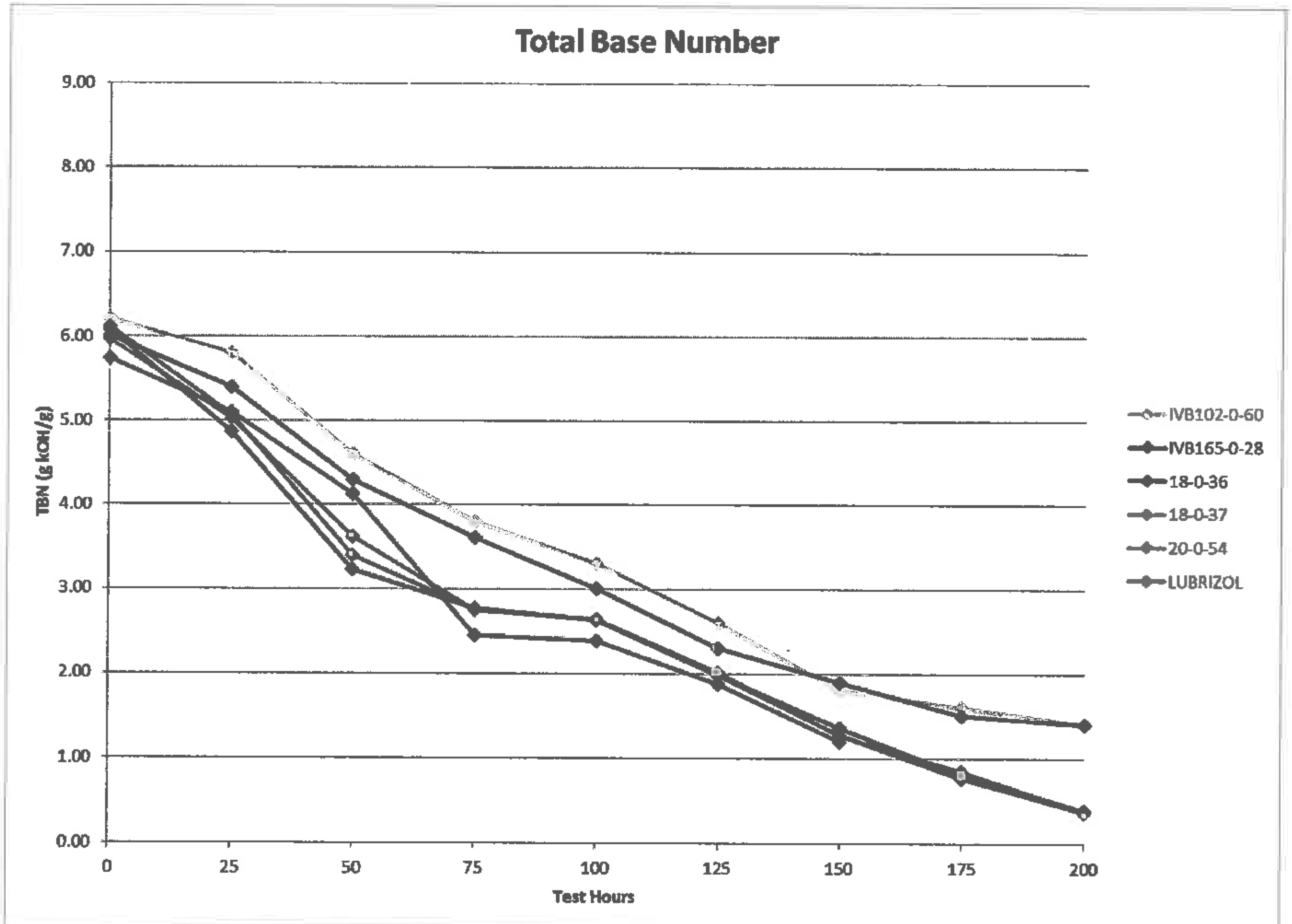

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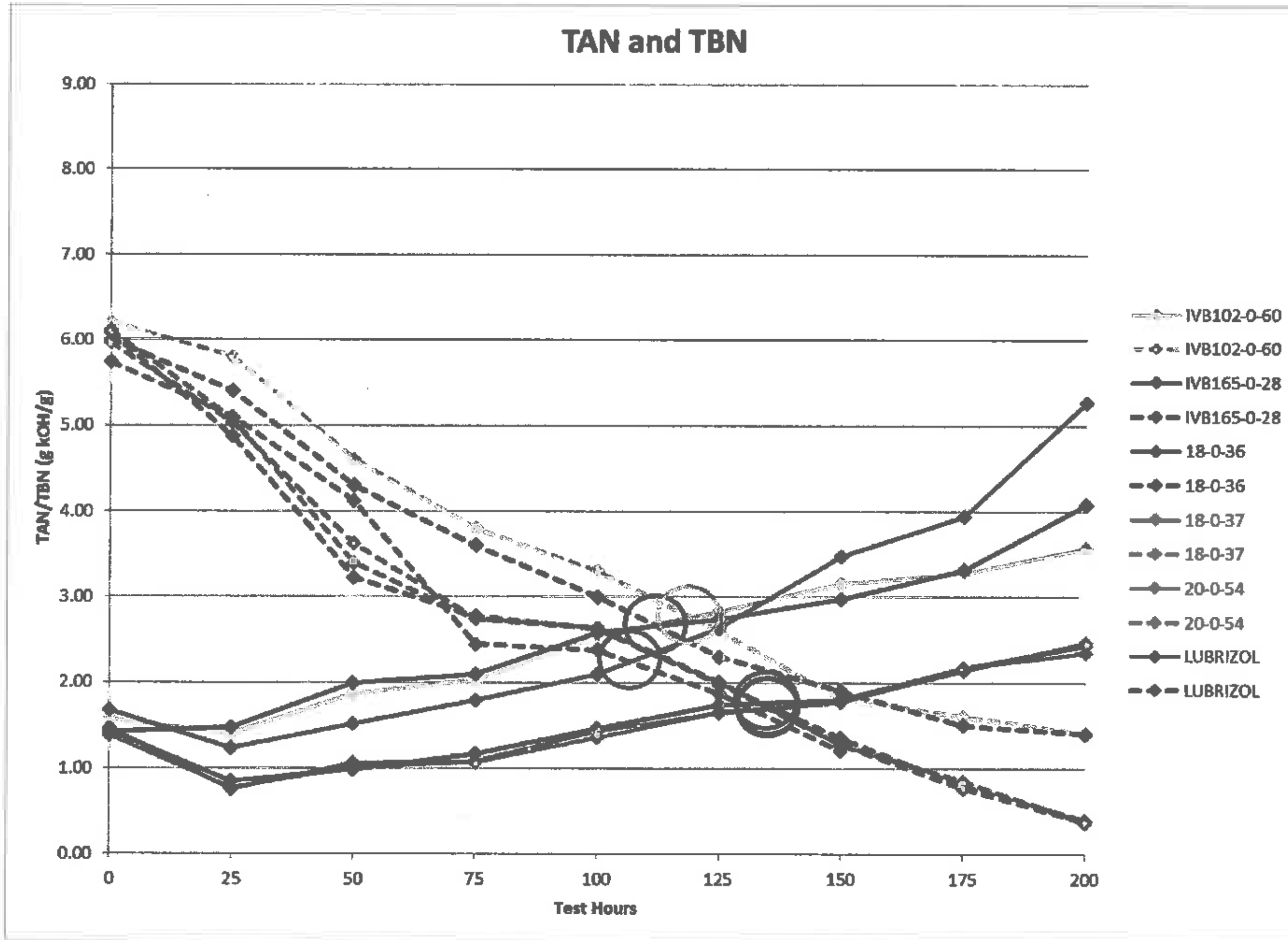
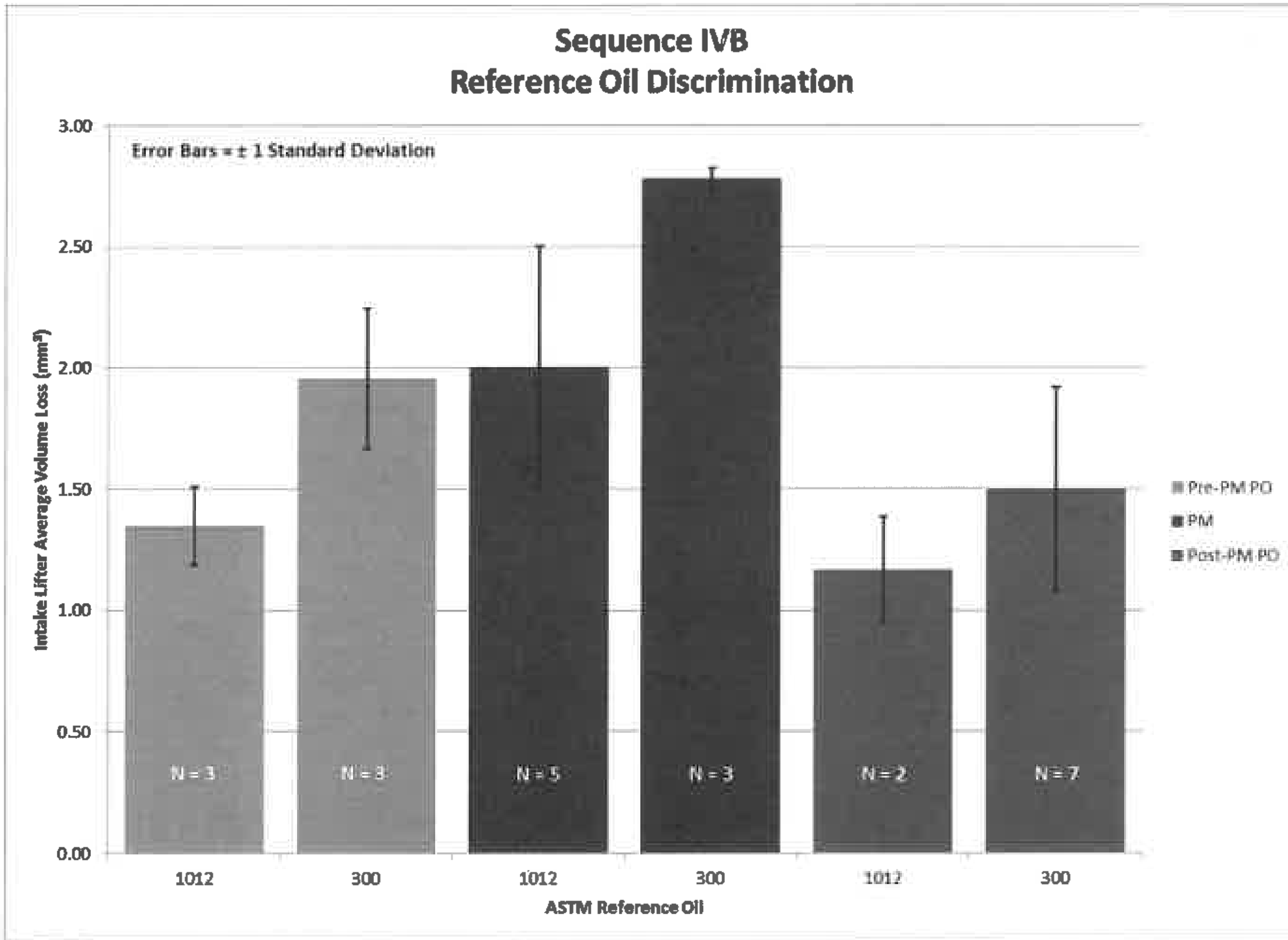


PROVE-OUT TESTING: ASTM REO 300

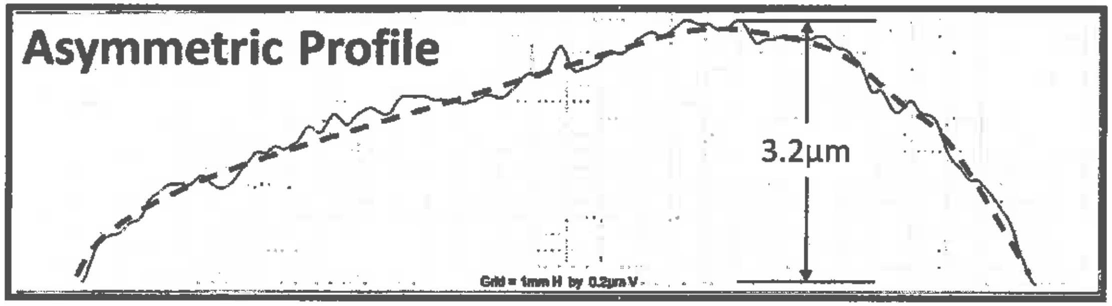
PROVE-OUT TESTING: ASTM REO 300

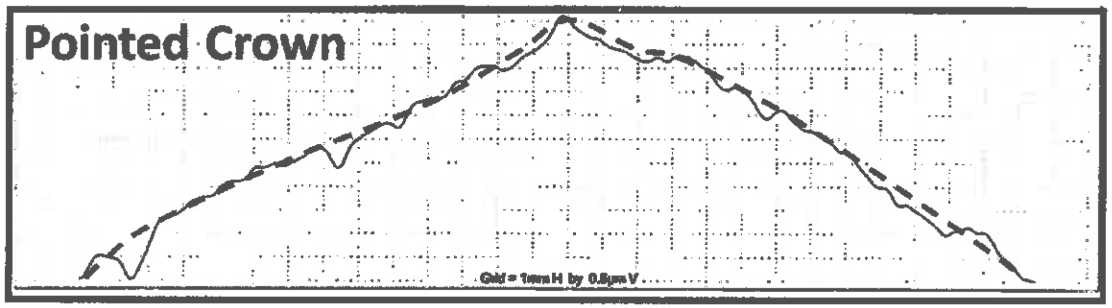
OIL DISCRIMINATION

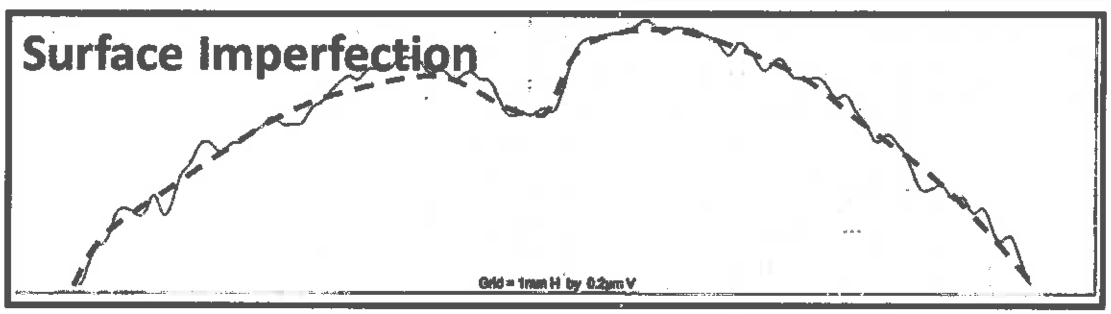


CHANGES INFLUENCE ON PRECISION AND SEVERITY

INTAKE LIFTER CROWN PROFILE REJECTION CRITERIA







TIMELINE

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Quality Index for Coolant Temperature Out of Engine

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The Data Set

The table to the right shows the tests that were included in determination of QI recommendations.

Lab	Test
IAR	IVB102-0-60
	IVB102-0-61
	IVB165-0-26
	IVB165-0-28
SwRI	18-0-35
	18-0-36
	18-0-37
	20-0-52
	20-0-54
Lubrizol	TRNN2RZPB
ExxonMobil	3109-0-1

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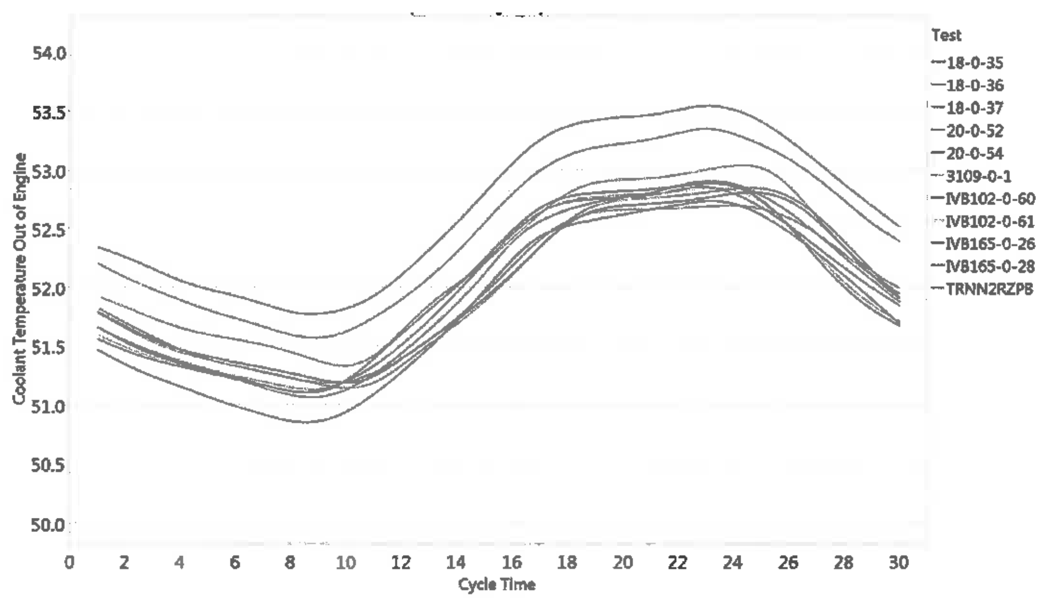
How to Control Coolant Temp Out

This parameter behaves cyclically. Two options to use QIs are:

1. Have a single target and window for all data.
2. Have separate stage 1 and stage 2 targets and windows.

Though the first option is certainly the easiest, it does not allow us to control the "swing" between stage 1 and 2. Is a test that swings very little around 52C the same as a tests we are running now?

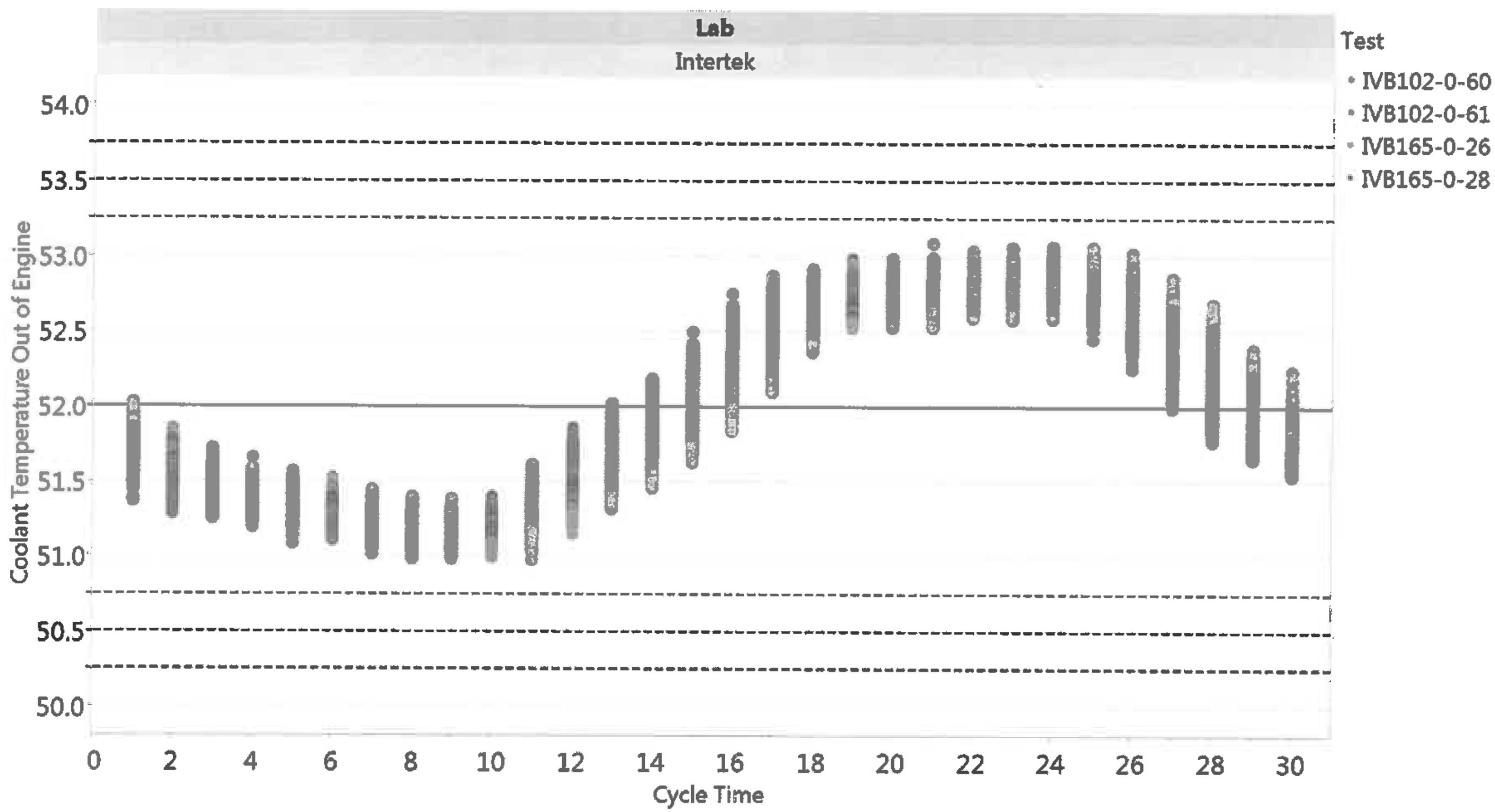


Option #1

Single Target and Window

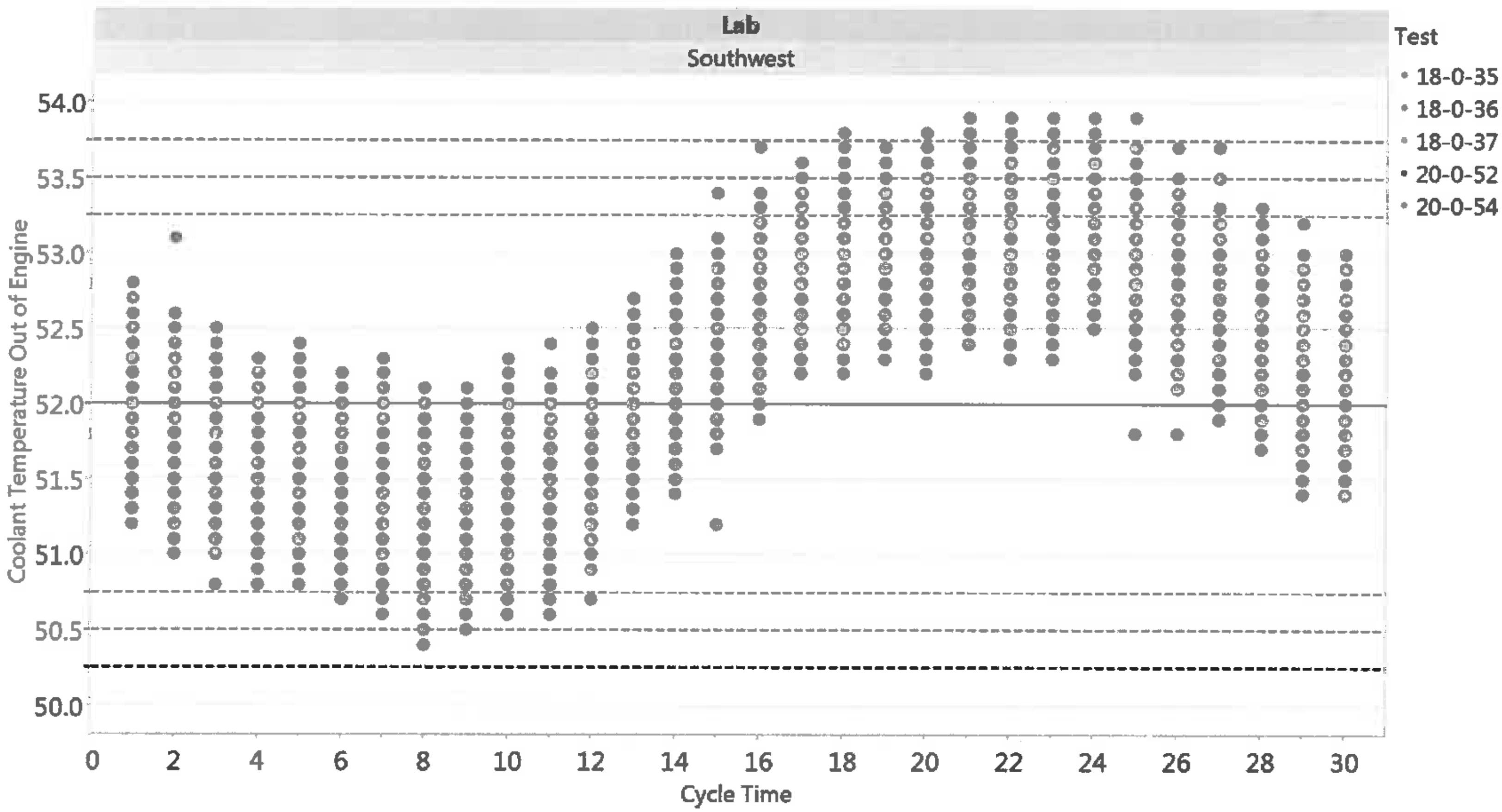
Engine Coolant Temp Out QI
Lab = IAR

- Target : 52 C
- Window size 1: +/- 1.75 C
- Window size 2: +/- 1.50 C
- Window size 3: +/- 1.25 C



Engine Coolant Temp Out QI
Lab = SwRI

- Target : 52 C
- Window size 1: +/- 1.75 C
- Window size 2: +/- 1.50 C
- Window size 3: +/- 1.25 C



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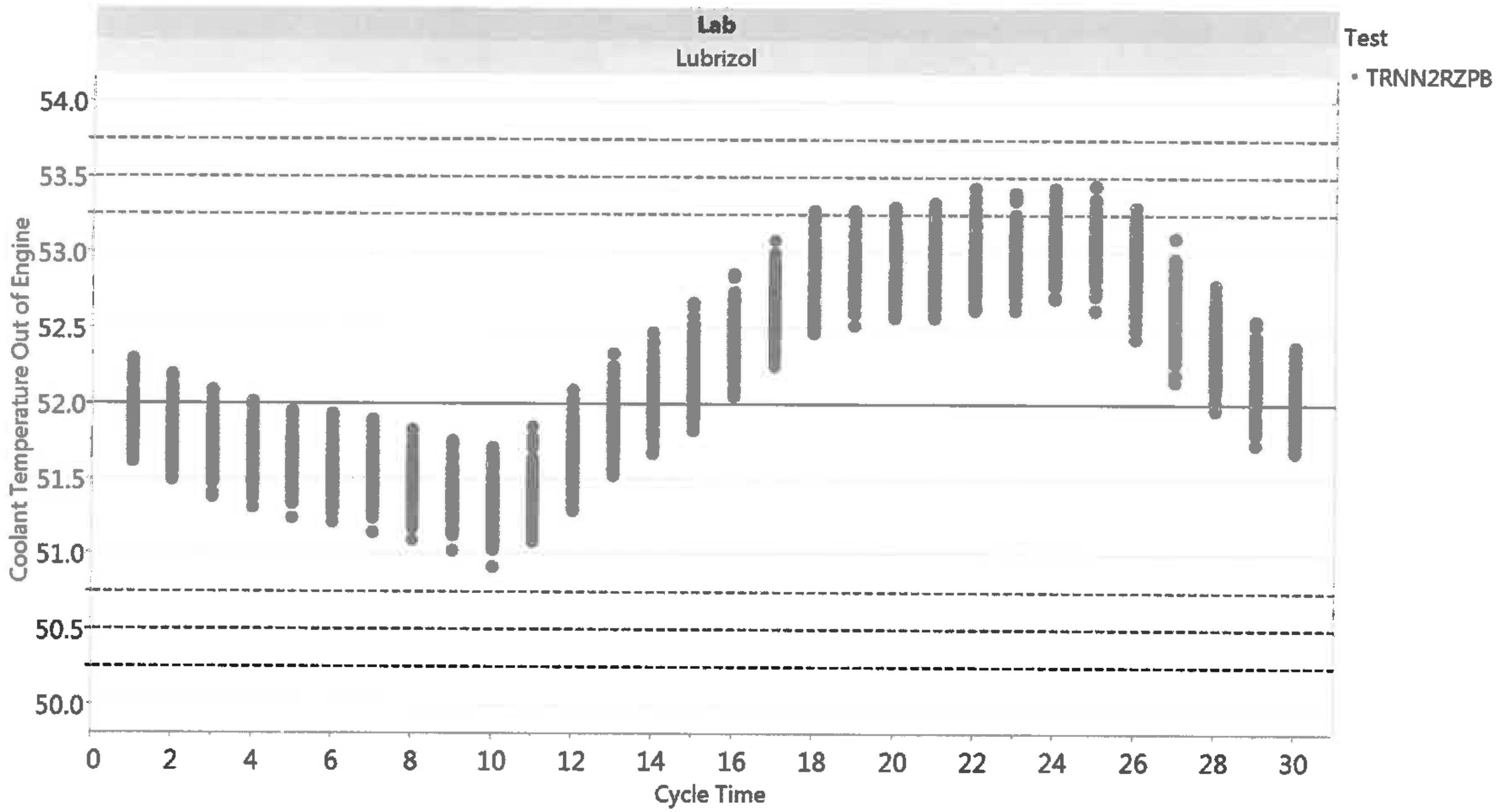
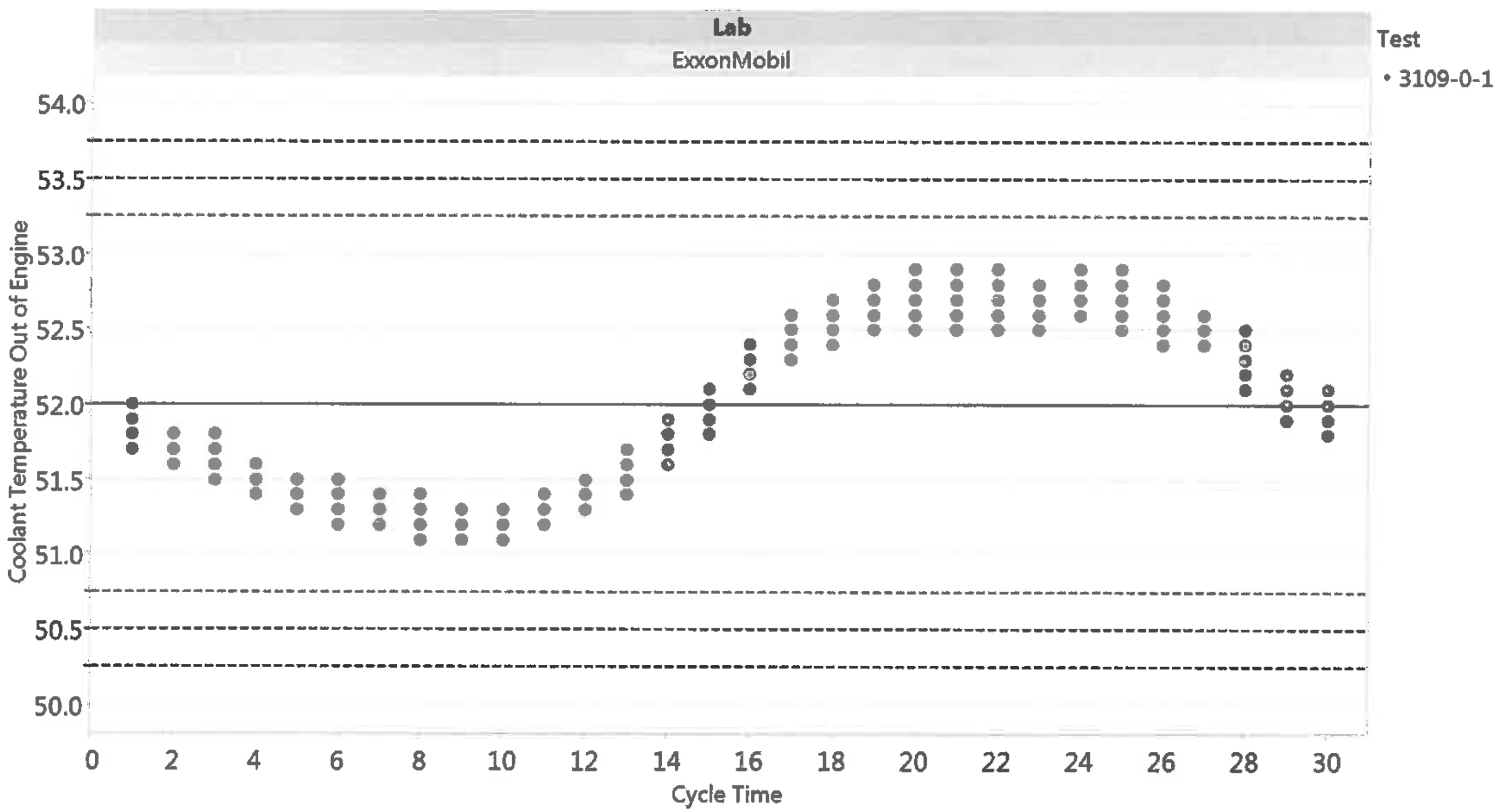
Engine Coolant Temp Out QI
Lab = Lubrizol

- Target : 52 C
- Window size 1: +/- 1.75 C
- Window size 2: +/- 1.50 C
- Window size 3: +/- 1.25 C



Engine Coolant Temp Out QI
Lab = ExxonMobil

- Target : 52 C
- Window size 1: +/- 1.75 C
- Window size 2: +/- 1.50 C
- Window size 3: +/- 1.25 C



Engine Coolant Temp Out QI

- Target : 52 C
- Window size 1: +/- 1.75 C
- Window size 2: +/- 1.50 C
- Window size 3: +/- 1.25 C

Test no.	Window 1 QI	Window 2 QI	Window 3 QI
IVB102-0-60	0.86	0.81	0.73
IVB102-0-61	0.87	0.82	0.75
IVB165-0-26	0.87	0.83	0.75
IVB165-0-28	0.89	0.85	0.78
18-0-35	0.87	0.82	0.74
18-0-36	0.71	0.61	0.44
18-0-37	0.79	0.72	0.59
20-0-52	0.84	0.78	0.68
20-0-54	0.86	0.80	0.72
TRNN2RZPB	0.87	0.82	0.74
3109-0-1	0.88	0.84	0.77
Average	**0.85**	**0.79**	**0.70**

Full Test QI

W1	W2	W3
0.81	0.74	0.63
0.55	0.45	0.35

Option #2

Separate Targets for Stage 1 and 2

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Stage I

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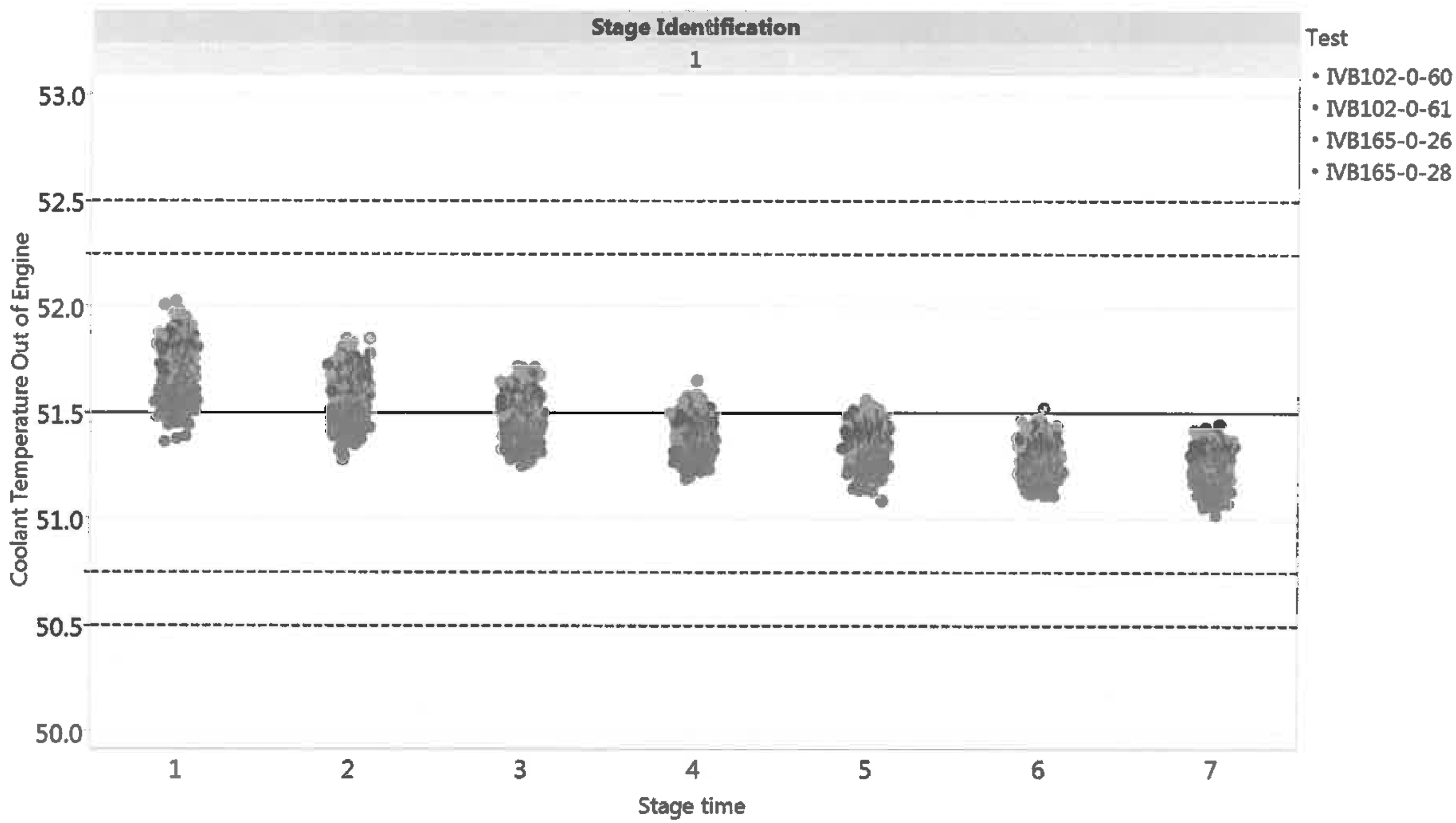
Engine Coolant Temp Out QI
Lab = IAR

- Target : 51.5 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C



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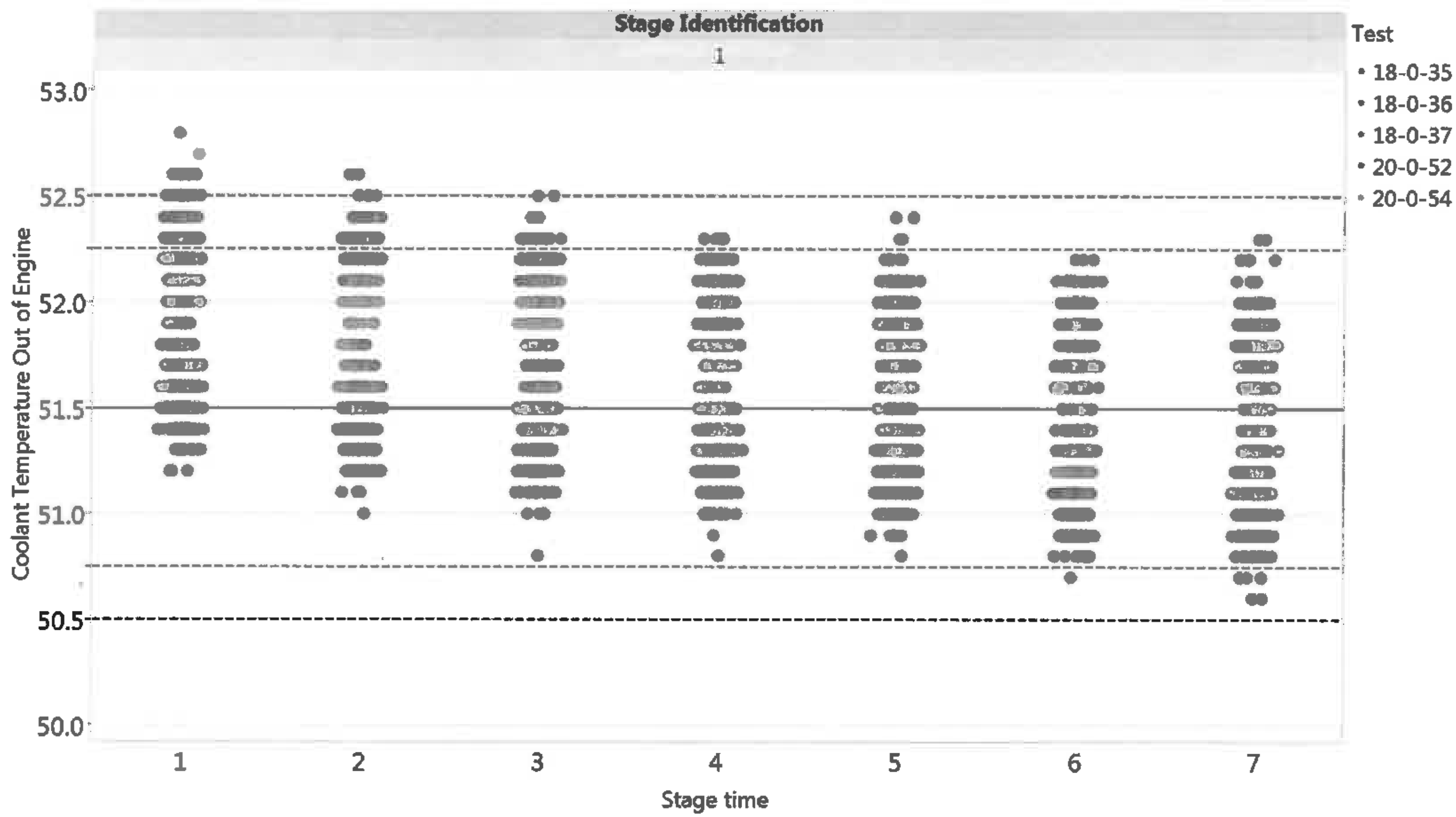
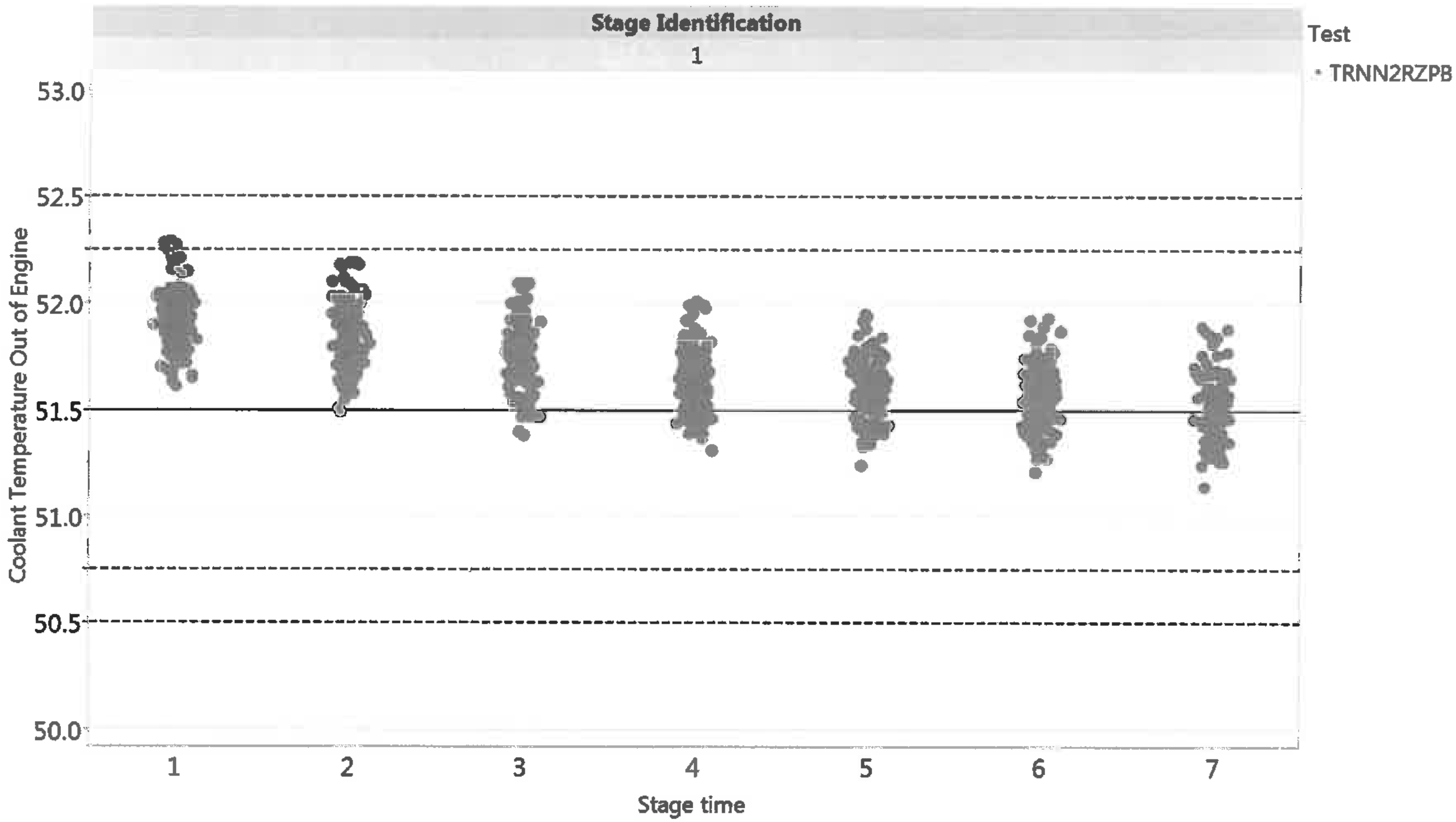
Engine Coolant Temp Out QI
Lab = SwRI

- Target : 51.5 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C



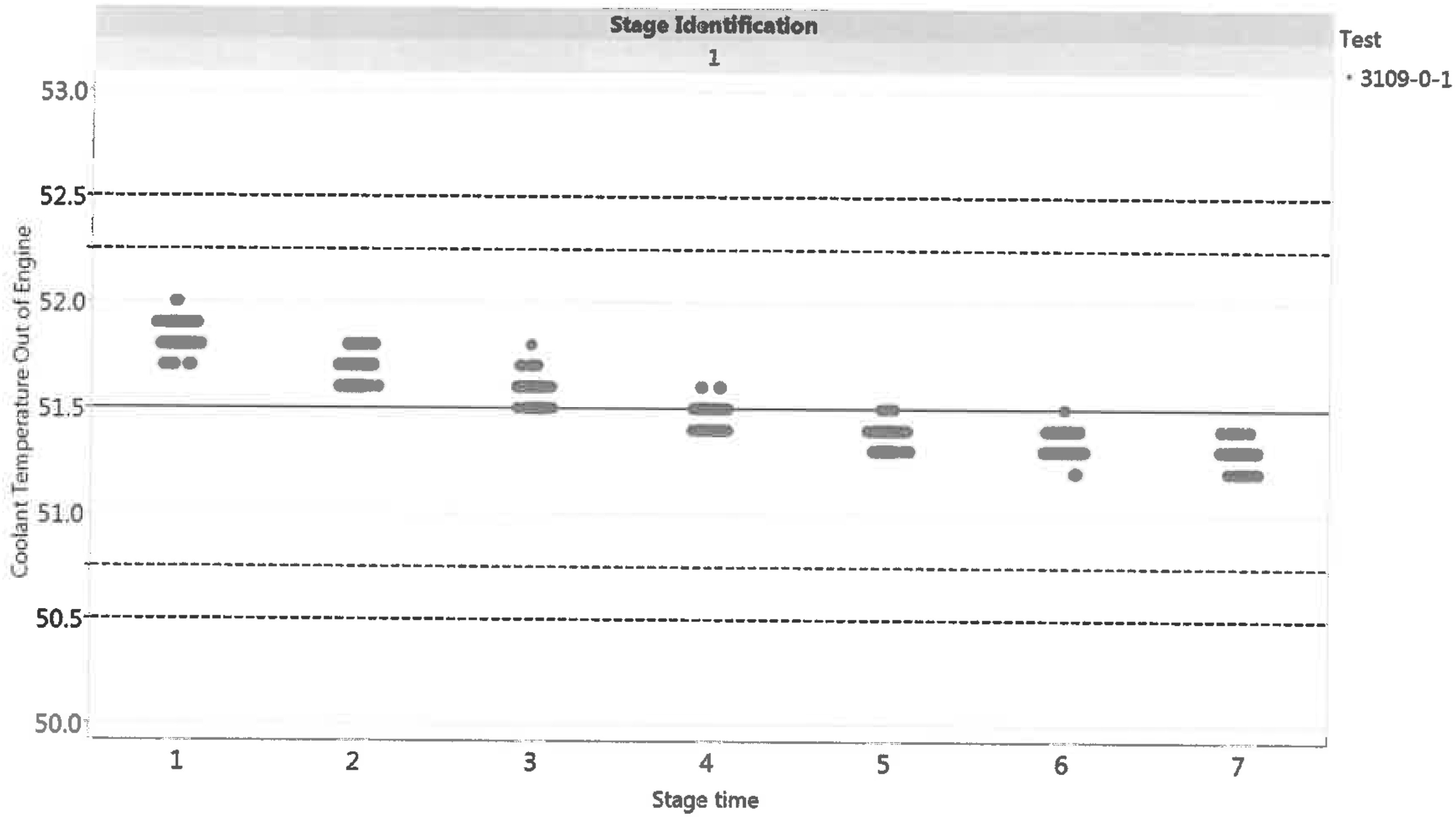
Engine Coolant Temp Out QI
Lab = LZ

- Target : 51.5 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C



Engine Coolant Temp Out QI
Lab = ExxonMobil

- Target : 51.5 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C



Engine Coolant Temp Out QI

- Target : 51.5 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C

Test no.	Stage 1 W1 QI	Stage 1 W2 QI
IVB102-0-60	0.96	0.92
IVB102-0-61	0.96	0.93
IVB165-0-26	0.97	0.94
IVB165-0-28	0.97	0.95
18-0-35	0.95	0.90
18-0-36	0.61	0.31
18-0-37	0.78	0.61
20-0-52	0.85	0.73
20-0-54	0.94	0.90
TRNN2RZPB	0.92	0.86
3109-0-1	0.96	0.93
Average	**0.90**	**0.82**

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Stage 2

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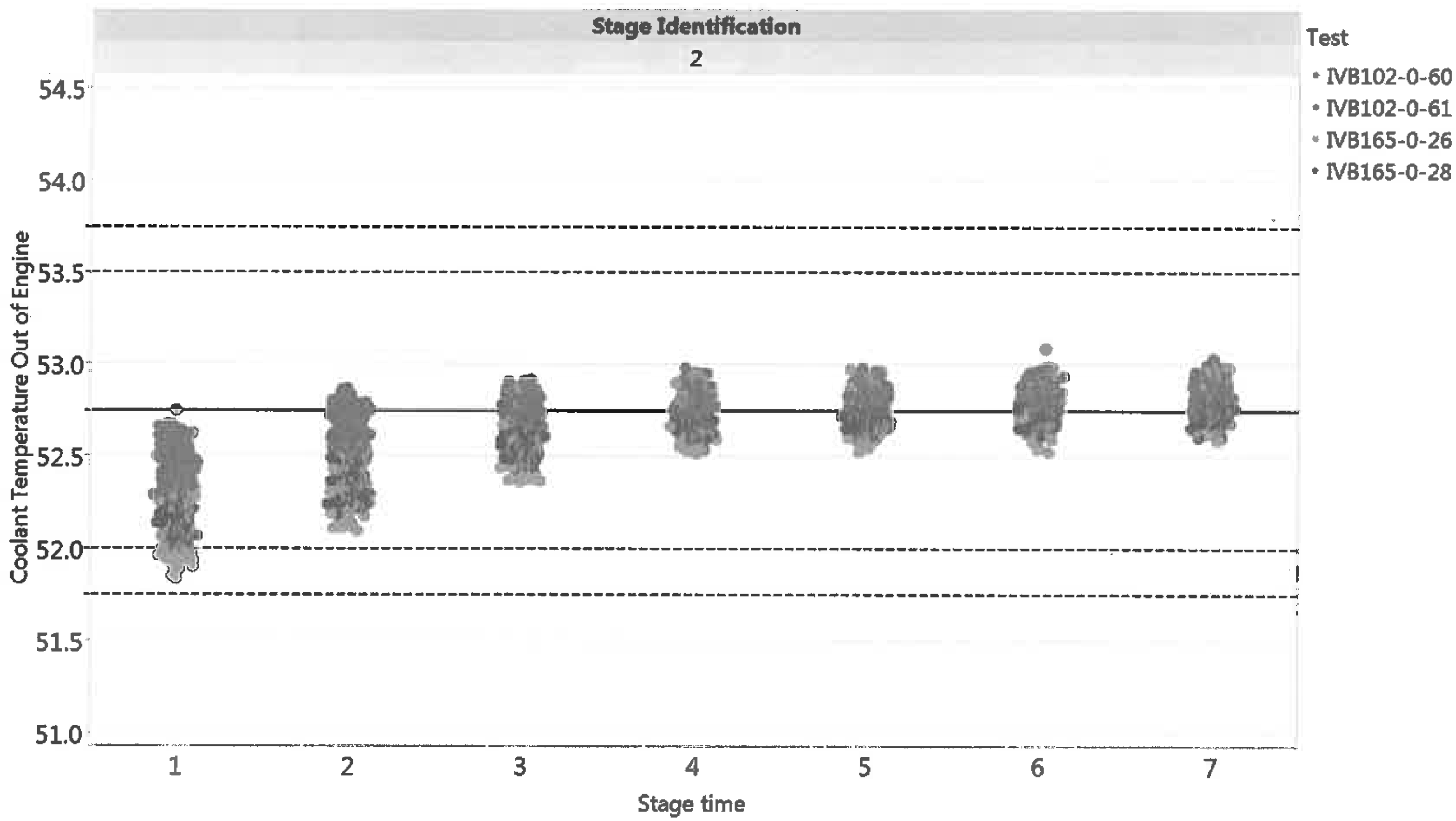
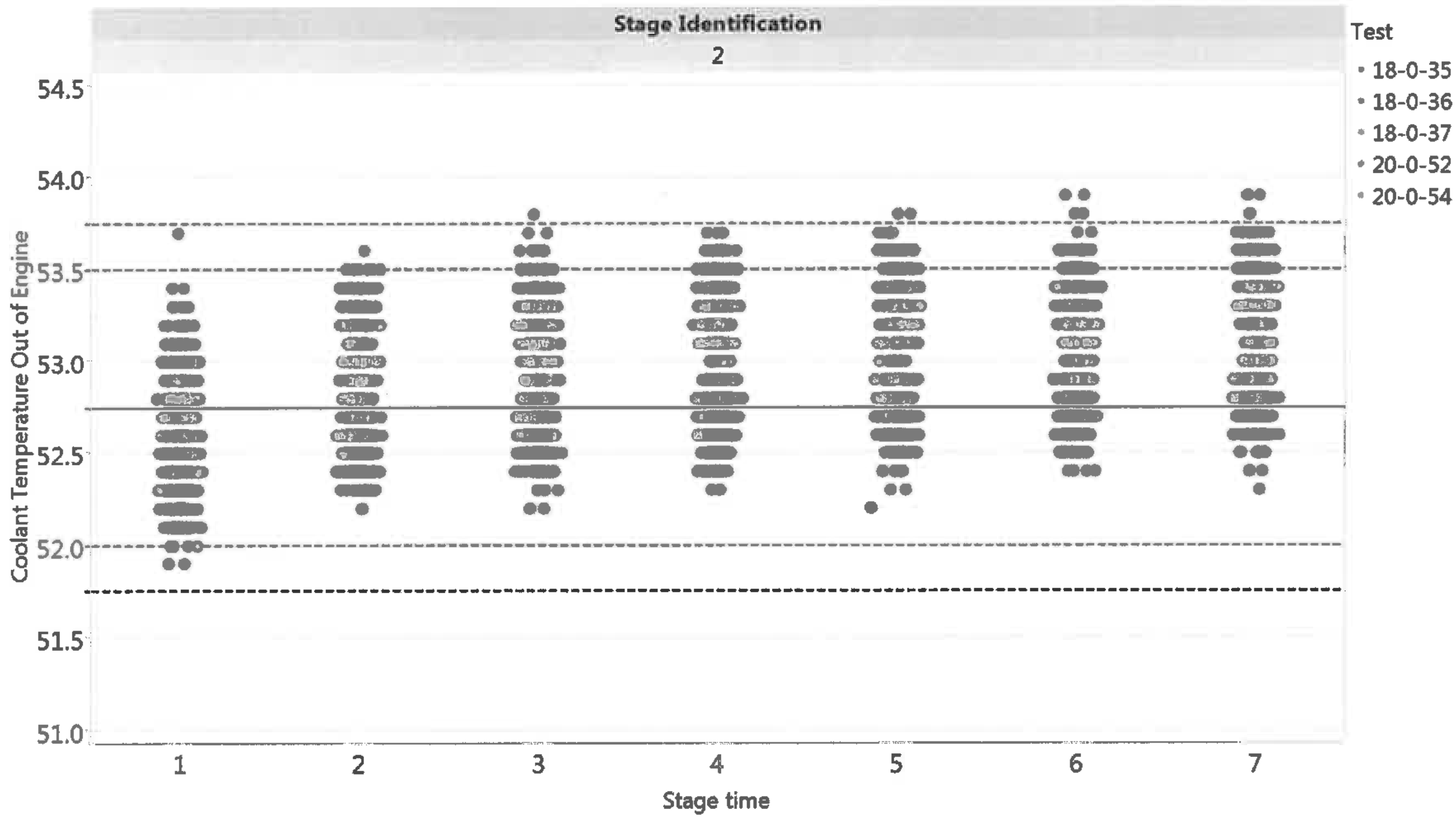
Engine Coolant Temp Out QI
Lab = IAR

- Target : 52.75 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C



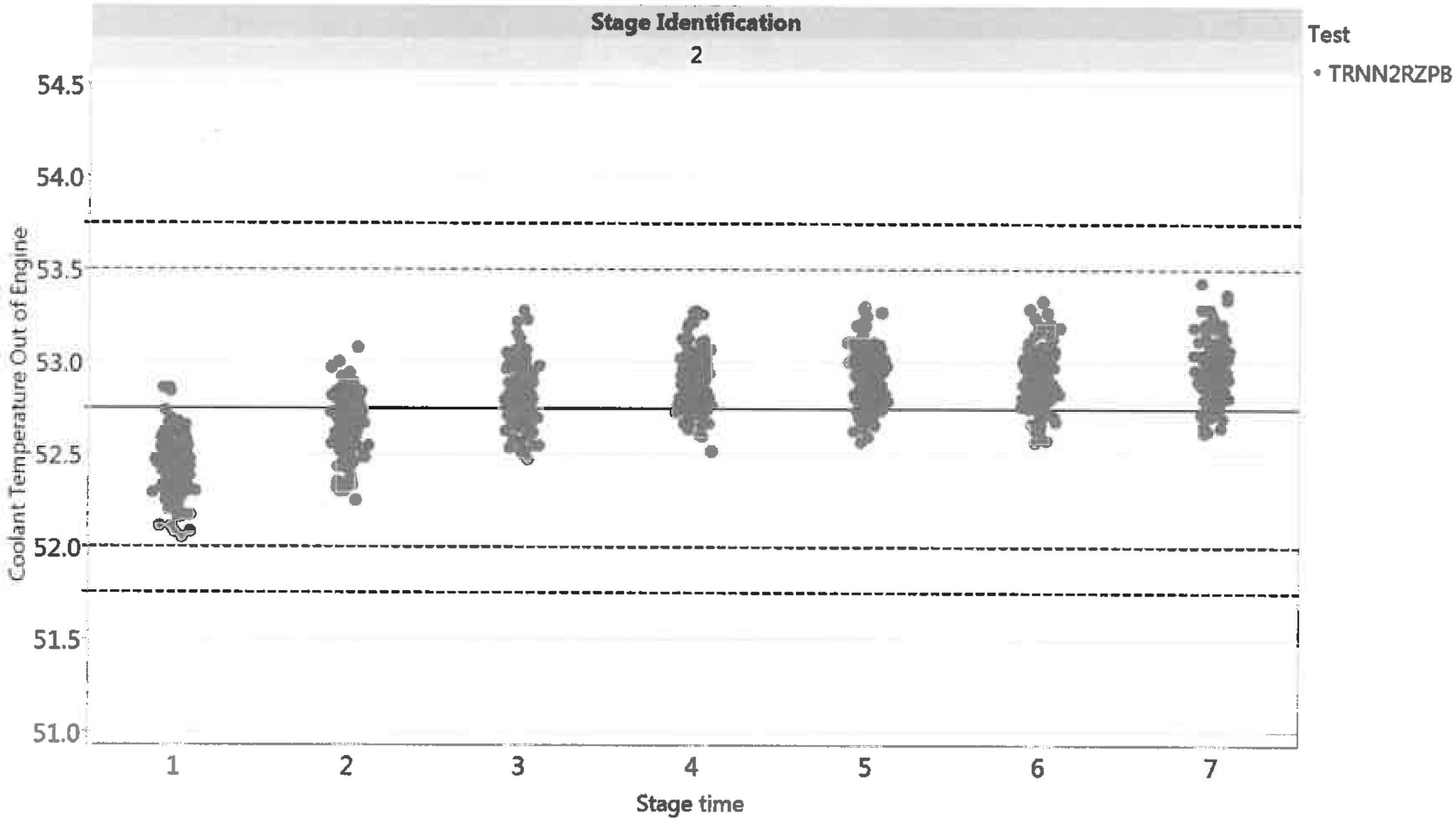
Engine Coolant Temp Out QI
Lab = SwRI

- Target : 52.75 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C



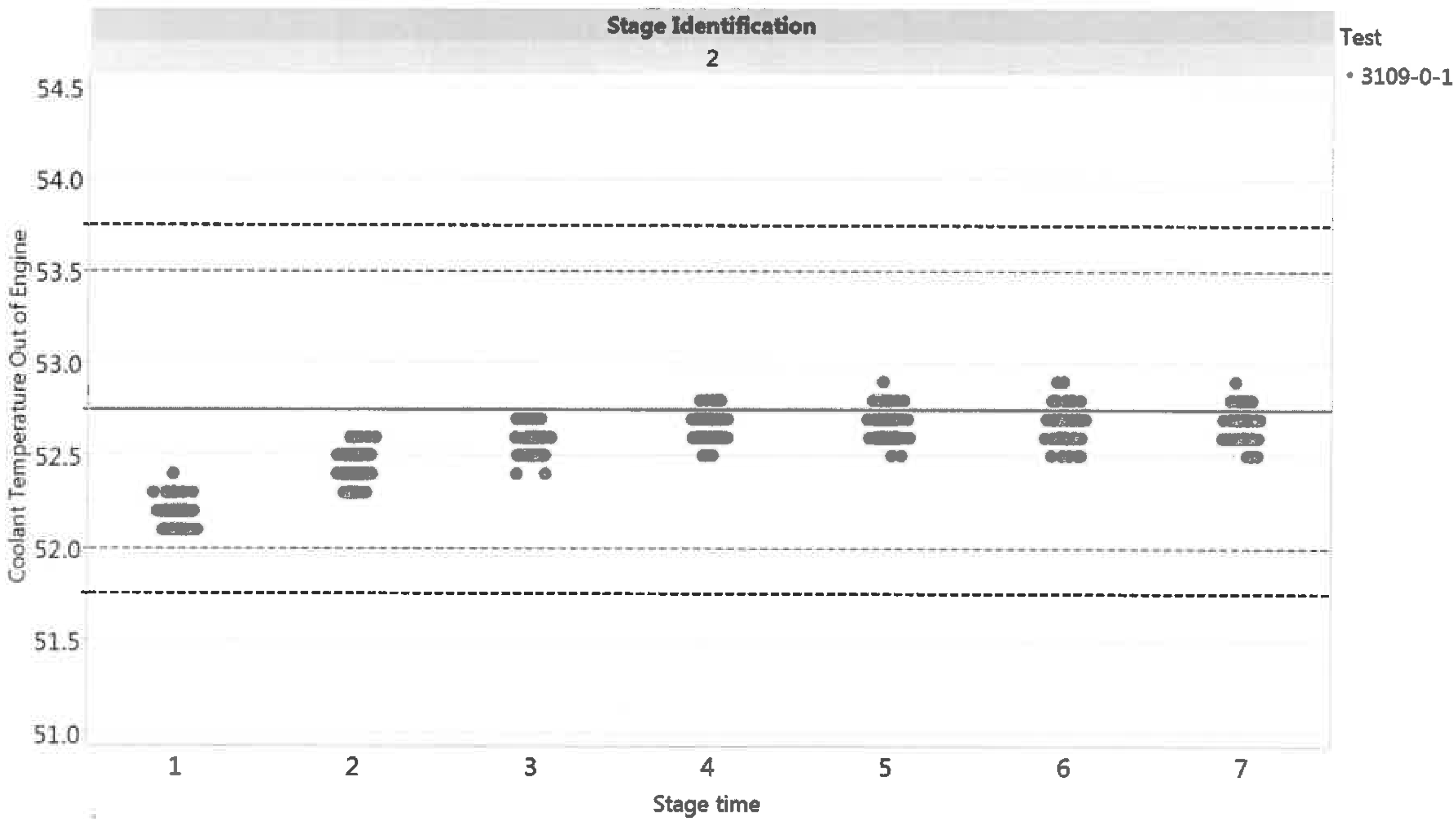
Engine Coolant Temp Out QI
Lab = LZ

- Target : 52.75 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C



Engine Coolant Temp Out QI
Lab = ExxonMobil

- Target : 52.75 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C



Engine Coolant Temp Out QI

- Target : 52.75 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C

Test no.	Stage 2 W1 QI	Stage 2 W2 QI
IVB102-0-60	0.98	0.97
IVB102-0-61	0.98	0.97
IVB165-0-26	0.90	0.82
IVB165-0-28	0.91	0.84
18-0-35	0.97	0.94
18-0-36	0.58	0.26
18-0-37	0.81	0.66
20-0-52	0.92	0.86
20-0-54	0.96	0.93
TRNN2RZPB	0.94	0.89
3109-0-1	0.92	0.87
Average	**0.90**	**0.82**

Engine Coolant Temp Out QI

- Target : 52.75 C
- Window size 1: +/- 1.00 C
- Window size 2: +/- 0.75 C

Test no.	Final W1 QI	Final W2 QI
IVB102-0-60	0.97	0.95
IVB102-0-61	0.97	0.95
IVB165-0-26	0.94	0.88
IVB165-0-28	0.94	0.90
18-0-35	0.96	0.92
18-0-36	0.60	0.29
18-0-37	0.80	0.64
20-0-52	0.89	0.80
20-0-54	0.95	0.92
TRNN2RZPB	0.93	0.88
3109-0-1	0.94	0.90
Average	**0.90**	**0.82**

Full Test QI

W1	W2
0.81	0.67
0.45	0.04

Sequence IVB
Prove-Out Data Analysis

Statistics Group

Oct. 11, 2017

Statistics Group

- Arthur Andrews, ExxonMobil
- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Kevin O'Malley, Lubrizol
- Martin Chadwick, Intertek
- Richard Grundza, TMC
- Lisa Dingwell, Afton
- Todd Dvorak, Afton
- Travis Kostan, SwRI

Summary

- 9 Prove-out data
- Labs
  - IAR: 2 stands
  - SwRI: 2 stands
  - Lz: 1 stand
  - XOM: 1 stand
- Oils
  - 1012 (5W-20): 2 tests
  - 300 (5W-30): 7 tests
- Given limited data on Volume Loss with talc, oils marginally differentiate

Prove-out Data

Post-Precision Matrix Prove-Out Testing

Lab	Stand	Test Oil	Test Number	Intake Lifter Average Volume Loss mm^3
Intertek	102	ASTM REO 1012	IVB102-0-61	1.32
SwRI	18	ASTM REO 1012	18-0-35	1.01
Intertek	102	ASTM REO 300	IVB102-0-60	1.79
Intertek	165	ASTM REO 300	IVB165-0-28	2.26
SwRI	18	ASTM REO 300	18-0-36	1.16
SwRI	18	ASTM REO 300	18-0-37	1.53
SwRI	20	ASTM REO 300	20-0-54	1.50
Lubrizol	1	ASTM REO 300	TRNN2RZPB	1.08
ExxonMobil	1	ASTM REO 300	3109-0-1	1.53

Intake Bucket Lifters Average Area Loss

Summary of Fit

RSquare	0.97666
RSquare Adj	0.906641
Root Mean Square Error	0.12294
Mean of Response	1.422222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	1.2649270	0.210821	13.9485
Error	2	0.0302286	0.015114	Prob > F
C. Total	8	1.2951556		0.0684

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.3426786	0.067737	19.82	0.0025*
Oil[1012]	-0.142143	0.05691	-2.50	0.1298
Lab[IAR]	0.49375	0.075285	6.56	0.0225*
Lab[LZ]	-0.404821	0.101273	-4.00	0.0573
Lab[SwRI]	-0.134107	0.07161	-1.87	0.2020
Lab[IAR]:Stand[I-102]	-0.281429	0.080483	-3.50	0.0729
Lab[SwRI]:Stand[S-18]	-0.149286	0.073471	-2.03	0.1792

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Oil	1	1	0.09428810	6.2383	0.1298
Lab	3	3	0.80436178	17.7395	0.0538
Stand[Lab]	2	2	0.22951261	7.5926	0.1164

Least Squares Means Table

Level	Least Sq Mean
1012	1.20
300	1.48

Summary of Fit

RSquare	0.799452
RSquare Adj	0.598904
Root Mean Square Error	0.254824
Mean of Response	1.422222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	1.0354144	0.258854	3.9863
Error	4	0.2597412	0.064935	Prob > F
C. Total	8	1.2951556		0.1045

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.235	0.127412	9.69	0.0006*
Oil[1012]	-0.234706	0.107048	-2.19	0.0934
Lab[IAR]	0.4767647	0.151388	3.15	0.0345*
Lab[LZ]	-0.389706	0.209587	-1.86	0.1365
Lab[SwRI]	-0.147353	0.138198	-1.07	0.3464

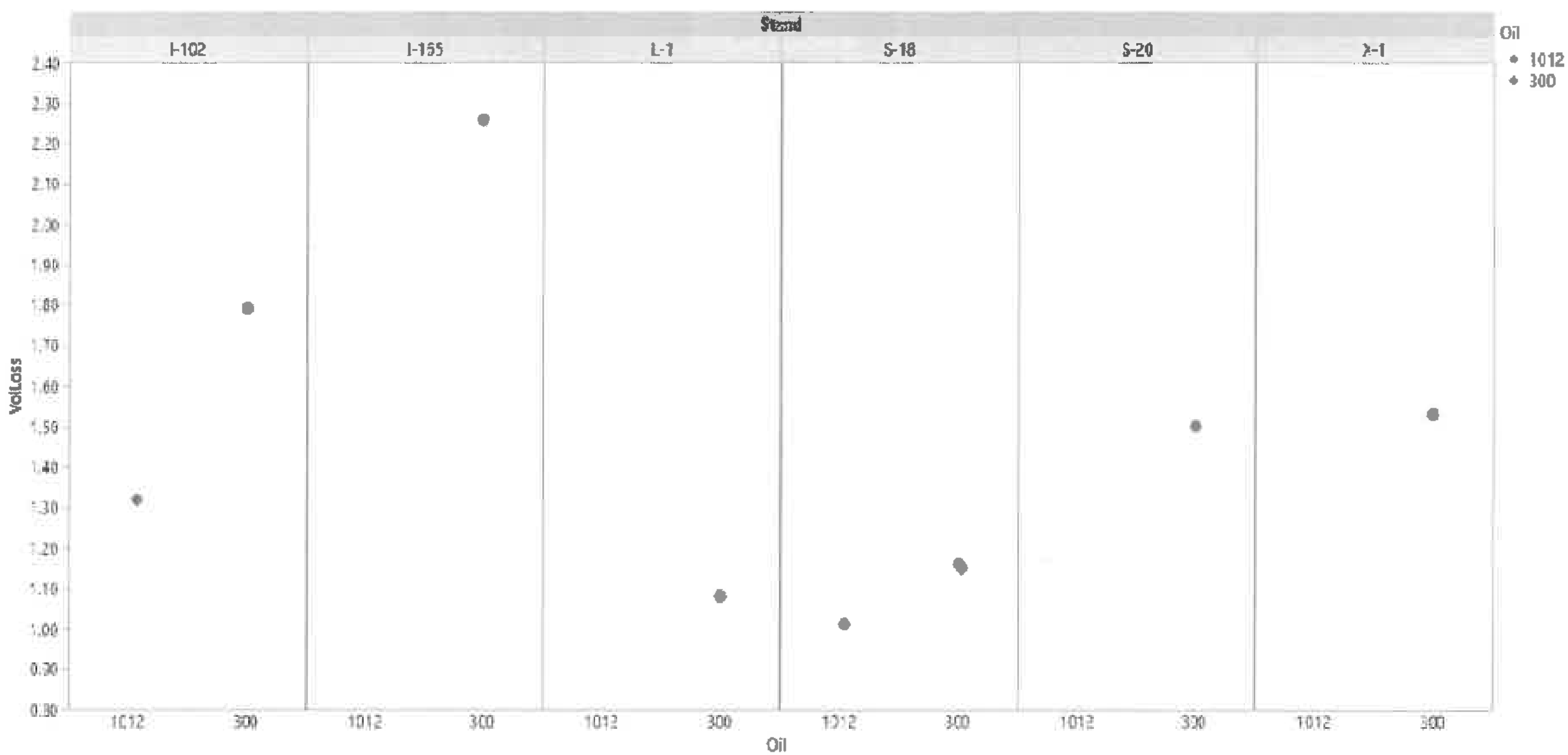
Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Oil	1	1	0.31215882	4.8072	0.0934
Lab	3	3	0.86528025	4.4418	0.0919

Least Squares Means Table

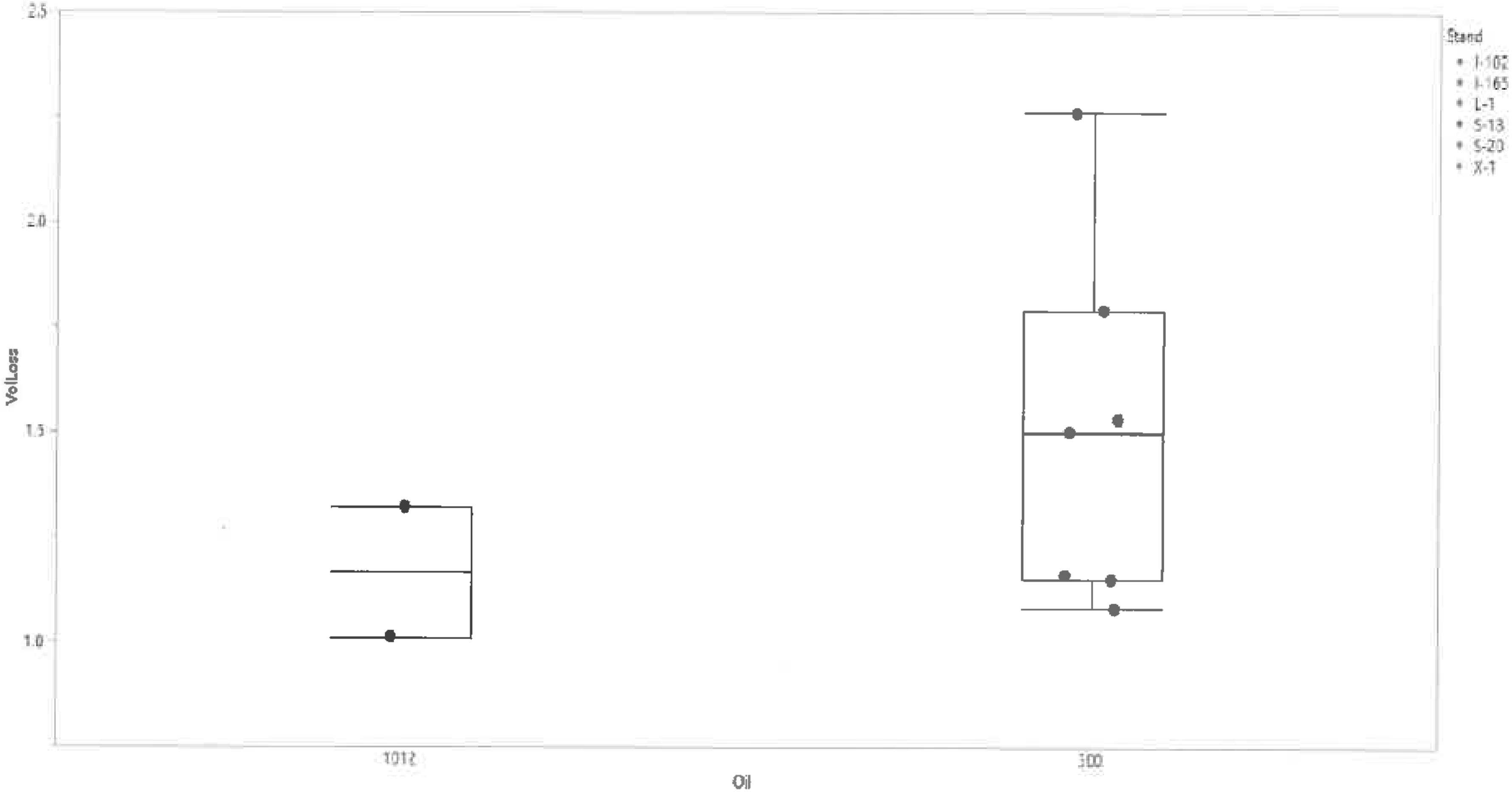
Level	Least Sq Mean
1012	1.00
300	1.47

Intake Lifters Volume Loss



300 > 1012 (p=0.13 or 0.09)

Intake Lifters Volume Loss



300 > 1012 (p=0.13 or 0.09)