

# **Statistical Summary of the Sequence IIIIG Matrix**

*Jo Martinez, Chevron Oronite*

*Elisa Santos, Infineum*

*Phil Scinto, Lubrizol*

June 6<sup>th</sup>, 2003

# Outline

- Sequence IIIG Matrix Summary
- Matrix Design
- The data
- Correlations among parameters
- Statistical Analysis of the matrix data by parameter
- Summary of Means and Standard Deviations by Oil
- Appendix
  - Transformation Analysis and Residual Plots by Time Order
  - Plots of the data for each parameter by Lab and by Stand
  - Summary of unusual observations by parameter
  - Correlation of MRV and PVIS:
    - Used Oil MRV over Fresh Oil MRV versus PVIS
    - Used Oil MRV over Fresh Oil MRV versus PVIS by Oil

# Sequence IIIG Matrix Summary

- Matrix included 24 operationally valid tests
  - Three other tests were invalid due to high oil consumption
- Model factors considered for all analysis include
  - Lab (A,G),
  - Stand within Lab,
  - Oil (434, 435, 438)
  - Cam/Phosphate Batch (30203, 30422)
- Final model fits for all parameters include Lab and Oil
  - There was not enough Statistical Evidence to Include Stand within Lab or Cam/Phosphate Batch in the final models

# Sequence IIIG Matrix Summary

- Parameters of study include
  - Percent Viscosity Increase (VIS),
  - Adjusted Percent Viscosity Increase (NVIS),
  - Average Camshaft plus Lifter Wear (ACLW),
  - Average Piston Varnish (APV),
  - Weighted Piston Deposits (WPD),
  - New Weighted Piston Deposits (NWPD),
  - Oil Consumption (OC),
  - Cold Crank Simulator Viscosity (CCS),
  - MRV Viscosity (MRV)

# Sequence IIG Matrix Summary

- Transformations to stabilize the variance
  - Natural Log Transformations indicated by Box-Cox Analysis for VIS (but not NVIS) and ACLW;
  - Inverse Square Root Transformation indicated for MRV
- There is a general high correlation among VIS, OC and MRV
- There are Lab effects in OC
- There is also an indication of a Lab effect in VIS and MRV.
- There is a Lab by Oil Interaction for Weighted Deposits

# Sequence IIIG Matrix Summary

- Ep is Below the ACC Precision Target for Percent Viscosity Increase, WPD, NWPD (but closer), and CCS
- Ep is Above the ACC Precision Target for Adjusted Percent Viscosity Increase and ACLW
- Ep is just at the ACC Precision Target for APV and MRV (Depends)

# Sequence IIG Matrix

- 24 runs, 2 labs, 6 stands, 4 tests/stand
- Degrees of Freedom (Nested model)
  - Oil 2
  - Lab 1
  - Lab(Stand) 4
  - Cam batch 1
  - Mean 1
  - Error 15
- Variance Inflation Factor
  - Lab 3.00
  - Lab1(Stand2) 1.72
  - Lab1(Stand3) 1.72
  - Lab2(Stand2) 1.72
  - Lab2(Stand3) 1.72
  - Oil2 1.42
  - Oil3 1.42
  - Cam Batch 1.00

Run	Laboratory	Stand	Oil	Cam Batch
1	SWRI	1	1	1
2	SWRI	1	2	1
3	SWRI	1	3	2
4	SWRI	1	1	2
5	SWRI	2	1	2
6	SWRI	2	2	1
7	SWRI	2	3	1
8	SWRI	2	2	2
9	SWRI	3	1	1
10	SWRI	3	2	2
11	SWRI	3	3	2
12	SWRI	3	3	1
13	PE	1	1	2
14	PE	1	2	2
15	PE	1	3	1
16	PE	1	1	1
17	PE	2	1	1
18	PE	2	2	2
19	PE	2	3	2
20	PE	2	2	1
21	PE	3	1	2
22	PE	3	2	1
23	PE	3	3	1
24	PE	3	3	2

TESTKEY	OIL	LAB	STAND	CAMBATCH	SAEVISC	PVIS	ACLW	APV	WPD	OILCON	CCS	MRV
47905	435	G	3	NF	5W20	163.4	30.9	8.57	2.9	3.86	11370	84800
47888	435	A	3	NF	5W20	172.2	45.8	8.84	3.26	3.74	16160	84500
47893	438	A	1	NF	5W20	102.3	14.4	8.96	3.04	3.62	10200	19300
47901	434	G	5	NJ	5W30	133.3	41.1	8.61	3.15	3.86	17200	48900
47884	434	A	2	NJ	5W30	89.9	26.2	9.43	5.83	3.98	15640	31900
47910	438	G	2	NF	5W20	132.6	16.8	9.39	3.68	4.27	9080	23700
47900	434	G	3	NF	5W30	127.6	43.7	8.81	3.39	4.23	23640	49200
47894	438	A	3	NJ	5W20	111.7	21.2	8.86	3.14	3.47	9920	20500
47906	435	G	5	NJ	5W20	279	26.8	8.76	3.3	4.3	8530	210700
47889	435	A	1	NF	5W20	222.2	31.6	7.98	3.31	4.22	19370	300200
47911	438	G	2	NJ	5W20	143.2	15.3	8.91	2.85	4.33	15400	30400
47902	434	G	3	NJ	5W30	99.2	33.1	8.76	4.32	3.9	19480	45600
47886	434	A	2	NF	5W30	249.5	37.1	8.74	4.77	4.65	22500	86400
47891	435	A	3	NJ	5W20	176.4	33	8.32	3.92	4.25	14040	91900
47913	438	G	3	NJ	5W20	91.7	15.6	8.65	4.17	3.41	9180	19000
47908	435	G	2	NJ	5W20	304.8	48.7	8.11	4.12	4.31	17540	400000
47883	434	A	1	NJ	5W30	86.7	39.1	8.83	4.42	3.47	19000	34200
47907	435	G	5	NF	5W20	230.2	34.6	8.63	2.97	4.21	17200	294000
47895	438	A	2	NF	5W20	88.6	22	9.2	3.08	3.32	8320	16700
47885	434	A	3	NF	5W30	62.8	34.2	9.04	4.99	3.71	20600	29000
47896	438	A	1	NJ	5W20	90.5	21.4	8.82	3.26	3.28	8550	18000
47914	438	G	5	NF	5W20	120.6	20.8	8.26	3	3.87	10530	20500
47890	435	A	2	NJ	5W20	167.7	46.8	8.36	3.28	3.79	15600	110100
48605	434	G	2	NF	5W30	185.7	40.2	8.36	3.83	4.39		

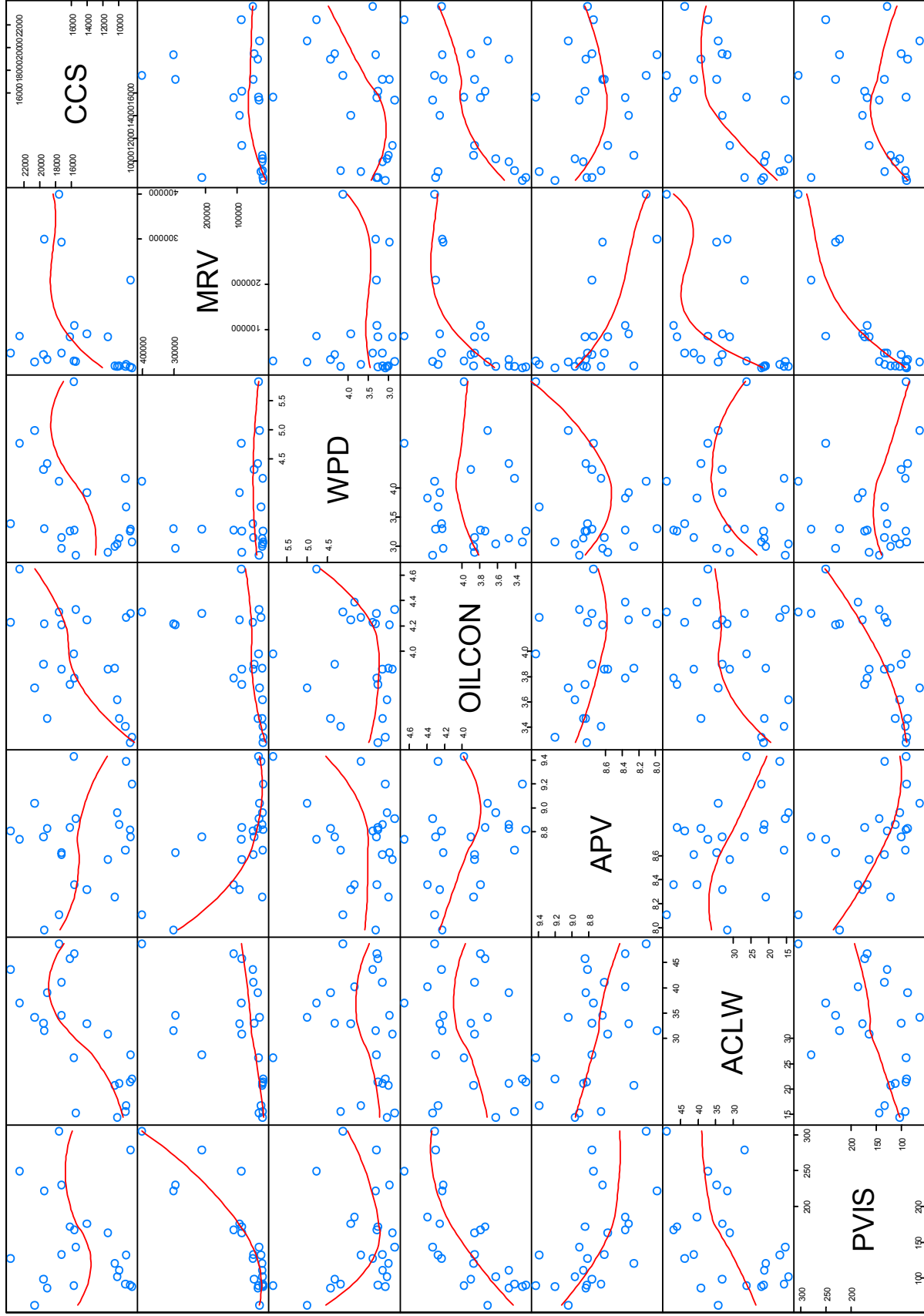


# Sequence IIG Correlations

<b>Vis*</b>	0.75	0.40	-0.58	-0.25	-0.27	0.74	0.16	<b>0.84</b>
0.50	<b>NVIS</b>	0.34	-0.55	-0.42	-0.41	0.12	-0.16	-0.64
0.10	0.48	<b>ACLW*</b>	-0.42	0.21	0.23	0.30	0.70	-0.71
-0.20	-0.24	-0.34	<b>APV</b>	0.28	0.32	-0.28	-0.20	0.57
-0.05	-0.20	-0.36	0.18	<b>WPD</b>	0.99	0.12	0.40	0.01
-0.10	-0.20	-0.36	0.26	0.99	<b>NWPD</b>	0.09	0.40	0.00
0.76	-0.16	-0.24	0.01	0.17	0.13	<b>OC</b>	0.45	-0.66
0.33	-0.06	0.31	-0.41	-0.18	-0.26	0.42	<b>CCS</b>	-0.49
<b>-0.88</b>	-0.37	-0.03	0.29	0.06	0.13	-0.74	-0.58	<b>MRV*</b>

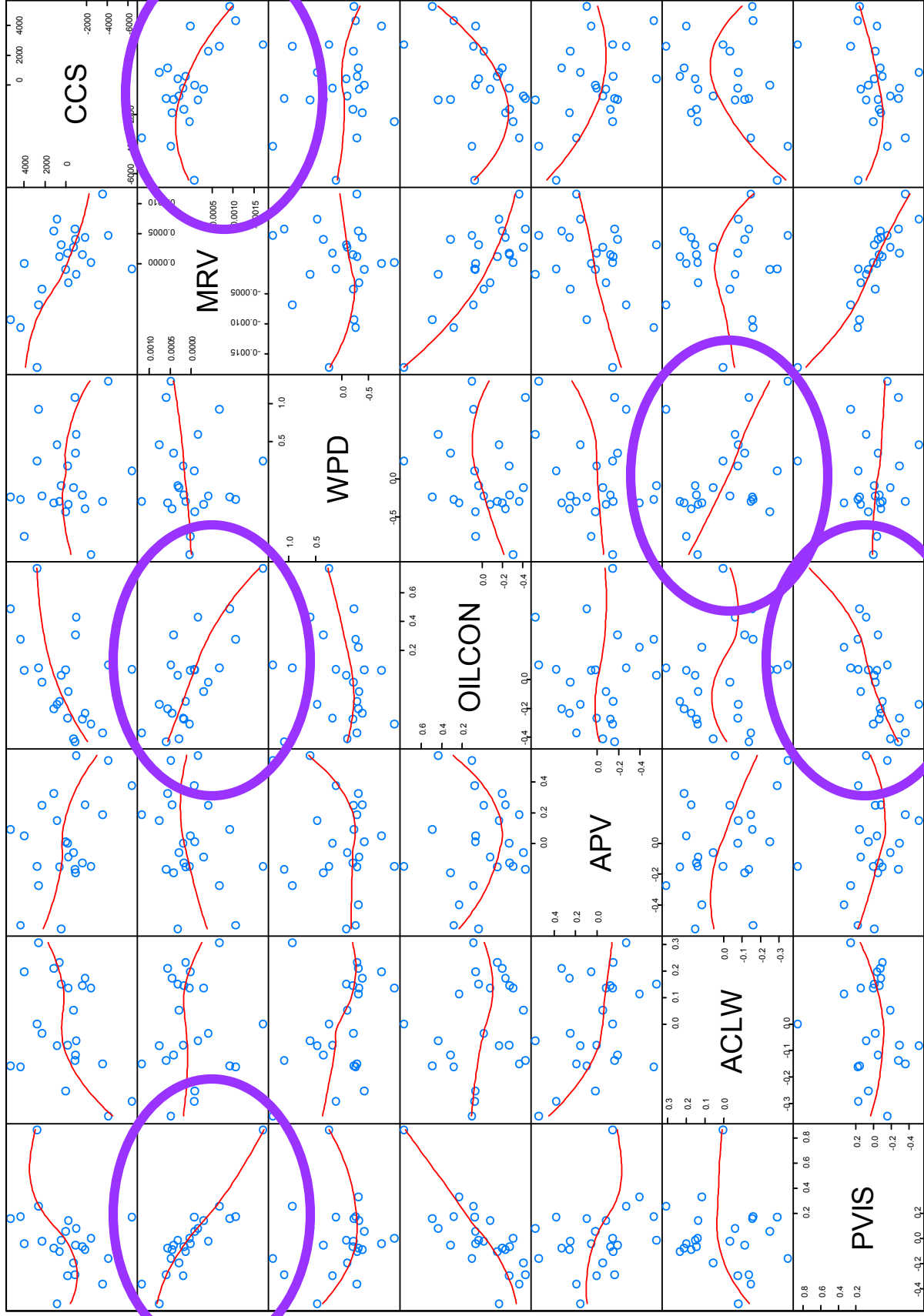
Raw Data Correlations on Upper Triangle; Partial Correlations on Lower Triangle

# Scatter Plot Matrix of Raw Data with Loess Smoother





# Scatter Plot Matrix of Residuals with Loess Smoother



# Percent Viscosity Increase (VIS)

- Analyzed on Natural Log Scale
- Root Mean Squared Error=0.291911 (20 df)
- Some Statistical Evidence that the Labs Differ
- Strong Statistical Evidence that the Oils Differ

# Percent Viscosity Increase (VIS)

p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean	
	434	435			438
Oil 434		0.003	0.828	118.26	95.36 to 146.67
Oil 435	0.003		0.001	208.86	168.40 to 259.03
Oil 438	0.828	0.001		108.52	87.50 to 134.59

p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	Lab A	Lab G		
Lab A		0.063	123.56	103.64 to 147.30
Lab G	0.063		156.17	131.00 to 186.18

# Adjusted Viscosity Increase (NVIS)

- Test Results Adjusted for Oil Consumption
- Root Mean Squared Error=23.34226 (20 df)
- Marked Improvement in Test Precision
- No Statistical Evidence that the Labs Differ
- Strong Statistical Evidence that the Oils Differ

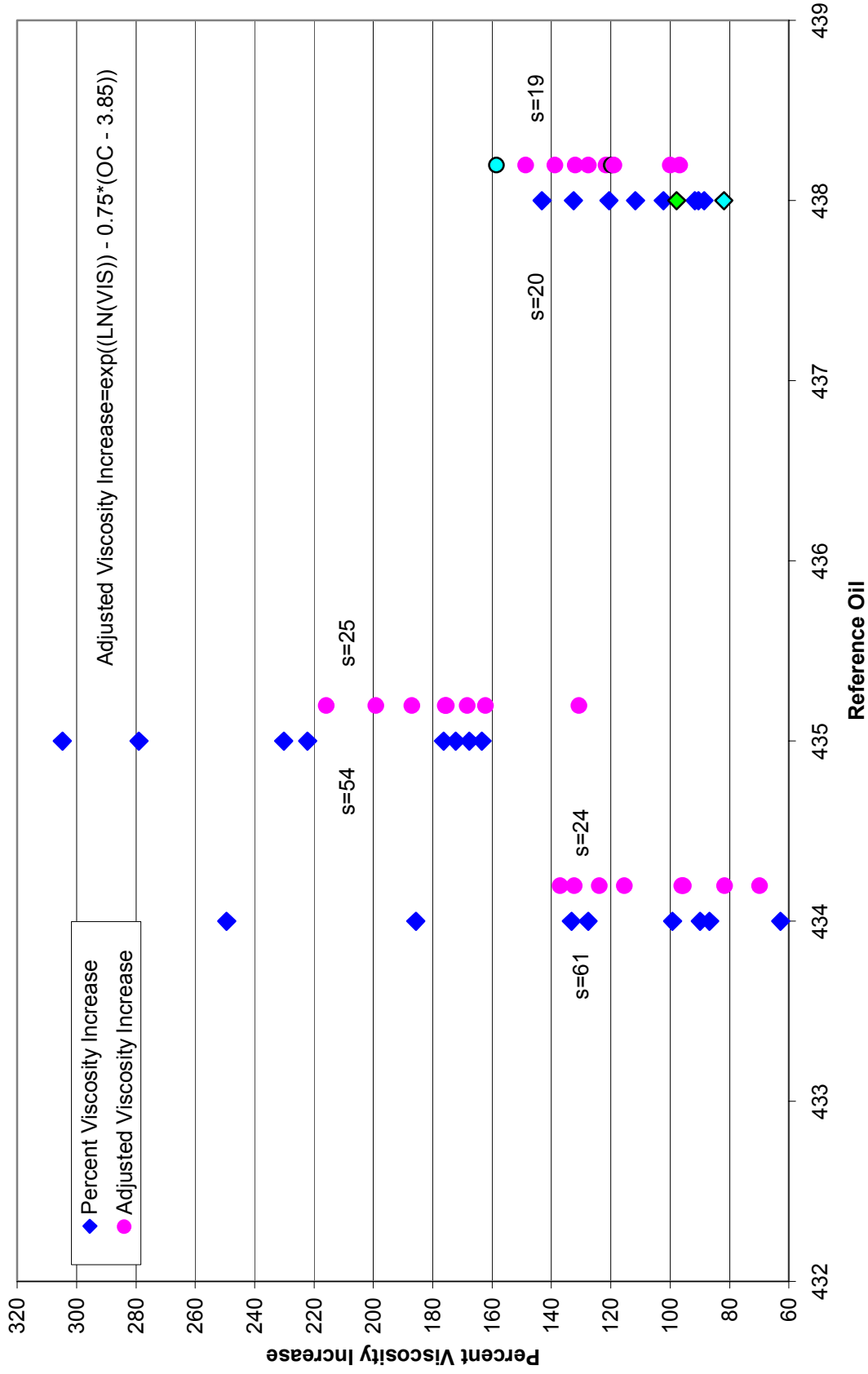
# Adjusted Viscosity Increase (NVIS)

	p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	434	435	438		
Oil 434		0.000	0.350	106.40	89.18 to 123.61
Oil 435	0.000		0.001	176.79	159.58 to 194.00
Oil 438	0.350	0.001		122.97	105.75 to 140.18

	p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	Lab A	Lab G			
Lab A		0.744		133.81	119.75 to 147.86
Lab G	0.744			136.96	122.91 to 151.02

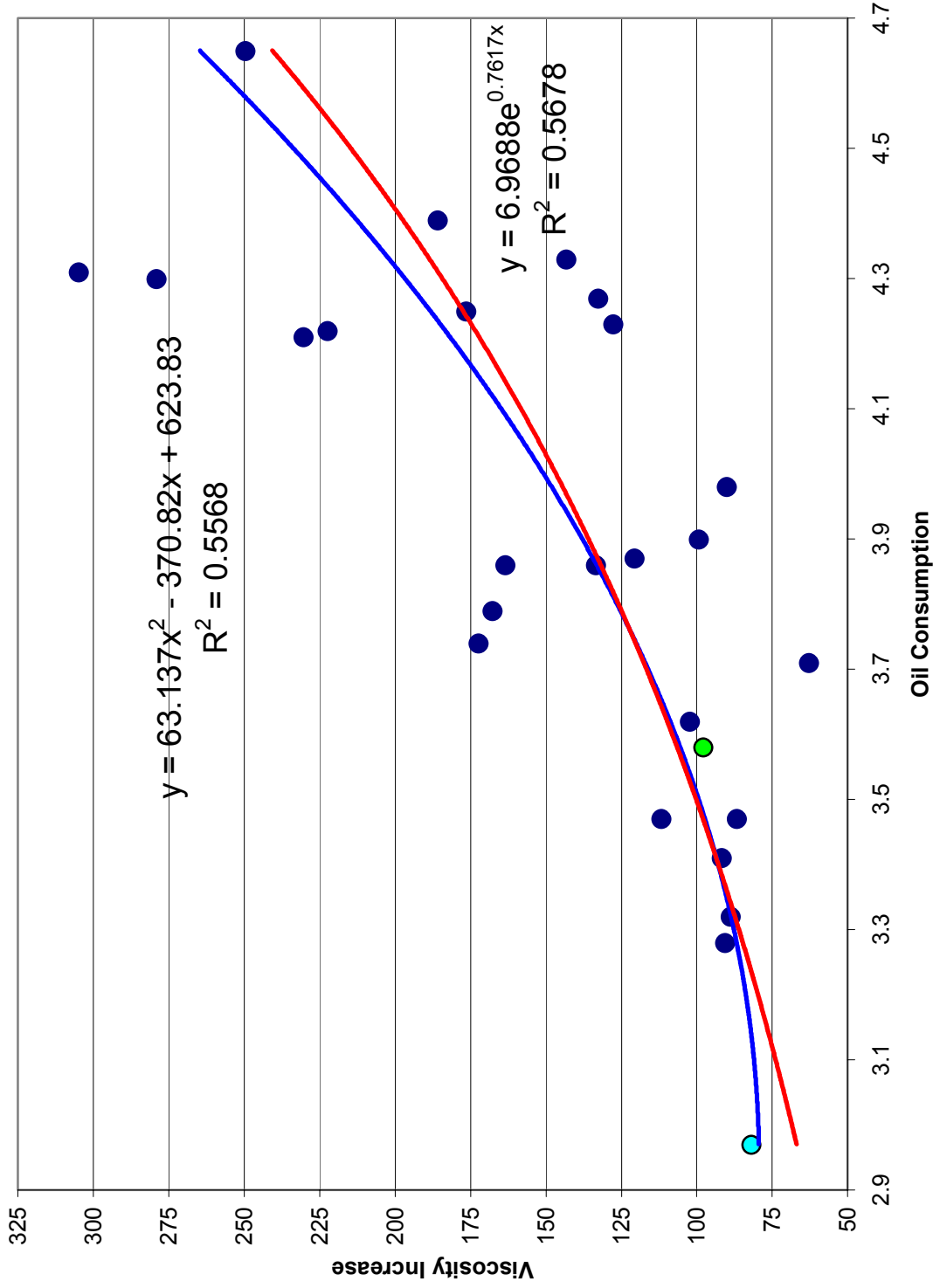


## Comparison of Viscosity Increase Calculation Methods

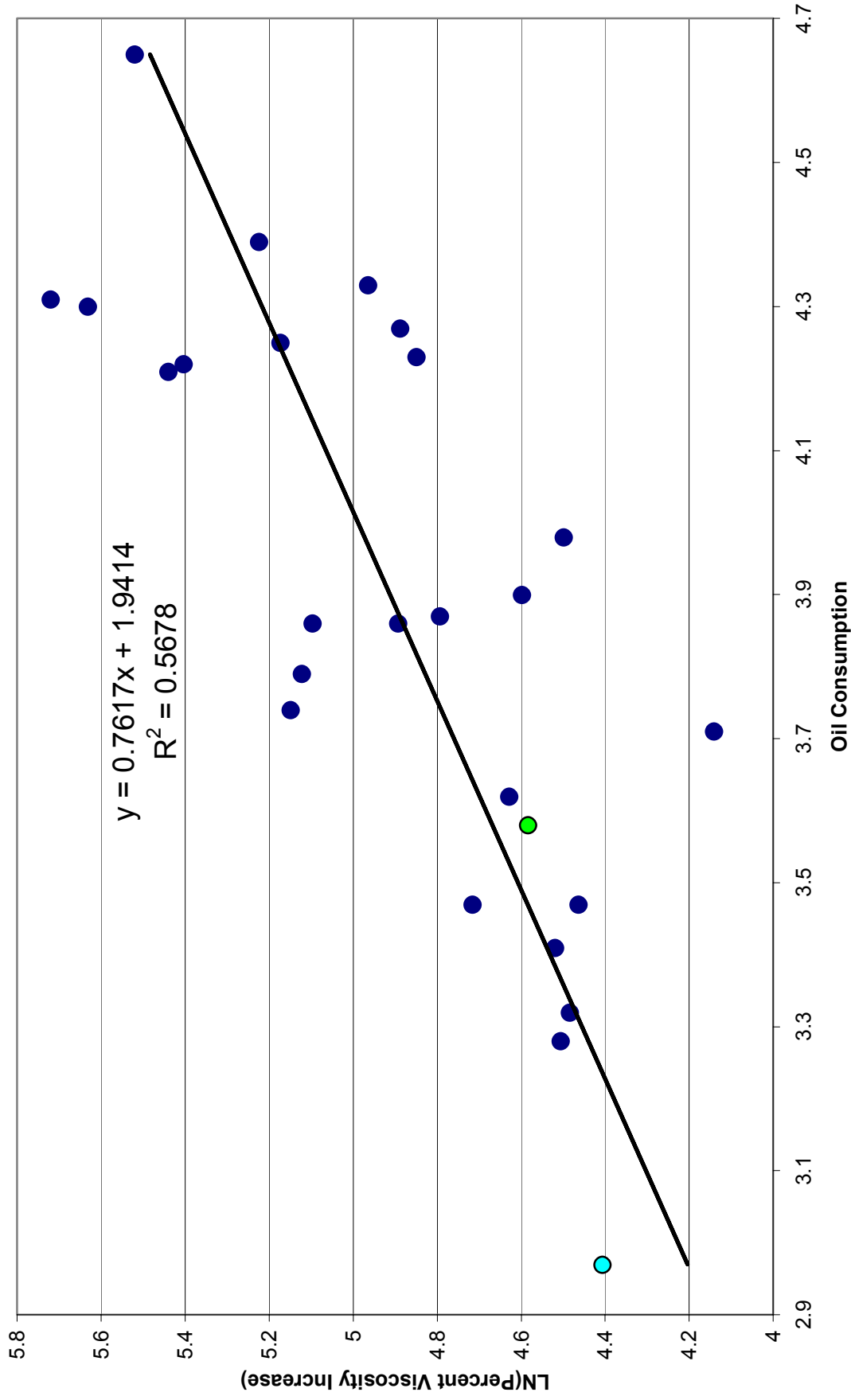




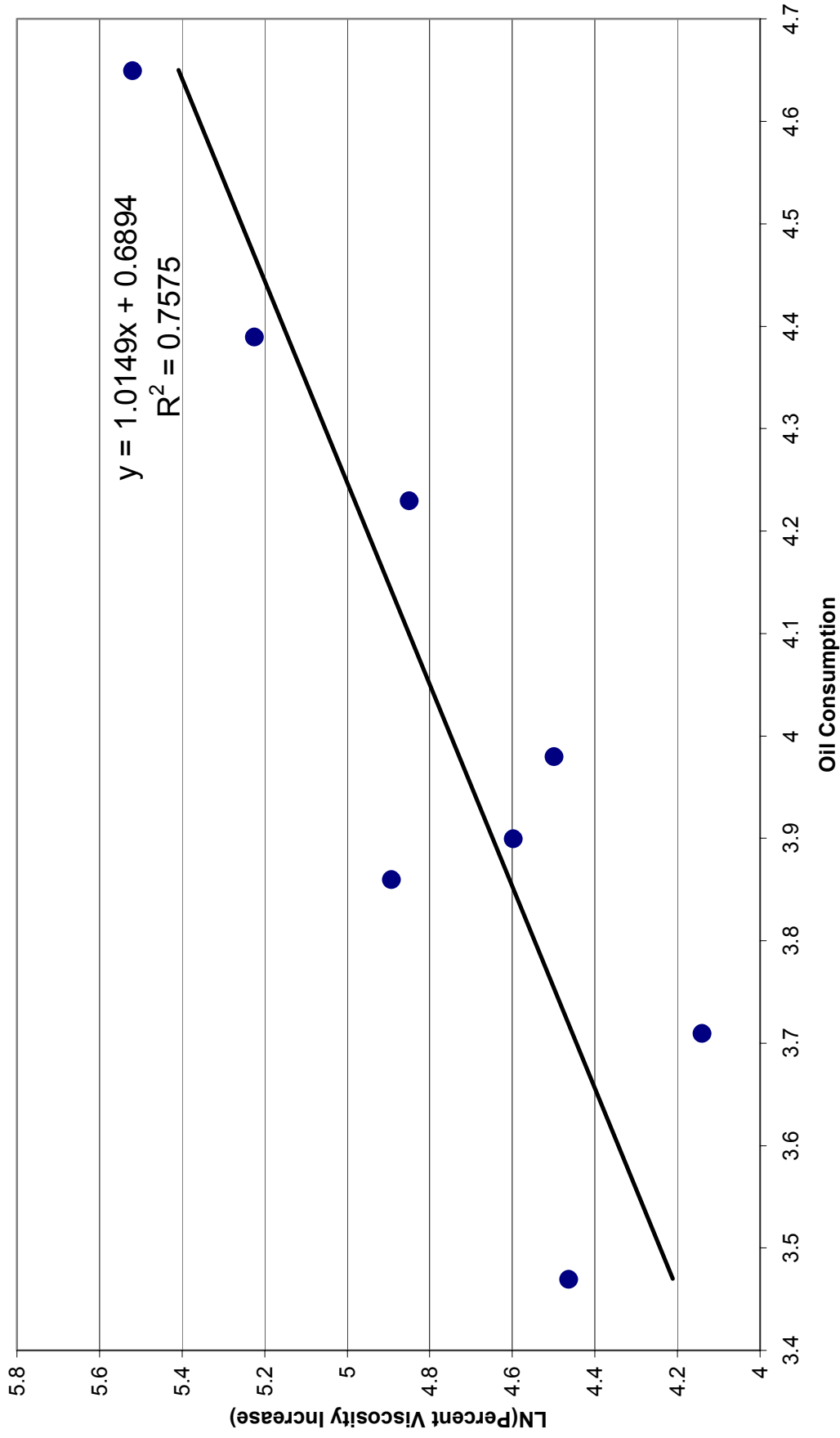
# Viscosity Increase as a Function of Oil Consumption



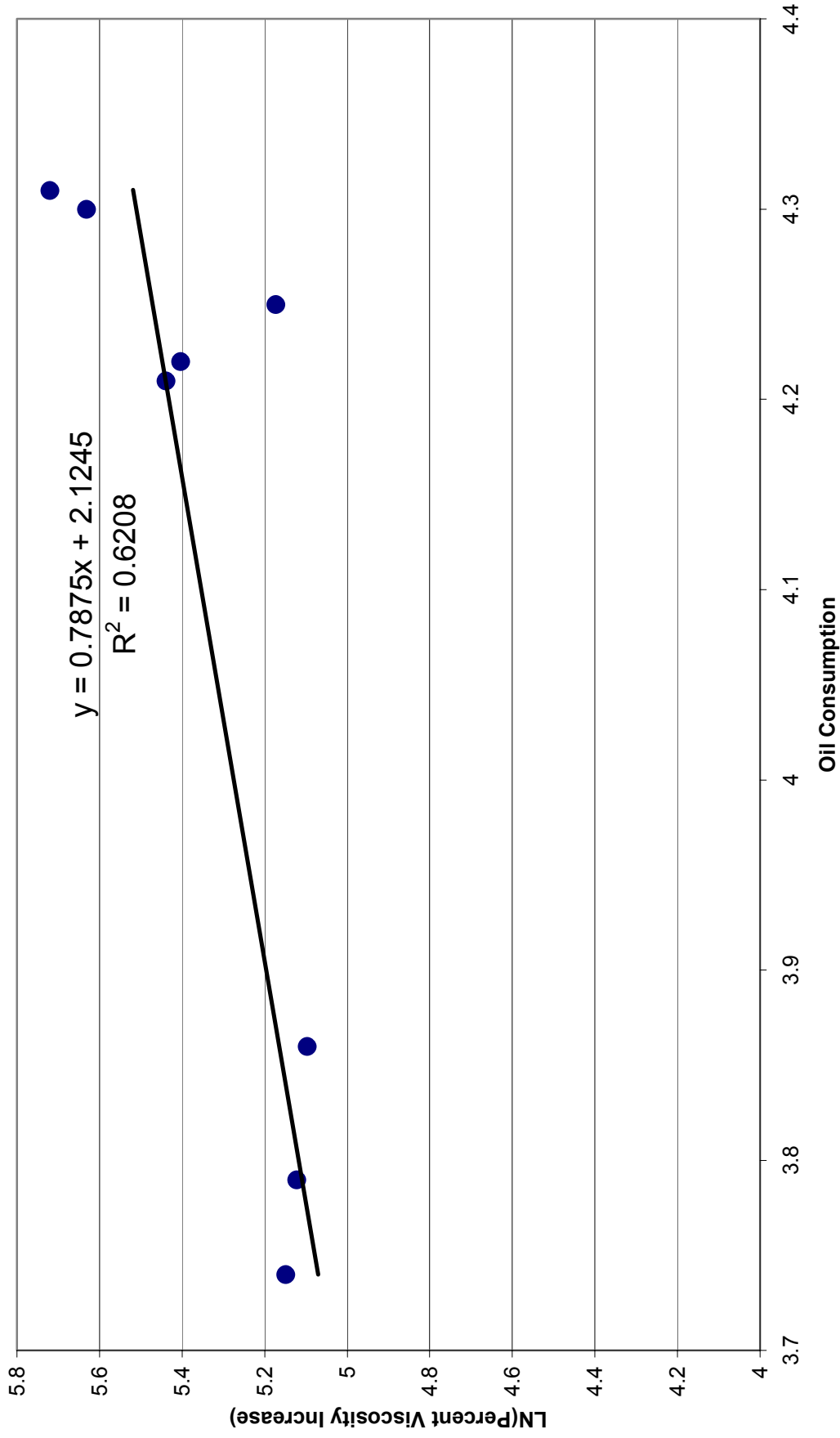
Natural Log of Percent Viscosity Increase as a Function of Oil Consumption



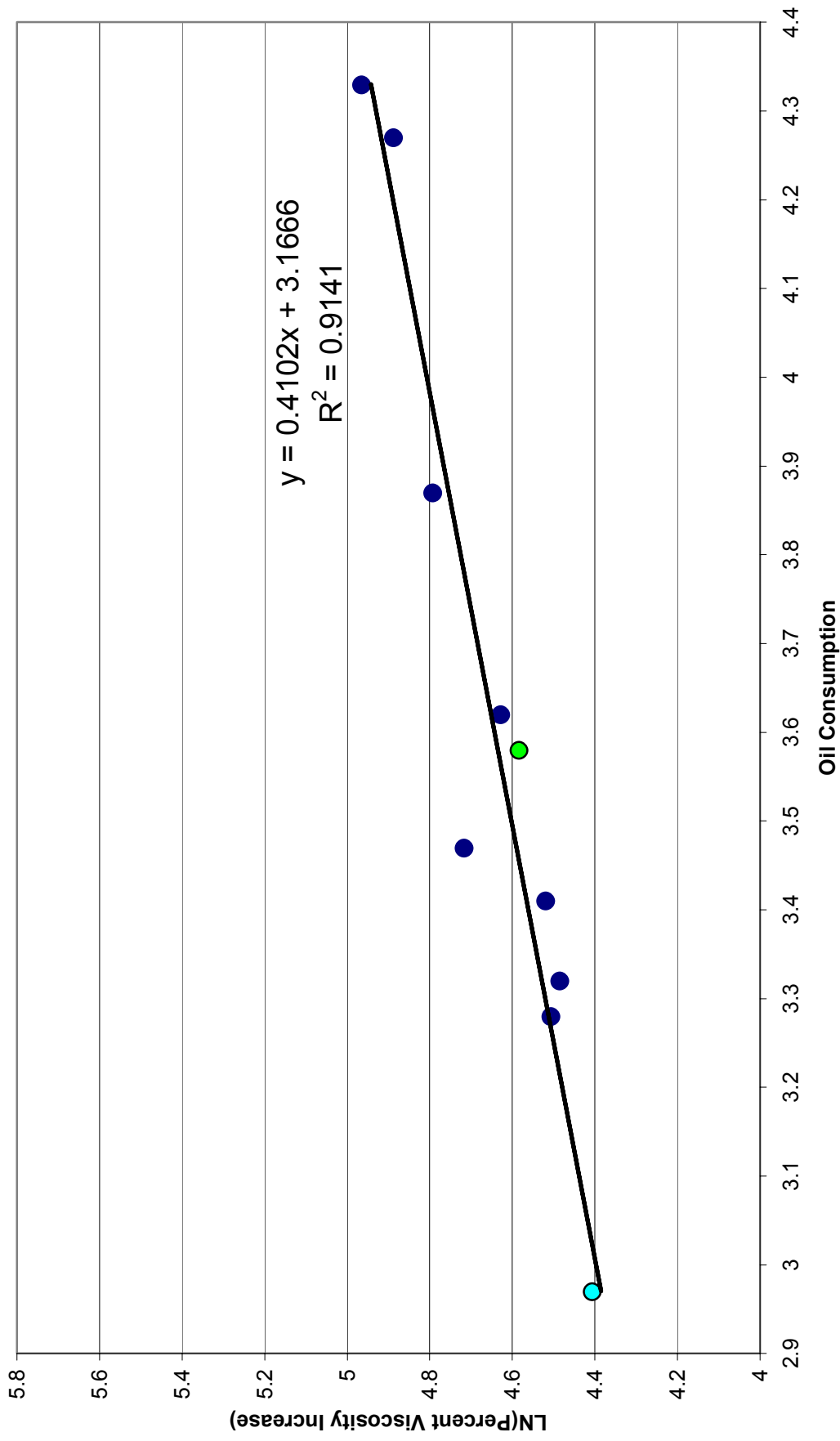
### Natural Log of Percent Viscosity Increase as a Function of Oil Consumption Reference Oil 434



### Natural Log of Percent Viscosity Increase as a Function of Oil Consumption Reference Oil 435



### Natural Log of Percent Viscosity Increase as a Function of Oil Consumption Reference Oil 438



# Weighted Piston Deposits (WPD)

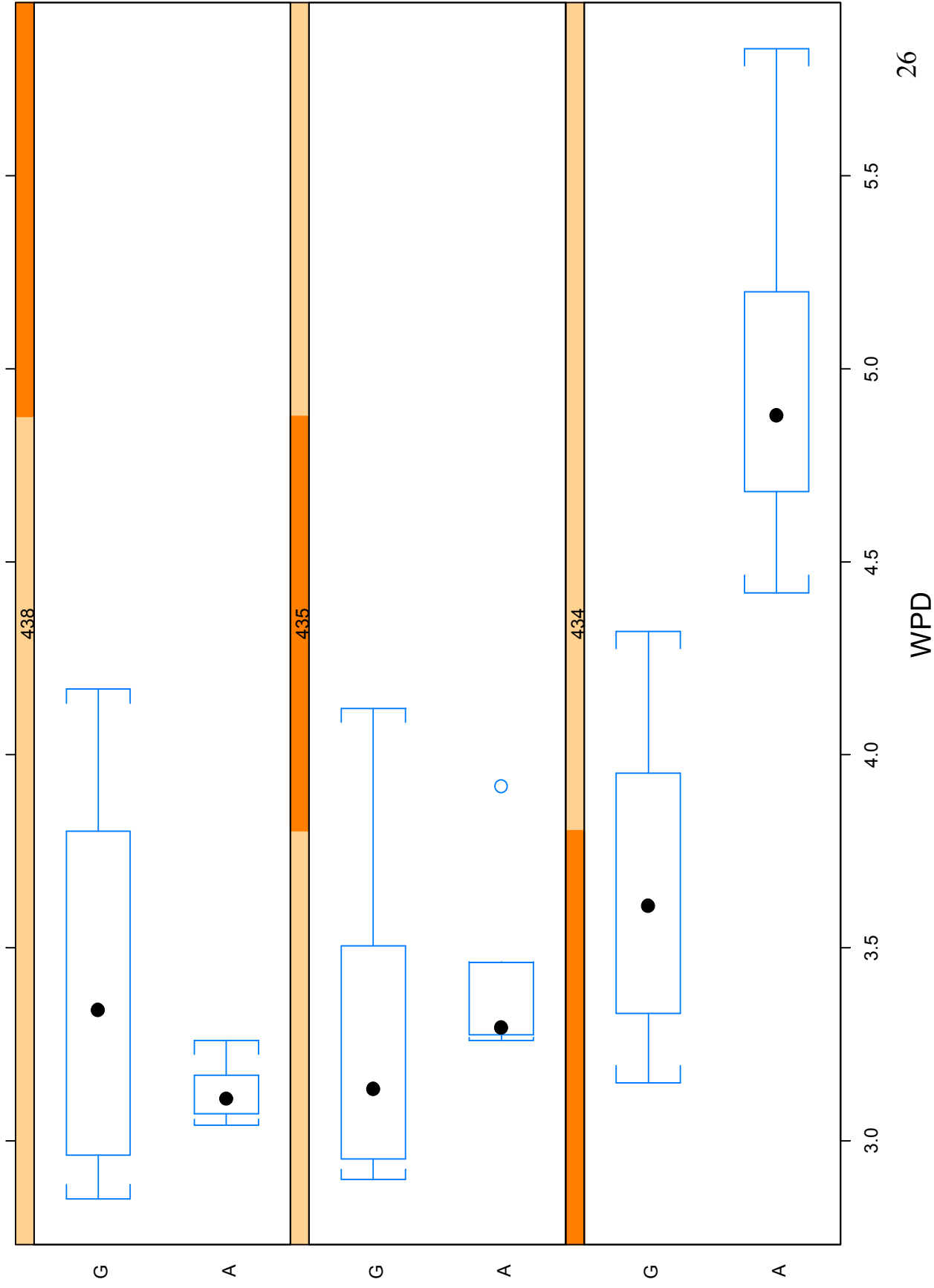
- Root Mean Squared Error=0.597072 (20 df)
- There is Evidence of a Lab Difference ONLY for Oil 434
- Strong Statistical Evidence that the Oils Differ in Lab A,  
But **No Evidence** that Oils Differ in Lab G

	LAB G Data Only		Mean	95% Confidence Interval for the Mean	
	p-values in Hypothesis Test of No Difference				
Oil 434	434	435	438	3.67	3.03 to 4.31
Oil 435	0.667	0.667	0.813	3.32	2.68 to 3.96
Oil 438	0.813	0.964	0.964	3.43	2.79 to 4.06

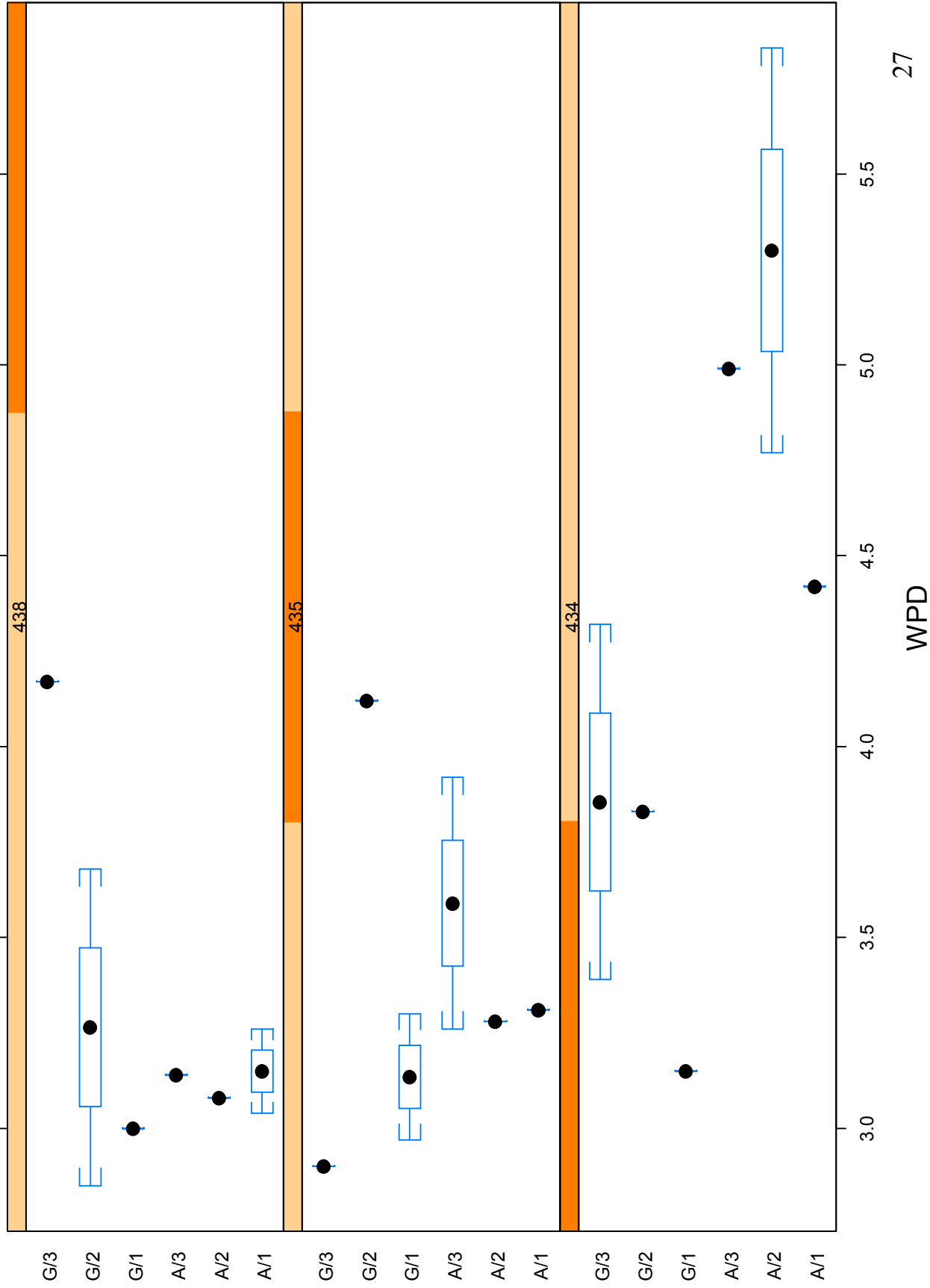




# WPD by Lab and Oil



# WPD by Ref. Oil and Stand



# Weighted Piston Deposits (WPD)

	p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	434	435	438		
Oil 434		0.012	0.005	4.34	3.90 to 4.78
Oil 435	0.012		0.934	3.38	2.94 to 3.82
Oil 438	0.005	0.934		3.28	2.84 to 3.72

	p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	Lab A	Lab G			
Lab A		0.130		3.86	3.50 to 4.22
Lab G	0.130			3.47	3.11 to 3.83

# New Weighted Piston Deposits (NWPD)

- This is one Example of a Weighting Change
- Root Mean Squared Error=0.466414 (20 df)
- There is Evidence of a Lab Difference ONLY for Oil 434
- Strong Statistical Evidence that the Oils Differ in Lab A,  
But **No Evidence** that Oils Differ in Lab G

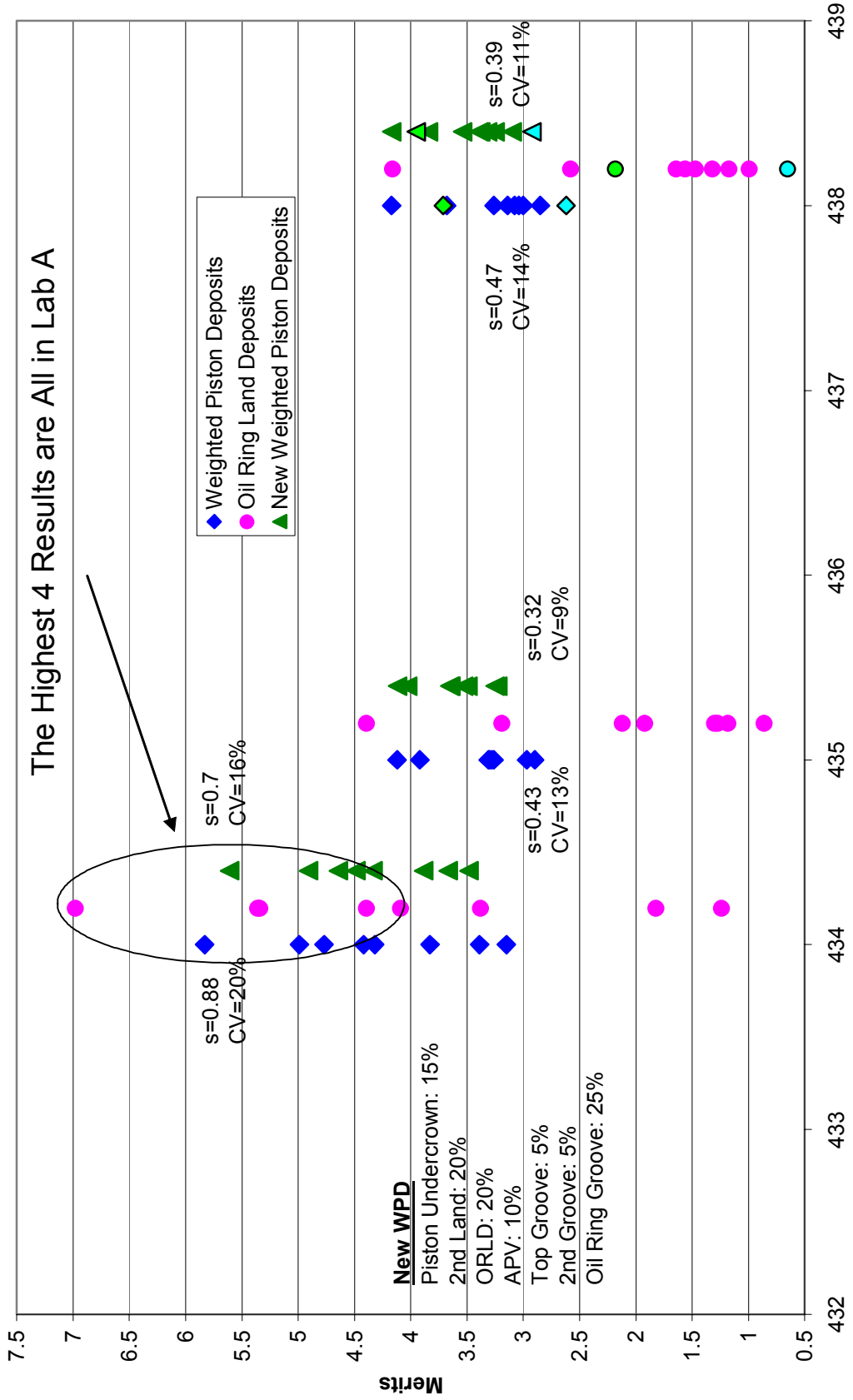
p-values in Hypothesis Test of No Difference	LAB G Data Only		Mean	95% Confidence Interval for the Mean	
	434	435			438
Oil 434		0.644	0.698	3.84	3.35 to 4.33
Oil 435	0.644		0.995	3.56	3.07 to 4.05
Oil 438	0.698	0.995		3.59	3.10 to 4.08

# New Weighted Piston Deposits (NWPD)

	p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	434	435	438		
Oil 434		0.011	0.003	4.38	4.03 to 4.72
Oil 435	0.011		0.868	3.62	3.27 to 3.96
Oil 438	0.003	0.868		3.50	3.15 to 3.84

	p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	Lab A	Lab G			
Lab A		0.096		4.00	3.72 to 4.28
Lab G	0.096			3.67	3.38 to 3.95

# Comparison of Weighted Deposits



## Average Piston Varnish (APV)

- Root Mean Squared Error=0.320346 (20 df)
- No Statistical Evidence that the Labs Differ
- Statistical Evidence that the Oils Differ

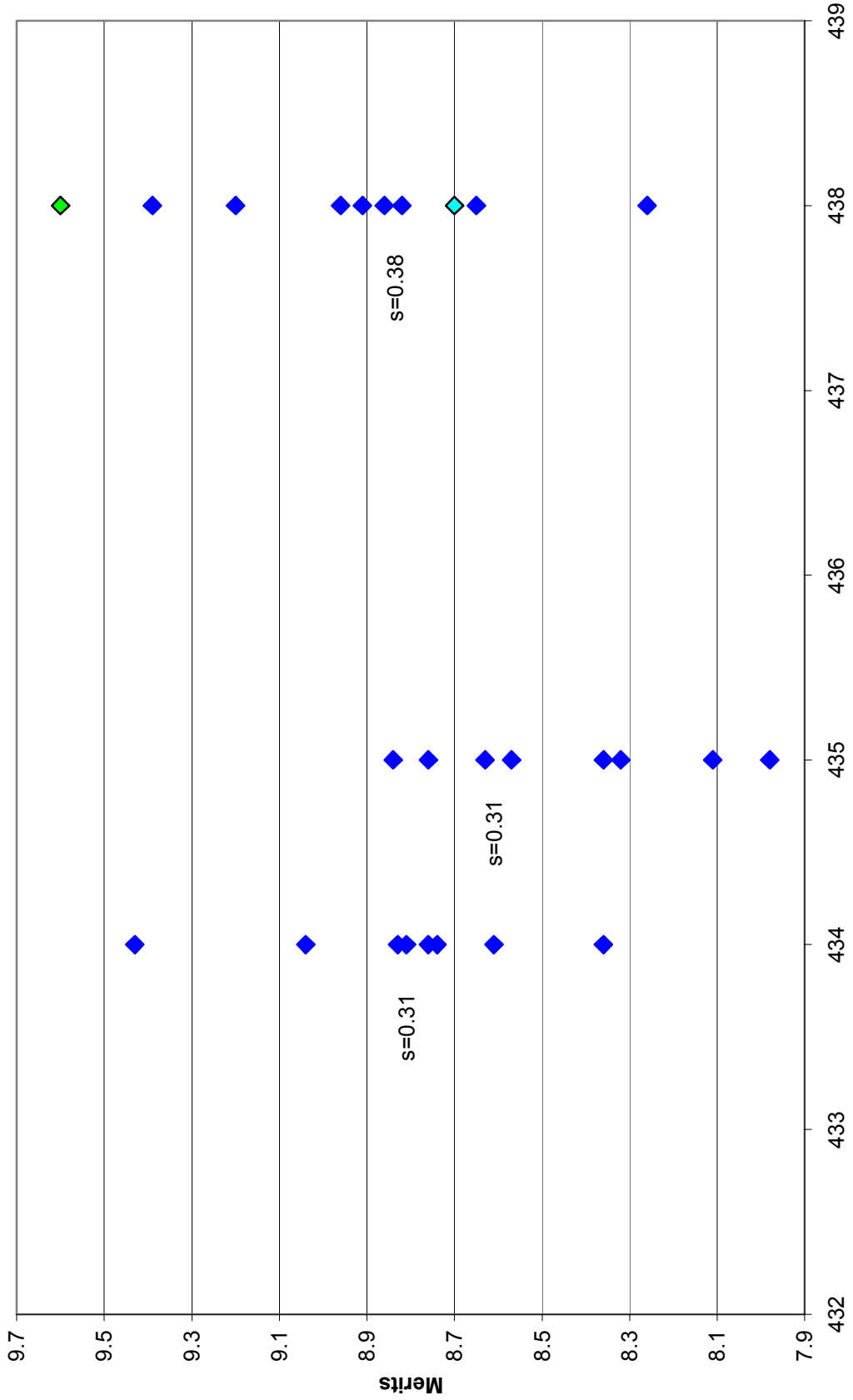


# Average Piston Varnish (APV)

	p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	434	435	438		
Oil 434		0.072	0.929	8.82	8.59 to 9.06
Oil 435	0.072		0.034	8.45	8.21 to 8.68
Oil 438	0.929	0.034		8.88	8.64 to 9.12

	p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	Lab A	Lab G			
Lab A		0.332		8.78	8.59 to 8.97
Lab G	0.332			8.65	8.46 to 8.84

# Average Piston Varnish



## Average Camshaft plus Lifter Wear (ACLW)

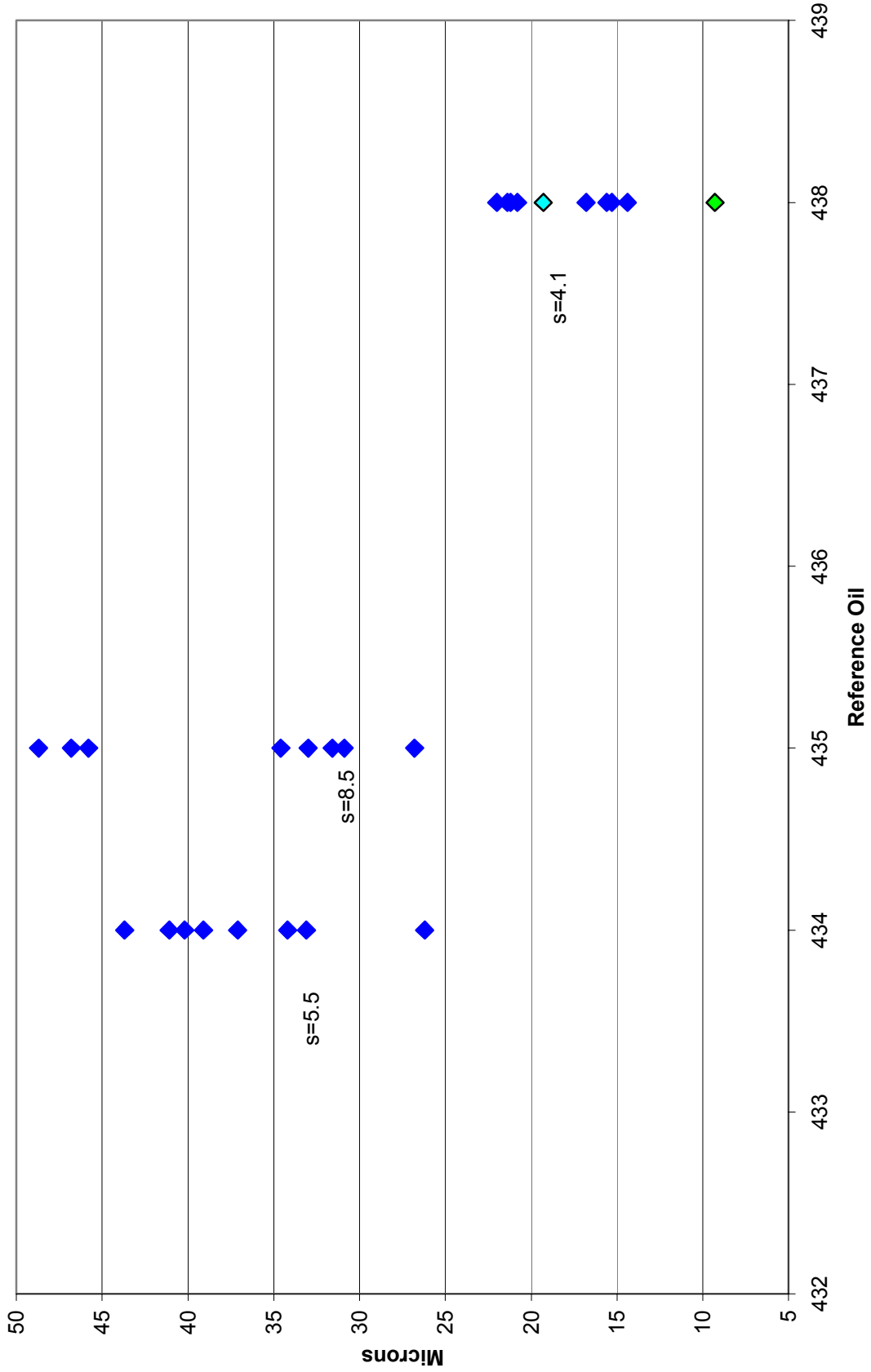
- Analyzed on Natural Log Scale
- Root Mean Squared Error=0.193585 (20 df)
- No Statistical Evidence that the Labs Differ
- Strong Statistical Evidence that the Oils Differ

# Average Camshaft plus Lifter Wear (ACLW)

p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	434	435		
Oil 434		1.000	36.44	31.59 to 42.03
Oil 435	1.000		36.45	31.60 to 42.05
Oil 438	0.000	0.000	18.19	15.77 to 20.98

p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	Lab A	Lab G		
Lab A		0.673	29.40	26.17 to 33.04
Lab G	0.673		28.42	25.30 to 31.94

# Average Camshaft plus Lifter Wear



# Oil Consumption (OC)

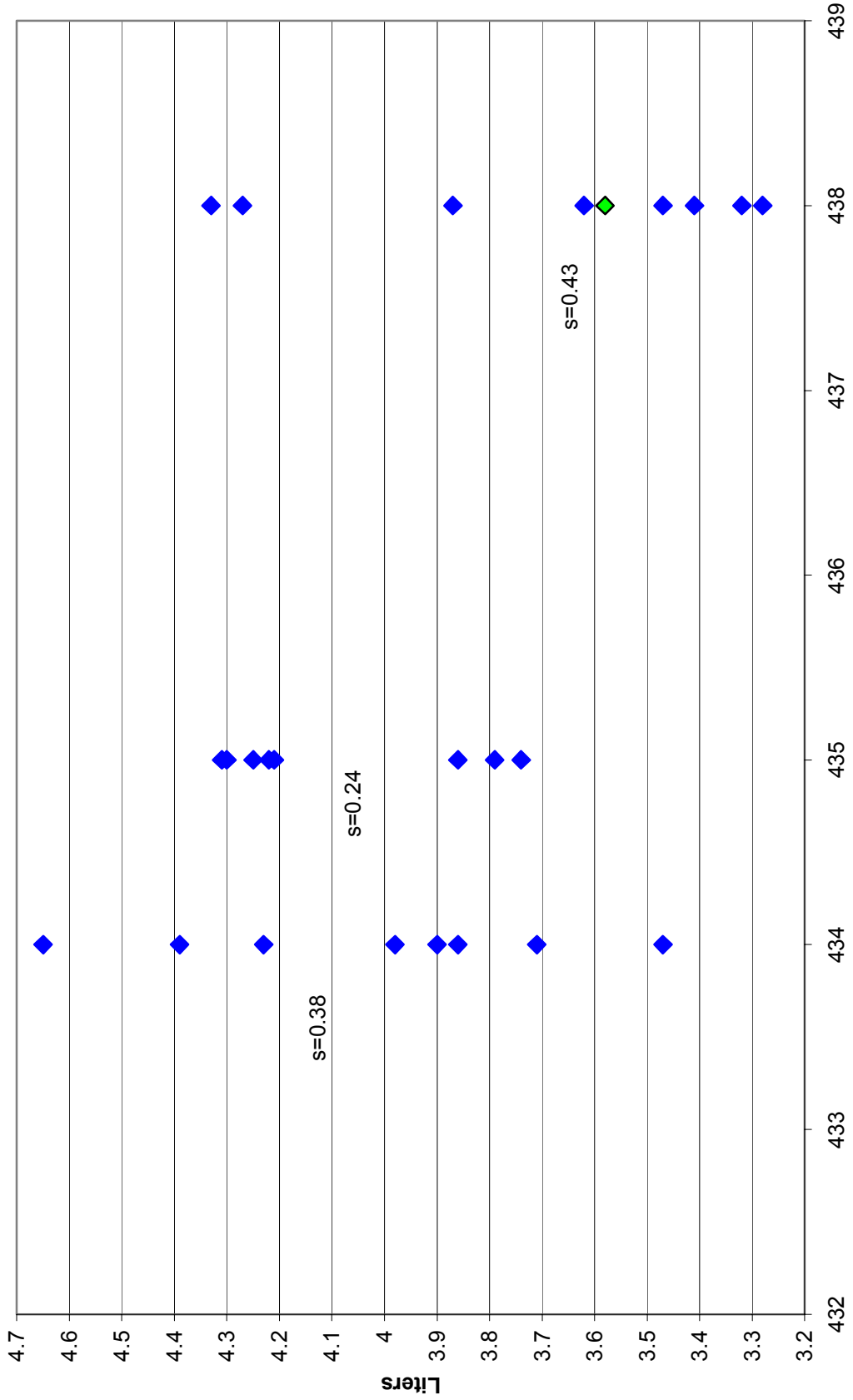
- Weak Evidence of a Stand Effect (Stand not Fit in Final Model)
- Root Mean Squared Error=0.3282 (20 df)
- Statistical Evidence that the Labs Differ
- Some Statistical Evidence that the Oils Differ

# Oil Consumption (OC)

p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	434	435		
Oil 434		0.926	4.02	3.78 to 4.27
Oil 435	0.926		4.09	3.84 to 4.33
Oil 438	0.138	0.069	3.70	3.45 to 3.94

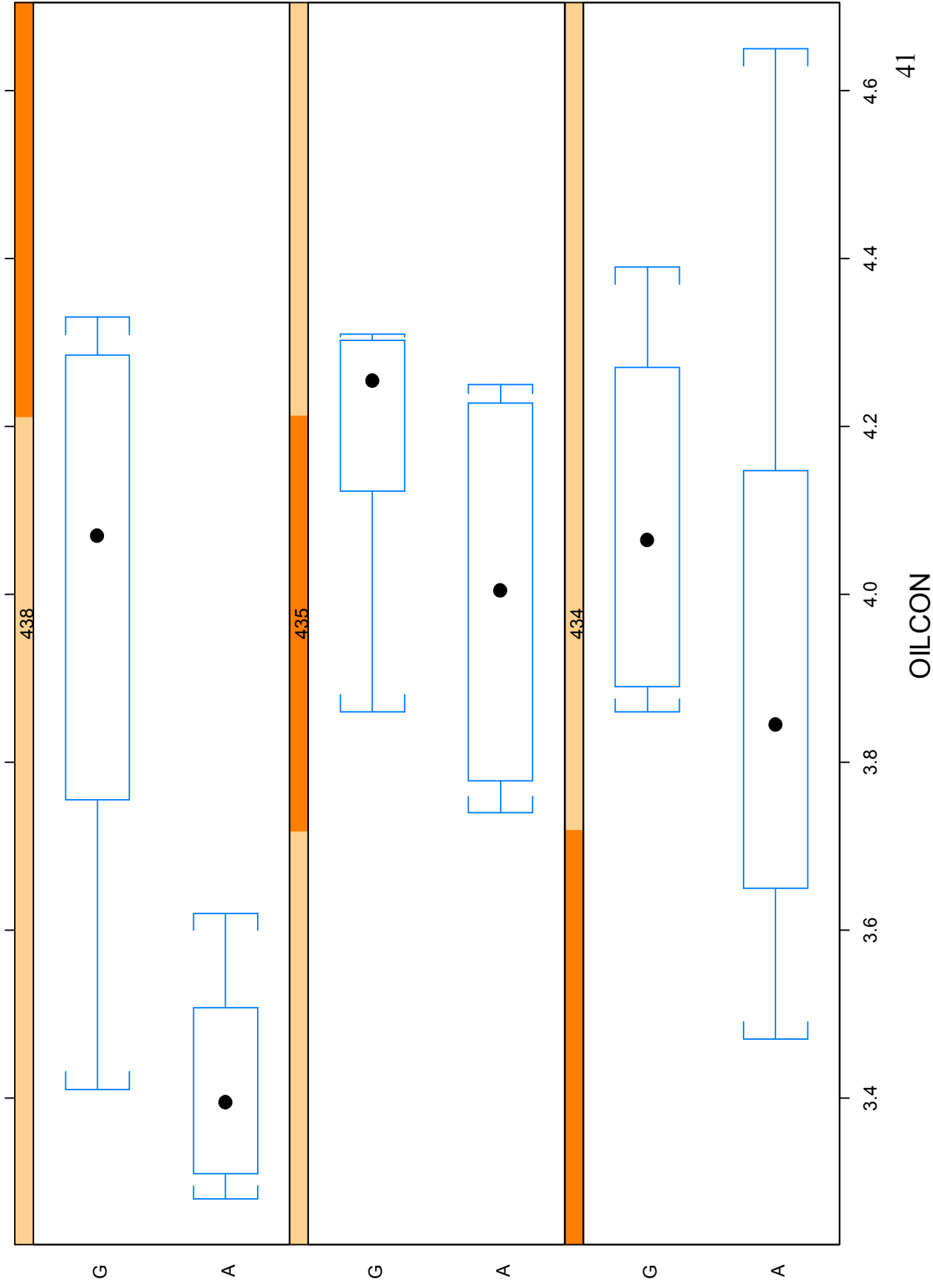
p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	Lab A	Lab G		
Lab A		0.045	3.79	3.59 to 3.99
Lab G	0.045		4.08	3.88 to 4.28

# Oil Consumption





# OILCON by Ref. Oil and Lab



# Cold Crank Simulator Viscosity (CCS)

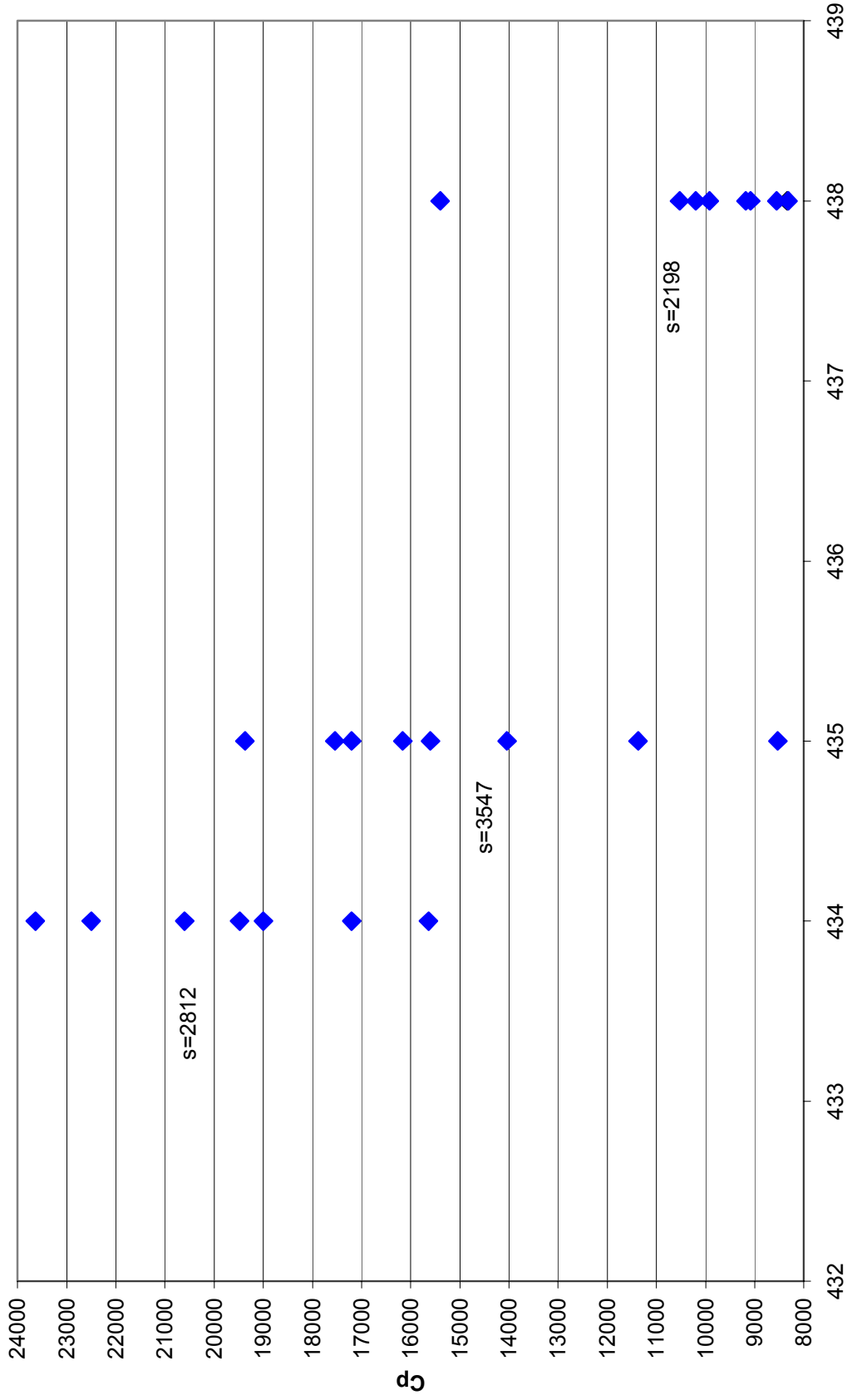
- Only 23 Out of 24 Matrix Results Available
- Root Mean Squared Error=3001.769 (19 df)
- No Statistical Evidence that the Labs Differ
- Strong Statistical Evidence that the Oils Differ

# Cold Crank Simulator Viscosity (CCS)

p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	434	435		
Oil 434		0.014	19,716	17,485 to 22,192
Oil 435	0.014		14,976	12,789 to 17,164
Oil 438	0.000	0.011	10,148	7960 to 12,335

p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	Lab A	Lab G		
Lab A		0.944	14,992	13,178 to 16,805
Lab G	0.944		14,902	13,000 to 16,804

# Cold Crank Simulator Viscosity at -30C



# MRV Viscosity (MRV)

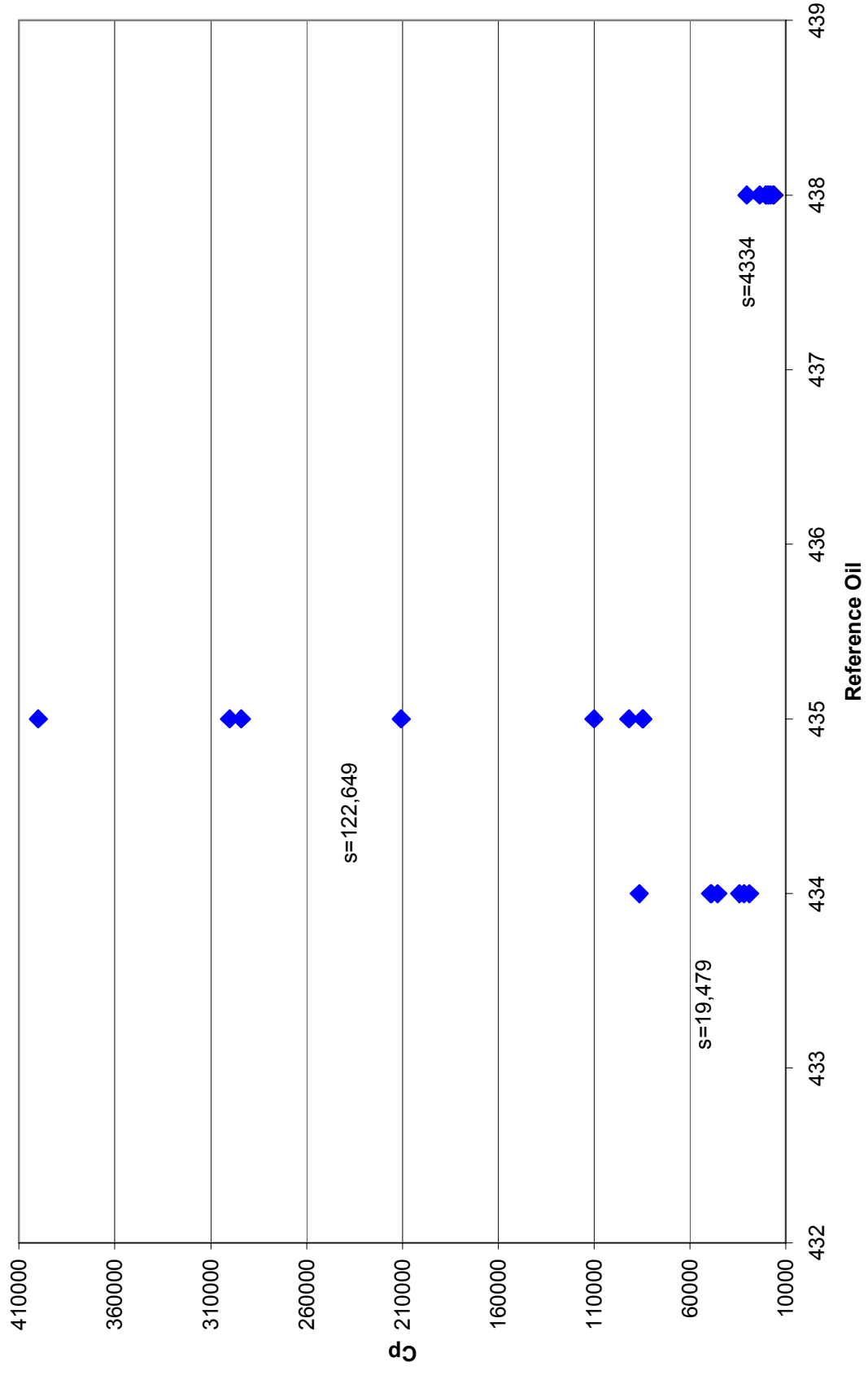
- Only 23 Out of 24 Matrix Results Available
- Analyzed on Inverse Square Root Scale
- Weak Evidence of a Stand Effect (Stand not Fit in Final Model)
- Root Mean Squared Error=0.000695 (19 df)
- Statistical Evidence that the Labs Differ
- Strong Statistical Evidence that the Oils Differ
- Analysis Performed with and without Oil 435, but Transformation Holds, Oil Discrimination Holds, and Standard Deviation in Transformed Units Remains Approximately the Same (Note, However, that there is only Some Evidence of Lab Effects)

# MRV Viscosity (MRV)

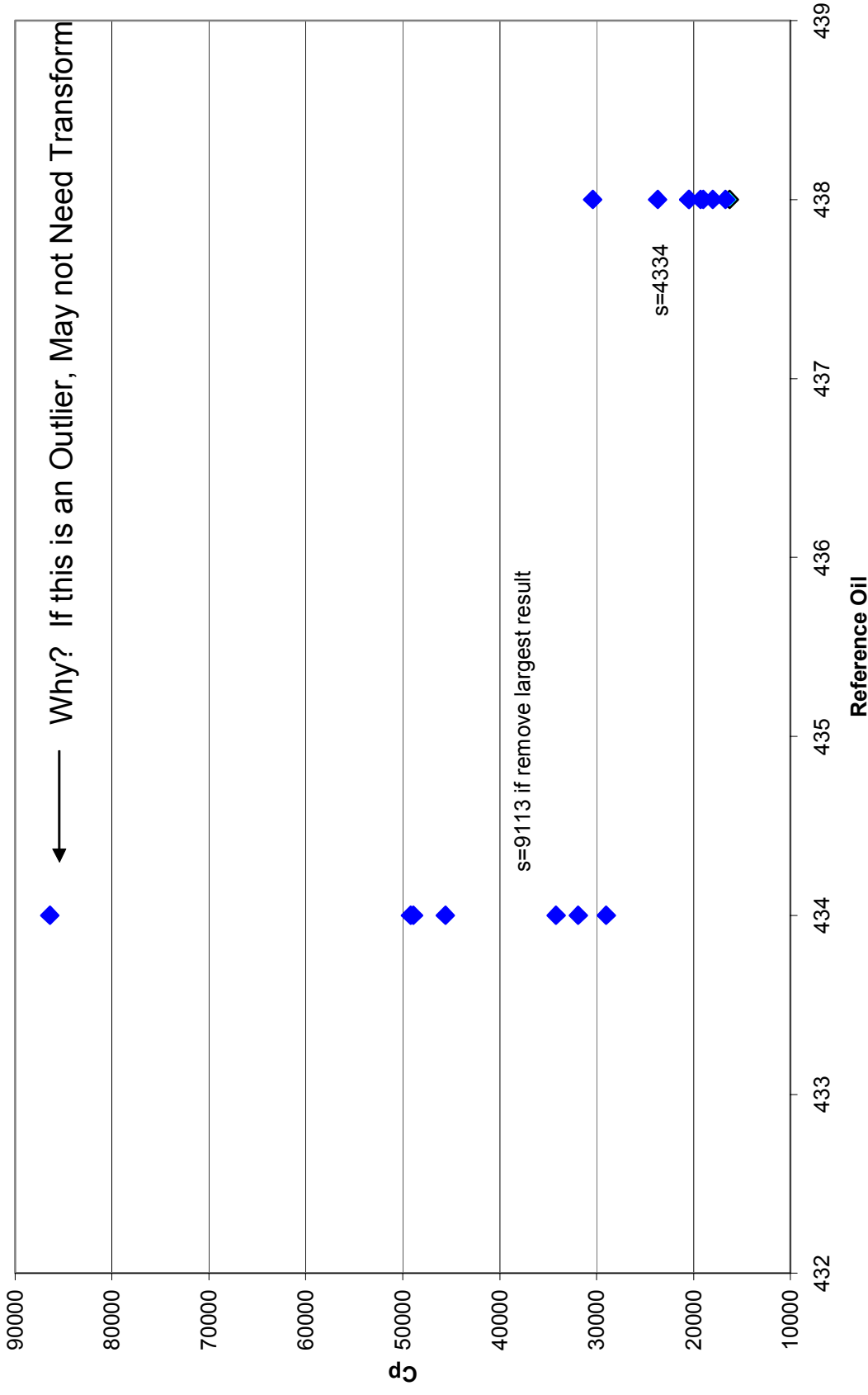
p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	434	435		
Oil 434		0.000	43,187	34,768 to 55,104
Oil 435	0.000		150,581	104,665 to 234,964
Oil 438	0.000	0.000	20,519	17,802 to 23,918

p-values in Hypothesis Test of No Difference			Mean	95% Confidence Interval for the Mean
	Lab A	Lab G		
Lab A		0.044	38,402	32,783 to 45,599
Lab G	0.044		49,891	41,362 to 61,390

# MRV Viscosity at -30C

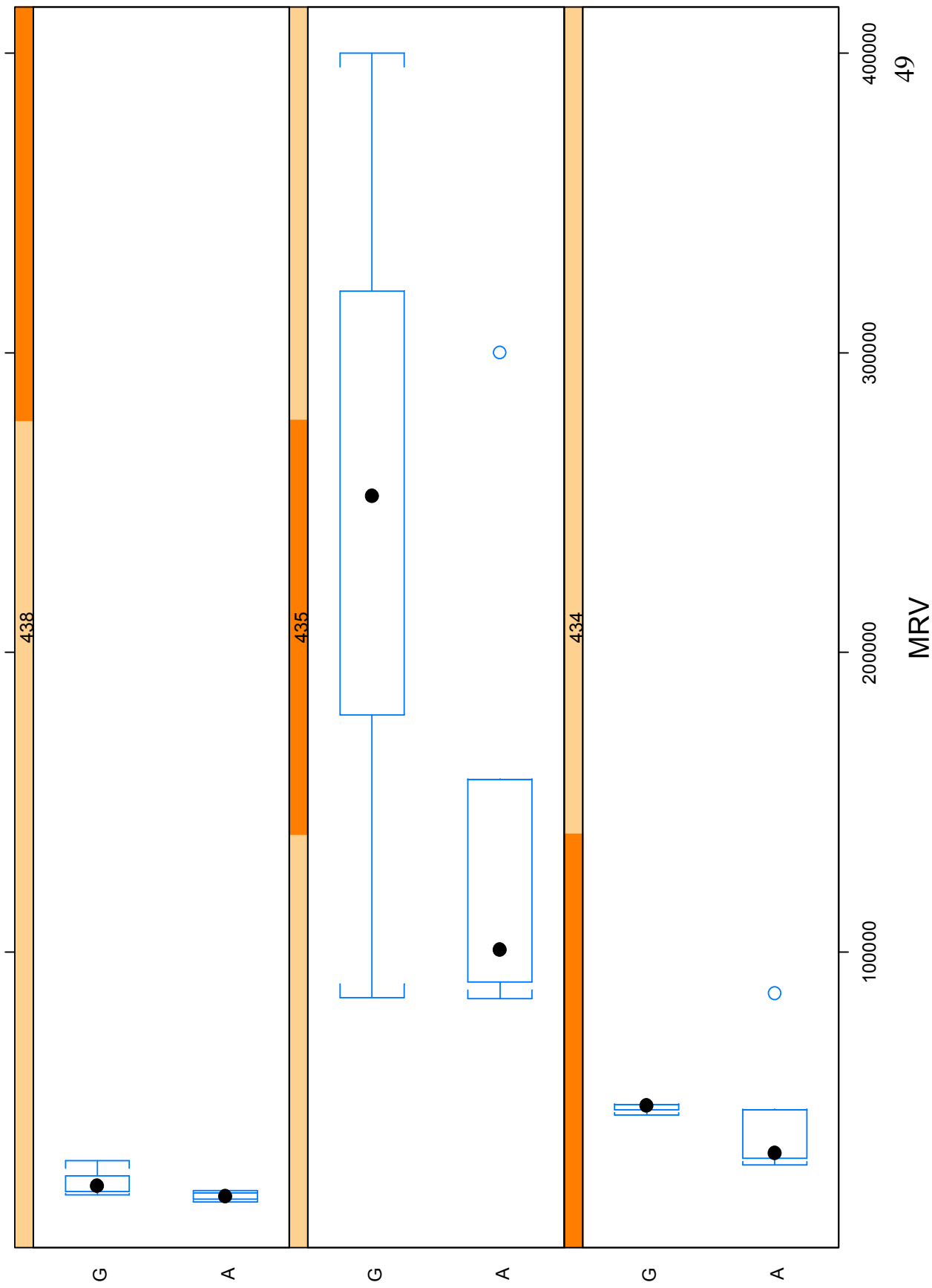


# MRV Viscosity at -30C

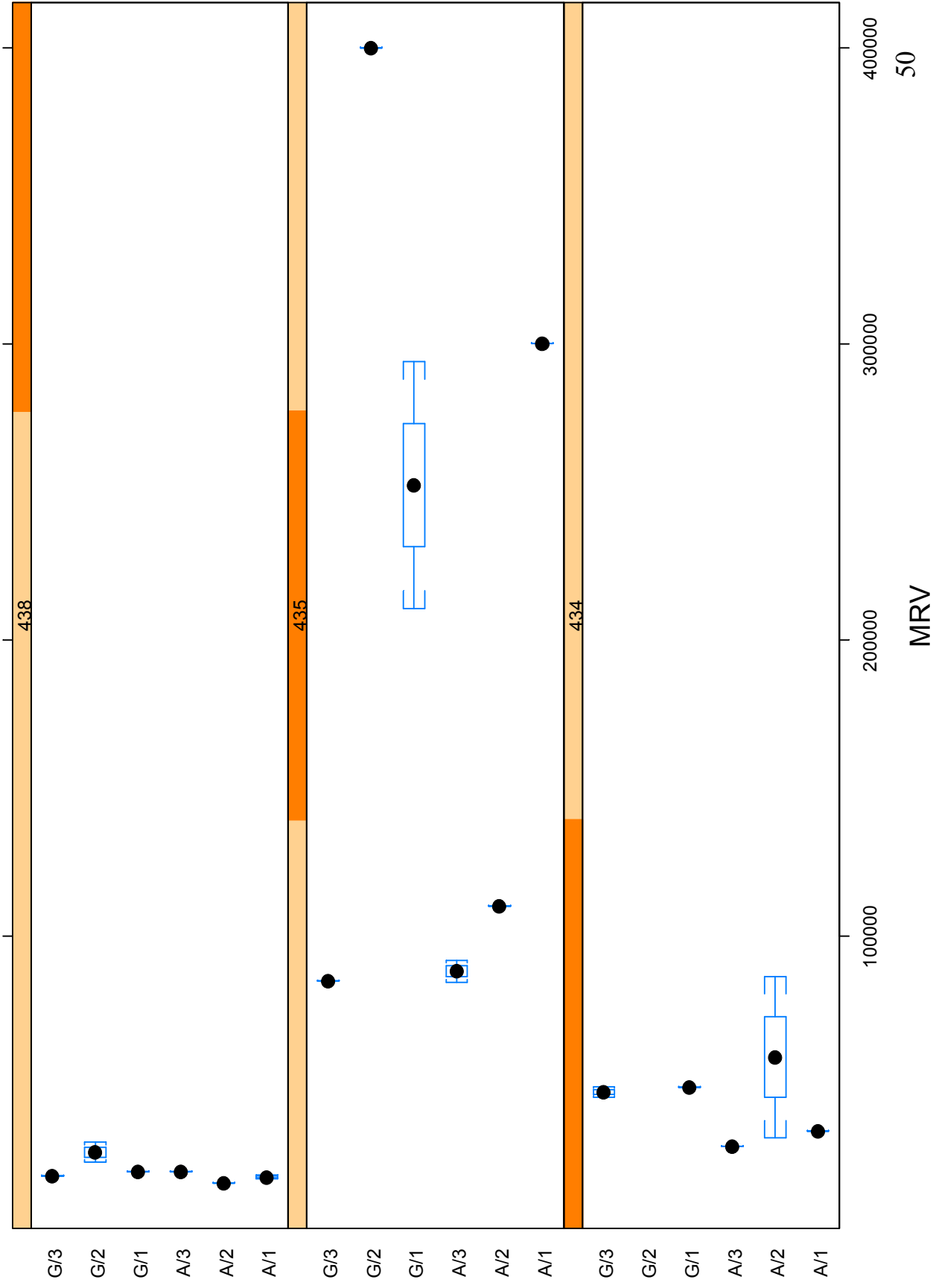




# MRV by Ref. Oil and Lab



# MRV by Ref. Oil and Stand



## Summary of Means and Standard Deviations by Oil

	VIS		LN(VIS)		NVIS	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Oil 434	129.34	61.35	4.7729	0.4447	106.40	24.42
Oil 435	214.49	54.33	5.3416	0.2433	176.79	25.47
Oil 438	110.15	20.57	4.6870	0.1832	122.97	17.89
Model		48.78		0.2919		23.34
Std Dev						
ACC Ep		<b>0.62</b>		<b>0.77</b>		<b>1.29</b>

# Summary of Means and Standard Deviations by Oil

	APV		WPD		NWPD	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Oil 434	8.82	0.31	4.34	0.88	4.38	0.70
Oil 435	8.45	0.31	3.38	0.43	3.62	0.32
Oil 438	8.88	0.34	3.28	0.44	3.50	0.35
Model Std Dev		0.32		0.60		0.47
ACC Ep		<b>0.94</b>		<b>0.50</b>		<b>0.65</b>

## Summary of Means and Standard Deviations by Oil

	ACLW		LN(ACLW)		OC	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Oil 434	36.84	5.55	3.5956	0.1624	4.02	0.38
Oil 435	37.28	8.47	3.5961	0.2247	4.09	0.24
Oil 438	18.44	3.20	2.9009	0.1767	3.70	0.42
Model Std Dev		6.13		0.1936		0.33
ACC Ep		<b>1.63</b>		<b>1.87</b>		<b>1.53</b>

# Summary of Means and Standard Deviations by Oil

	CCS		MRV		1/SQRT(MRV)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Oil 434	19,723	2812	46,457 (39,800)	19,479 (9113)	0.00485629	0.00084309
Oil 435	14,976	3547	197,025	122,649	0.00257696	0.00079675
Oil 438	10,148	2260	21,013	4318	0.00698055	0.00062174
Model Std Dev		3002	434,438 only	7131		0.000695
ACC Ep		<b>0.27</b>		<b>1.12</b>		<b>~1</b>