

DRAFT

Statistical Summary of the Mack T10 Precision/BOI Matrix

Summary

- This is a preliminary analysis. The statistician work group has not reviewed the presentation.
- Delta lead benefits from a natural log transformation.
- No other transformations were necessary.
- The matrix data have not been evaluated for ACC precision requirements.
- There was a significant positive correlation between delta lead from beginning to end of test and delta lead from 250 to 300 hours, between top ring weight loss and cylinder liner wear, and between method 5 IR and each of the delta lead measures.

Summary

(continued)

- Labs had significant effects for both delta lead measures and IR. They were marginally significant for cylinder liner wear.
- Stand within Lab was significant for IR and marginally significant for both delta lead measures.
- The interaction between technology and base oil was significant for cylinder liner wear and marginally significant for top ring weight loss.

Summary

(continued)

- Technology had a significant effect for the delta lead measures and IR.
- Base Oil was significant effect for cylinder liner wear and marginally significant for top ring weight loss.
- No observations with large Studentized residuals (>3.0) remain in the data set.
- Oil means and standard deviations are given for potential use in LTMS.

Data Set

- Table 1 shows the design for the matrix.
- All operationally valid data with the exception of CMIR 38815 and CMIR 38946 are included.
- The T10 Task Force decided to eliminate the test with CMIR 38815 from the analysis.
 - This was an early test in Lab B on Oil A which had high silicon and aluminum in the used oil. It also had high ring weight loss with low cylinder liner wear. The lab ran Oil A again with non-anomalous results. The matrix remained intact as planned with the deletion of this test.
- The Task Force later decided to eliminate the test with CMIR 38946.
 - This was a test of Oil D in Stand 1 in Lab G that had high delta lead (206 ppm), low EGR rates, and a different relation between delta lead and upper rod bearing weight loss.

Table 1. Mack T10 Precision Matrix Plan

Base Oil	Technology		
	X	Y	Z
Base Oil 1	PC-9A	PC-9D	PC-9G
Base Oil 2	PC-9B	PC-9E	PC-9H
Base Oil 3	PC-9C	PC-9F	PC-9J

Lab/Stand						
Lab A		Lab D	Lab G		Lab F	Lab B
1	2	1	1	2	6	7
A	A	A	A	A	A	A
G	A	G	D *	A	A	D
E	E	B	H	E	H	B
C	J	F	C	J	F	J

* The Task Force eliminated this test from the completed data set.

Table 2. Mack T10 Precision Matrix Data

from TMC 07/16/01

Obs	TESTKEY	LTMSLAB	LTMSAPP	LTMSDATE	Oil	Tech	Base Oil	DPBFNL	DPb250300	ATRWLFNL	CLWLFNL	OILCON	M5IR300	AvgSoot
1	38814	F	1	20001211	A	X	1	33	16	139	36.3	79.0	452	4.5
2	38809	A	1	20001219	A	X	1	23	8	158	33.3	52.3	348	4.7
3	38811	D	1	20001224	A	X	1	12	5	139	38.2	52.1	210	4.5
4	38945	D	1	20010215	F	Y	3	21	7	69	27.3	56.0	347	4.4
5	38953	F	1	20010217	H	Z	2	73	33	150	33.3	61.0	1042	4.2
6	38939	A	1	20010305	C	X	3	33	14	116	25.3	62.9	458	4.4
7	38810	A	2	20010313	A	X	1	19	7	168	38.0	46.5	334	4.9
8	38947	G	1	20010318	H	Z	2	115	58	156	34.0	64.0	1949	4.8
9	38937	A	1	20010329	E	Y	2	18	6	118	21.2	53.4	342	3.9
10	38951	G	2	20010330	A	X	1	37	14	125	33.0	53.3	497	4.5
11	38943	D	1	20010401	B	X	2	17	5	125	30.9	43.9	294	4.2
12	38957	B	1	20010403	D	Y	1	25	10	204	45.7	53.6	477	5.1
13	38942	A	2	20010408	A	X	1	16	2	87	27.4	40.5	280	4.1
14	38948	G	2	20010419	J	Z	3	90	27	119	35.4	46.9	1292	4.4
15	38952	F	1	20010419	F	Y	3	62	34	106	26.0	51.0	1244	4.4
16	38949	G	1	20010420	C	X	3	77	26	133	35.1	66.0	1454	5.4
17	38941	A	1	20010422	G	Z	1	71	38	107	29.0	52.3	910	4.4
18	38938	A	2	20010504	J	Z	3	44	16	153	31.4	57.7	980	4.8
19	38944	D	1	20010504	G	Z	1	27	10	154	39.4	46.7	348	4.4
20	38956	B	1	20010509	J	Z	3	50	16	127	29.5	34.5	1106	5.1
21	38950	G	2	20010512	E	Y	2	52	22	109	28.3	55.5	991	4.8
22	38940	A	2	20010528	E	Y	2	22	9	67	20.4	45.0	373	4.8
23	40919	B	1	20010529	B	X	2	34	17	121	23.6	53.9	415	4.3
24	40230	G	2	20010602	A	X	1	25	8	108	34.2	47.8	200	4.3
25	41135	F	1	20010611	A	X	1	28	10	128	26.4	60.2	482	4.6
26	41410	B	1	20010618	A	X	1	34	17	140	35.2	42.1	347	4.9
27	41412	G	1	20010703	A	X	1	66	30	123	39.4	64.4	1372	5.1

Transformations

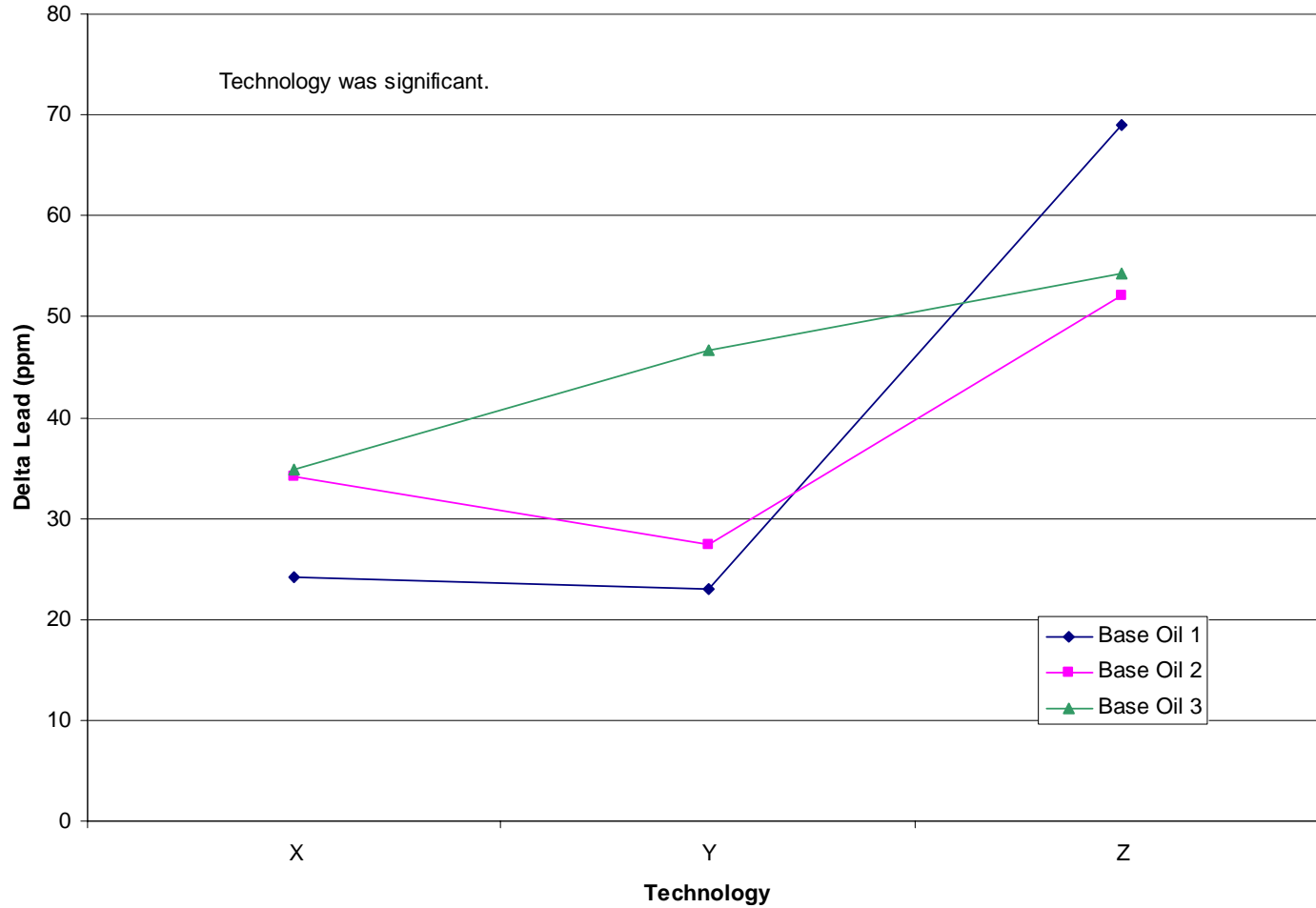
- Box-Cox procedure was applied using all matrix data.
- Delta lead benefits from a natural logarithm transformation.
- No data transformations are indicated for other responses analyzed.

Ln(Delta Lead)

Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Stand within Laboratory (A1,A2,G1,G2), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.
- Technology, and Lab were significant ($p < 0.05$), and Stand within Lab was marginally significant ($0.05 < p < 0.10$).
 - Root MSE from the model was 0.21 (12 df).
 - The R^2 for the model was 0.94.
 - Figure 1 illustrates the least squares means by oil.
 - Figure 2 summarizes least squares means for stands within labs.
 - Stand within Lab significance was driven by the two stands in Lab G which were almost significantly different from each other. Both stands were higher (in many cases significantly) than all other stands.
 - Log transformation was appropriate.
 - No observations had large Studentized residuals.

Figure 1
Least Squares Means for Oils

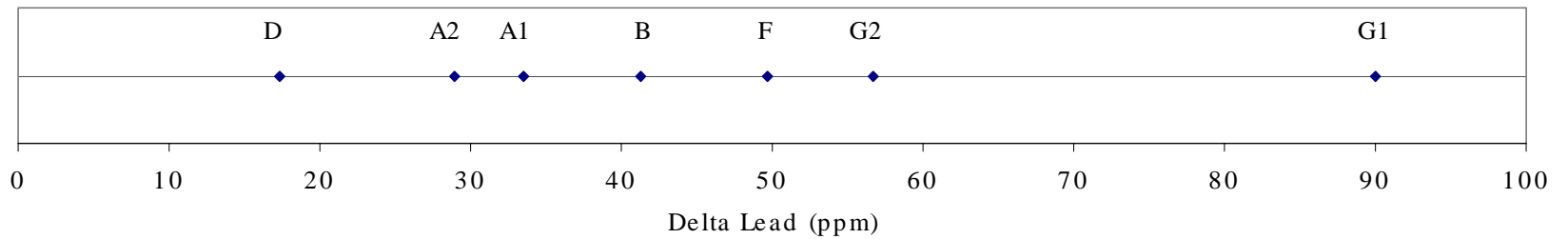


Technology	Least Squares Mean	p-value for test of equal means (Tukey)		
		vs X	vs Y	vs Z
X	31		0.33	0.00
Y	31	0.33		0.07
Z	58	0.00	0.07	

Figure 2

Least Squares Means for Stand within Lab Delta Lead (ppm)

Lab/ Stand	LS Mean	p-value for test of equal means (Tukey)						
		vs A1	vs A2	vs B	vs D	vs F	vs G1	vs G2
A1	34		0.97	0.93	0.03	0.37	0.00	0.10
A2	29	0.97		0.46	0.15	0.10	0.00	0.01
B	41	0.93	0.46		0.01	0.96	0.04	0.59
D	17	0.03	0.15	0.01		0.00	<.0001	0.00
F	50	0.37	0.10	0.96	0.00		0.07	0.99
G1	90	0.00	0.00	0.04	<.0001	0.07		0.29
G2	57	0.10	0.01	0.59	0.00	0.99	0.29	

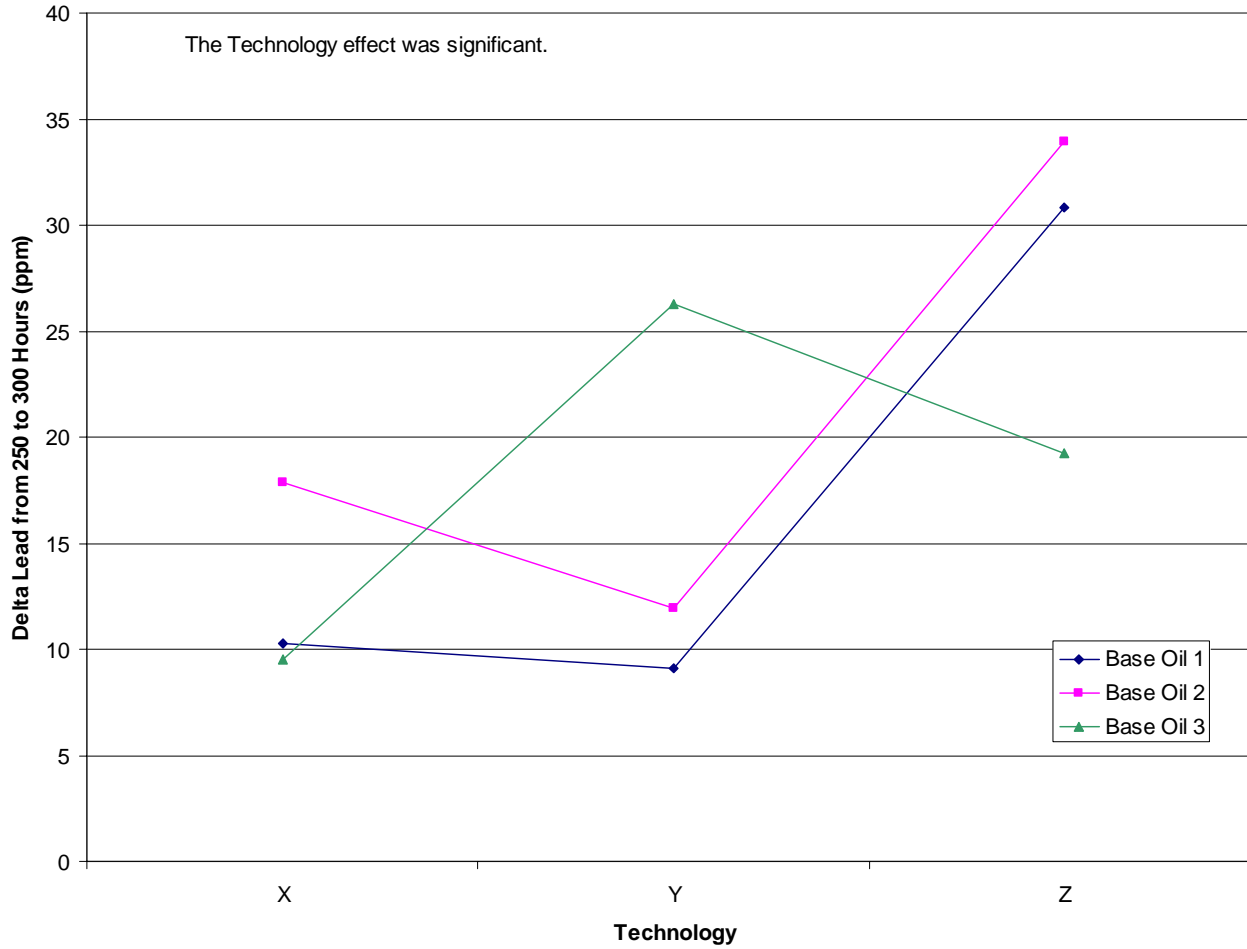


Delta Lead from 250 to 300 Hours

Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Stand within Laboratory (A1,A2,G1,G2), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.
- Technology, and Lab were significant ($p < 0.05$), and Stand within Lab was marginally significant ($0.05 < p < 0.10$).
 - Root MSE from the model was 6 (12 df).
 - The R^2 for the model was 0.88.
 - Figure 3 illustrates the least squares means by oil.
 - Figure 4 summarizes least squares means for stands within labs.
 - Stand within Lab significance was driven by the two stands in Lab G which were almost significantly different from each other. Both stands were higher (in many cases significantly) than all other stands.
 - No observations had large Studentized residuals.

Figure 3
Least Squares Means for Oils

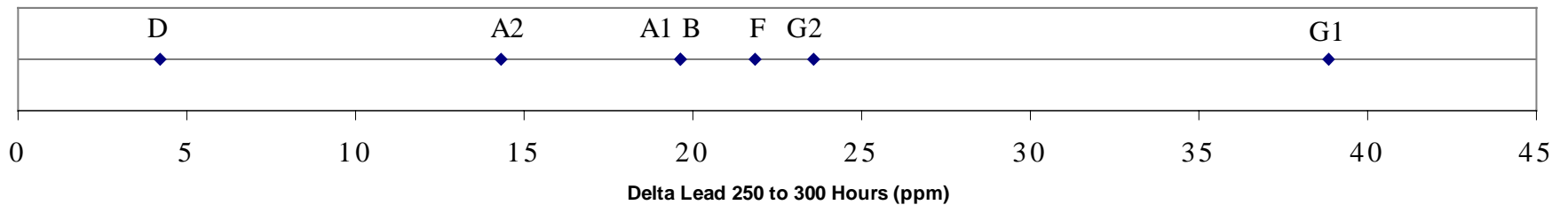


Technology	Least Squares Mean	p-value for test of equal means (Tukey)		
		vs X	vs Y	vs Z
X	13		0.70	0.00
Y	16	0.70		0.03
Z	28	0.00	0.03	

Figure 4

Least Squares Means for Stands within Labs Delta Lead from 250 to 300 Hours (ppm)

Lab/ Stand	LS Mean	p-value for test of equal means (Tukey)						
		vs A1	vs A2	vs B	vs D	vs F	vs G1	vs G2
A1	20		0.94	1.00	0.14	1.00	0.06	0.98
A2	14	0.94		0.95	0.56	0.79	0.02	0.45
B	20	1.00	0.95		0.16	1.00	0.13	0.99
D	4	0.14	0.56	0.16		0.06	0.00	0.05
F	22	1.00	0.79	1.00	0.06		0.10	1.00
G1	39	0.06	0.02	0.13	0.00	0.10		0.22
G2	24	0.98	0.45	0.99	0.05	1.00	0.22	



Top Ring Weight Loss Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.
- Base Oil and Interaction between Technology and Base Oil were marginally significant.
 - Root MSE from the model was 25 (14 df).
 - The R^2 for the model was 0.62.
 - Figure 5 illustrates the least squares means by oil.
 - Figure 6 illustrates the least squares means for laboratories.
 - No observations had large Studentized residuals.

Figure 5
Least Squares Means for Oils

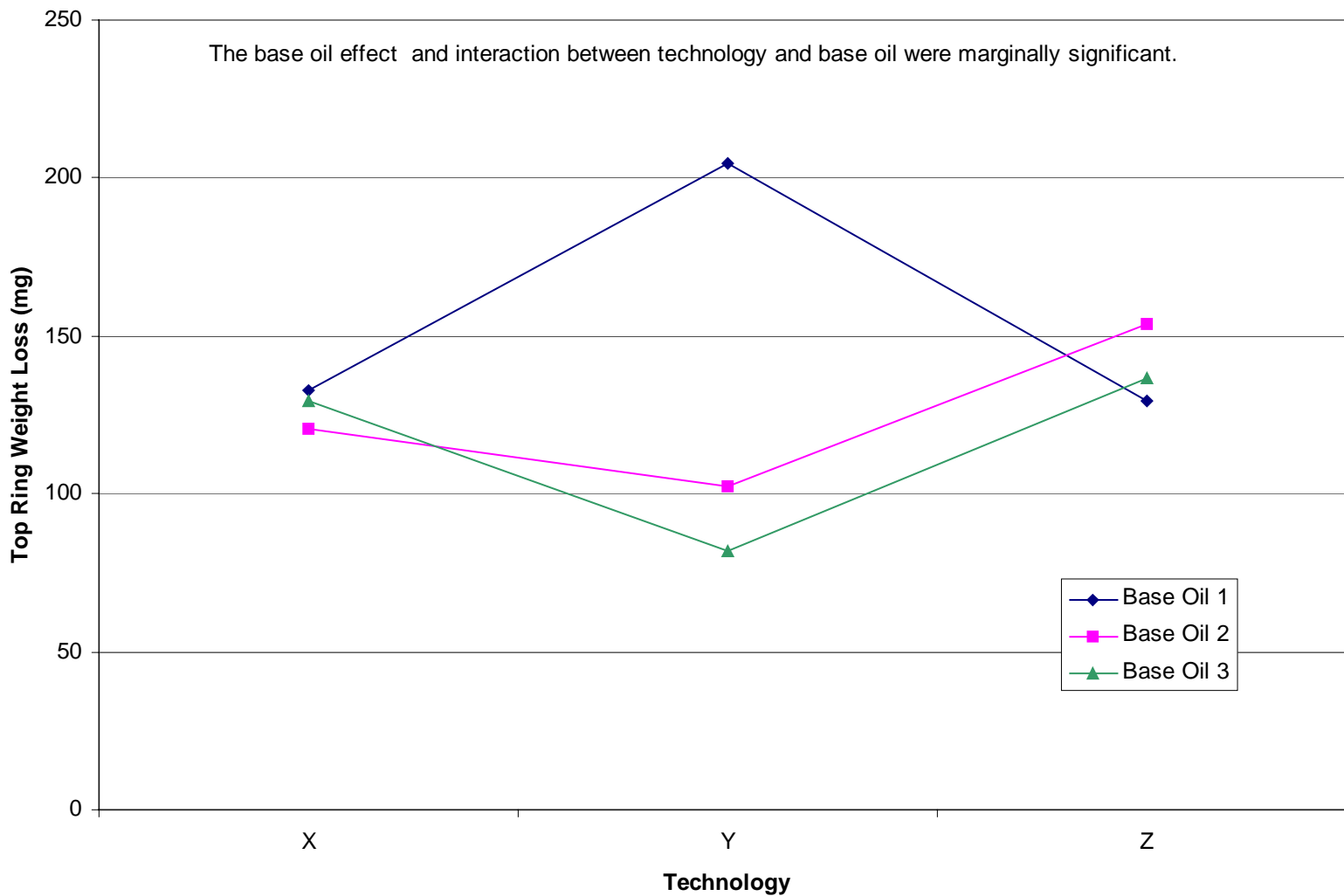
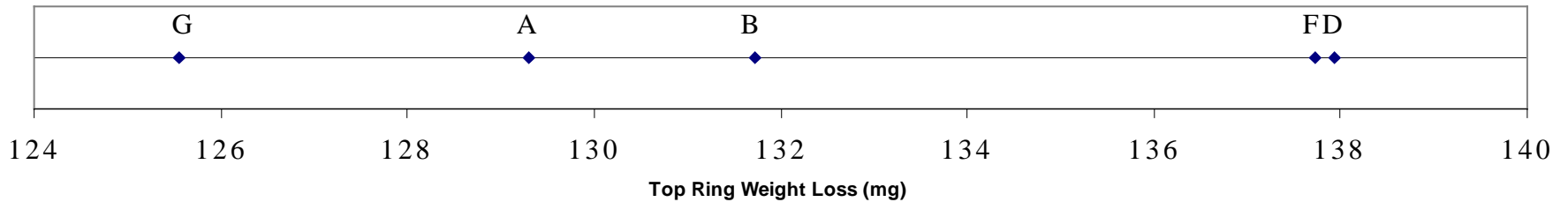


Figure 6

Lab Least Squares Means Top Ring Weight Loss (mg)

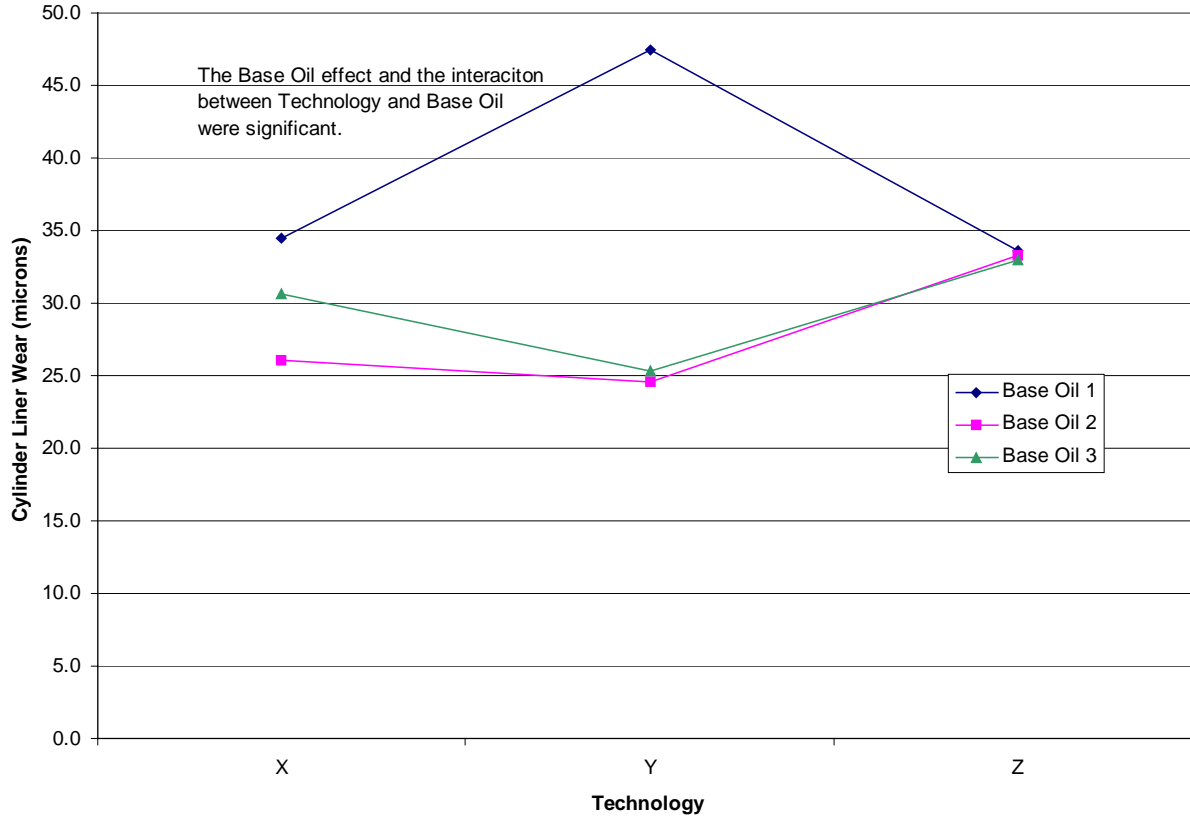
Lab	LS Mean	p-value for test of equal means (Tukey)				
		vs A	vs B	vs D	vs F	vs G
A	129		1.00	0.99	0.99	1.00
B	132	1.00		1.00	1.00	1.00
D	138	0.99	1.00		1.00	0.96
F	138	0.99	1.00	1.00		0.95
G	126	1.00	1.00	0.96	0.95	



Cylinder Liner Wear Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.
- The Base Oil effect and the interaction between Technology and Base Oil was significant. Lab was marginally significant.
 - Root MSE from the model was 3.7 (14 df).
 - The R^2 for the model was 0.80.
 - Figure 7 illustrates the least squares means by oil.
 - Figure 8 shows least squares means for base oils and labs.
 - There were no large Studentized residuals.

Figure 7
Least Squares Means for Oils

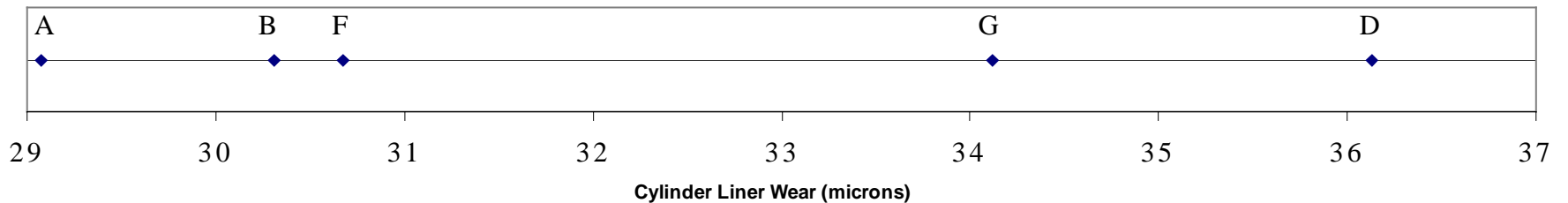


Tech	Base Oil	LS Mean	p-value for test of equal means (Tukey)								
			vs X1	vs X2	vs X3	vs Y1	vs Y2	vs Y3	vs Z1	vs Z2	vs Z3
X	1	34.5		0.29	0.92	0.18	0.03	0.17	1.00	1.00	1.00
X	2	26.1	0.29		0.97	0.01	1.00	1.00	0.61	0.75	0.64
X	3	30.7	0.92	0.97		0.11	0.69	0.92	1.00	1.00	1.00
Y	1	47.4	0.18	0.01	0.11		0.01	0.02	0.26	0.25	0.12
Y	2	24.6	0.03	1.00	0.69	0.01		1.00	0.31	0.37	0.25
Y	3	25.3	0.17	1.00	0.92	0.02	1.00		0.49	0.55	0.58
Z	1	33.7	1.00	0.61	1.00	0.26	0.31	0.49		1.00	1.00
Z	2	33.3	1.00	0.75	1.00	0.25	0.37	0.55	1.00		1.00
Z	3	33.0	1.00	0.64	1.00	0.12	0.25	0.58	1.00	1.00	

Figure 8

Lab Least Squares Means Cylinder Liner Wear (microns)

Lab	LS Mean	p-value for test of equal means (Tukey)				
		vs A	vs B	vs D	vs F	vs G
A	29.1		0.99	0.13	0.97	0.14
B	30.3	0.99		0.38	1.00	0.69
D	36.1	0.13	0.38		0.39	0.95
F	30.7	0.97	1.00	0.39		0.67
G	34.1	0.14	0.69	0.95	0.67	



Oil Consumption

Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.
- No effects were significant.
 - Root MSE from the model was 8.9 (14 df).
 - The R^2 for the model was 0.51.
 - Figure 9 illustrates the least squares means by oil.
 - Figure 10 show least squares means for labs.
 - There were no large Studentized residuals.

Figure 9
Least Squares Means for Oils

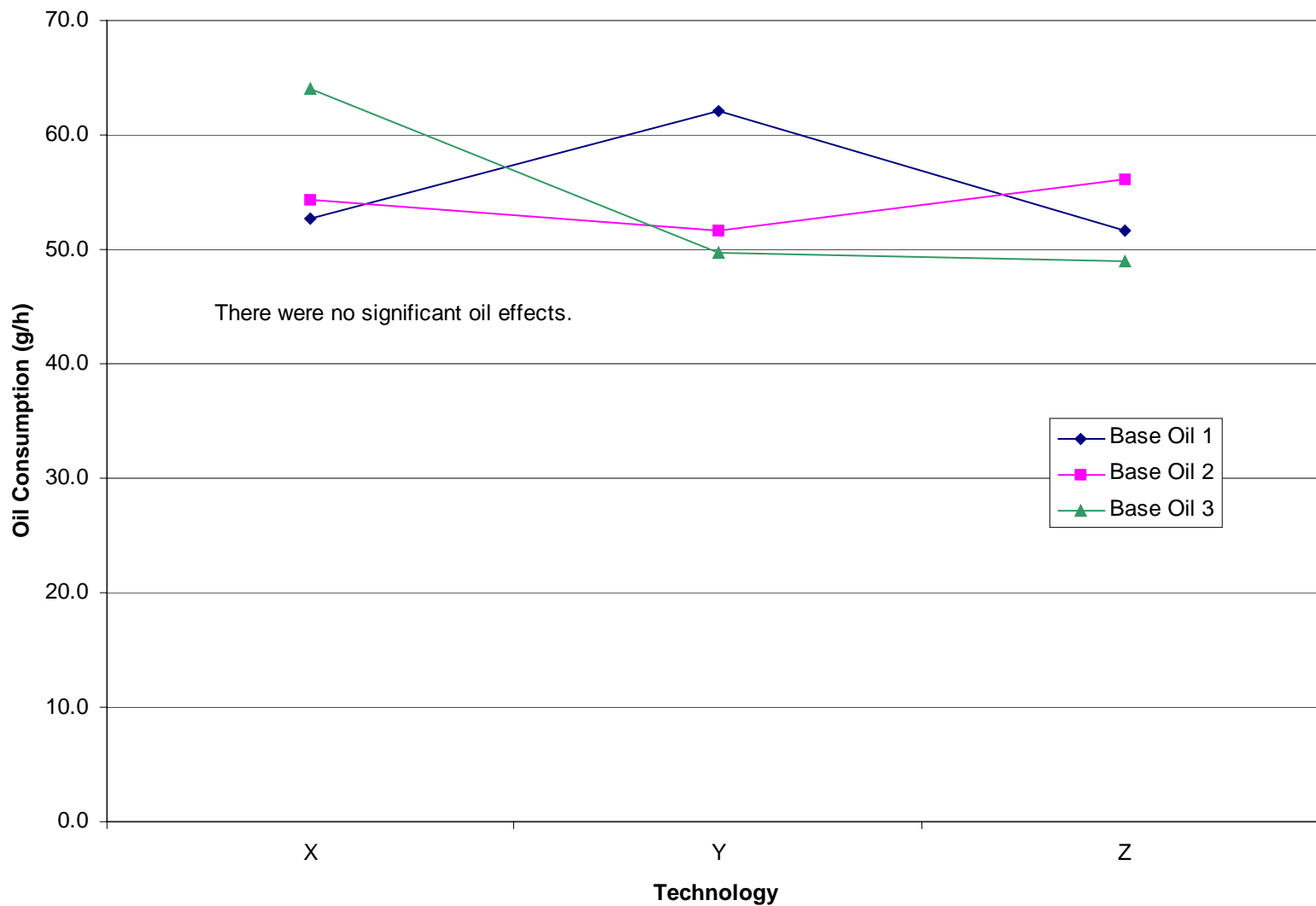
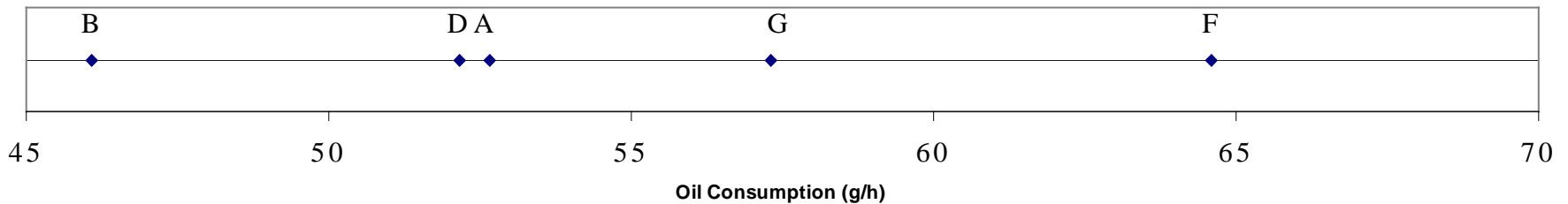


Figure 10

Lab Least Squares Means Oil Consumption (g/h)

Lab	LS Mean	p-value for test of equal means (Tukey)				
		vs A	vs B	vs D	vs F	vs G
A	52.7		0.87	1.00	0.39	0.87
B	46.1	0.87		0.93	0.19	0.52
D	52.2	1.00	0.93		0.44	0.94
F	64.6	0.39	0.19	0.44		0.76
G	57.3	0.87	0.52	0.94	0.76	

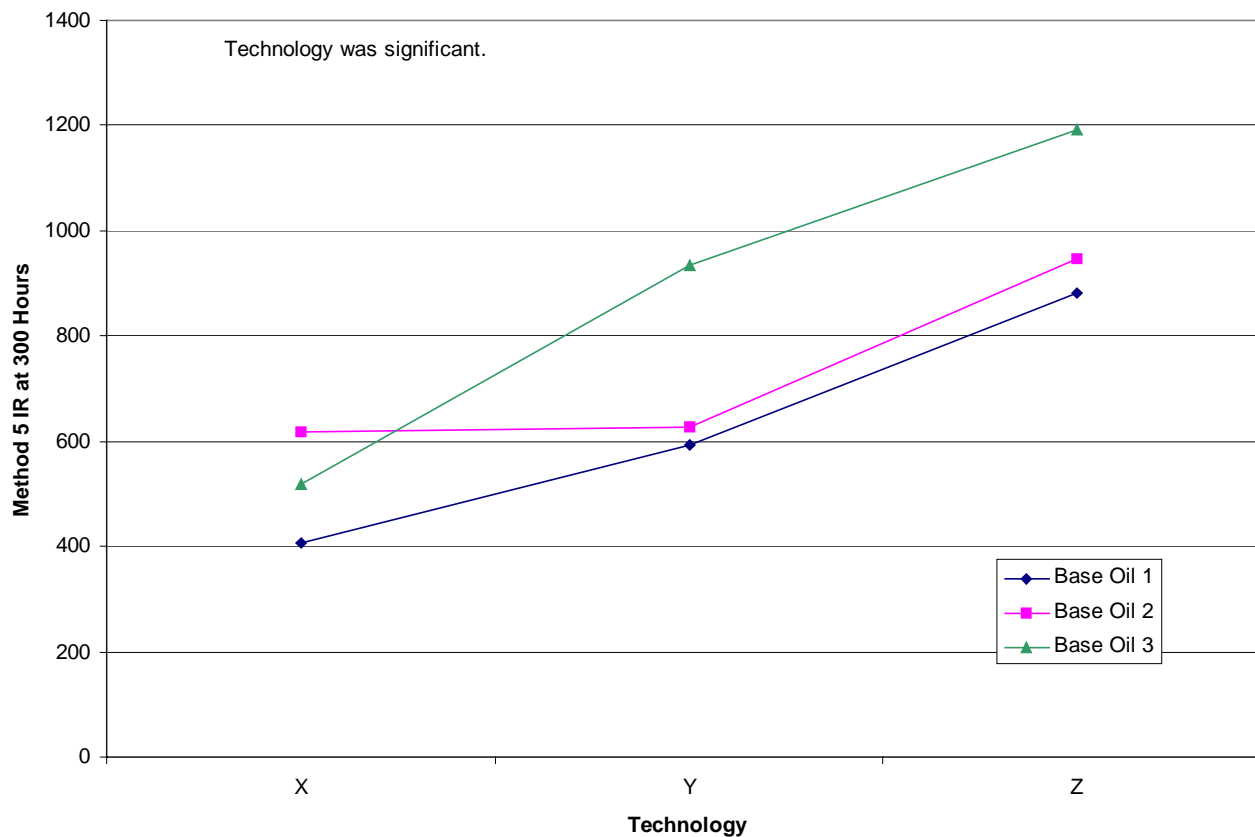


Method 5 IR at 300 Hours

Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Stand within Laboratory (A1,A2,G1,G2), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.
- Technology, and Lab, and Stand within Lab were significant.
 - Root MSE from the model was 181 (12 df).
 - The R^2 for the model was 0.93.
 - Figure 11 illustrates the least squares means by oil.
 - Figure 12 summarizes least squares means for stands within labs.
 - Stand within Lab significance was driven mainly by one stand in Lab G that was significantly higher than all other stands.
 - No observations had large Studentized residuals.

Figure 11
Least Squares Means for Oils

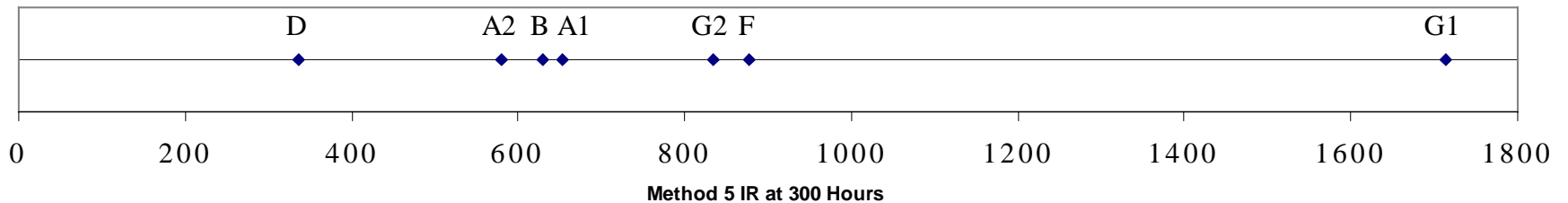


Technology	Least Squares	p-value for test of equal means (Tukey)		
		vs X	vs Y	vs Z
X	515		0.19	0.00
Y	719	0.19		0.06
Z	1007	0.00	0.06	

Figure 12

Least Squares Means for Stand within Lab Method 5 IR at 300 Hours

Lab/ Stand	LS Mean	p-value for test of equal means (Tukey)						
		vs A1	vs A2	vs B	vs D	vs F	vs G1	vs G2
A1	652		1.00	1.00	0.41	0.76	0.00	0.86
A2	580	1.00		1.00	0.70	0.47	0.00	0.47
B	630	1.00	1.00		0.52	0.74	0.00	0.82
D	336	0.41	0.70	0.52		0.04	<.0001	0.08
F	877	0.76	0.47	0.74	0.04		0.00	1.00
G1	1714	0.00	0.00	0.00	<.0001	0.00		0.00
G2	833	0.86	0.47	0.82	0.08	1.00	0.00	



Correlations Among the Criteria

Raw Data	In(Delta Pb)	DPb250300	TRWL	CLW	OC	M5IR300
In(Delta Pb)	1.00	0.91	0.08	0.09	0.33	0.91
DPb250300	0.91	1.00	0.10	0.08	0.37	0.88
TRWL	0.08	0.10	1.00	0.73	0.18	0.10
CLW	0.09	0.08	0.73	1.00	0.14	0.11
OC	0.33	0.37	0.18	0.14	1.00	0.31
M5IR300	0.91	0.88	0.10	0.11	0.31	1.00
Residuals	In(Delta Pb)	URBWL	TRWL	CLW	OC	M5IR300
In(Delta Pb)	1.00	0.75	0.12	0.40	0.19	0.68
DPb250300	0.75	1.00	0.09	0.23	0.14	0.76
TRWL	0.12	0.09	1.00	0.67	0.22	0.22
CLW	0.40	0.23	0.67	1.00	0.19	0.24
OC	0.19	0.14	0.22	0.19	1.00	-0.18
M5IR300	0.68	0.76	0.22	0.24	-0.18	1.00
Oil LS Means	In(Delta Pb)	URBWL	TRWL	CLW	OC	M5IR300
In(Delta Pb)	1.00	0.86	-0.28	-0.25	-0.42	0.82
DPb250300	0.86	1.00	-0.21	-0.22	-0.41	0.70
TRWL	-0.28	-0.21	1.00	0.94	0.61	-0.13
CLW	-0.25	-0.22	0.94	1.00	0.50	-0.11
OC	-0.42	-0.41	0.61	0.50	1.00	-0.54
M5IR300	0.82	0.70	-0.13	-0.11	-0.54	1.00

Oil Least Squares Means and Standard Deviations

Oil	InDeltaPb	DPb250300	TRWL	CLW	OilCon	M5IR300
A	3.1884	10	133	34.5	52.6	407.4
B	3.5301	18	121	26.1	54.3	618.1
C	3.5515	10	130	30.7	64.0	519.6
D	3.1351	9	205	47.4	62.1	593.3
E	3.3099	12	102	24.6	51.6	626.7
F	3.8439	26	82	25.3	49.7	935.6
G	4.2338	31	129	33.7	51.7	881.7
H	3.9526	34	154	33.3	56.1	946.6
J	3.9949	19	137	33.0	48.9	1191.3
Std Dev	0.2946	6	25	3.7	8.9	181