

Preliminary Analysis of Cummins M11EGR Precision/BOI Matrix

Report to: M11EGR Task Force
July 9, 2001
Columbus, IN

HDEOCP
July 11, 2001
Chicago, IL

M11EGR

Executive Summary

- Top Ring Weight Loss
 - No lab, technology, or base stock effects
 - Crosshead Wear
 - Significant lab differences
 - No Technology or base stock effect
 - Soot and blowby rate effects
 - Average Engine Sludge
 - Significant lab differences
 - Technology/base stock interaction
 - Oil Filter Delta Pressure
 - No lab differences
 - Technology effect (when extreme values are included)
 - Oil Consumption
 - Significant lab differences
 - No technology or base stock effects
 - Adjusting Screw Weight Loss
 - Significant lab differences
 - No technology or base stock effect
-
- Operational differences among labs
 - Intake and Exhaust CO2
 - Number of Shutdowns
 - Torque
 - Blowby
 - Parameters are uncorrelated

Experimental design

Lab A		Lab B	Lab D	Lab G	
S1	S2	S1	S1	S1	S2
B	A	B	C ^a	A	C ^b
E	E	D	D	E	E
E	E	E	E	E	E
F	J	J	H	F	G
G				H	

^a Replaced oil filter due to low oil gallery pressure

^b Terminated at 228 hrs. due to low oil gallery pressure

		Base stock		
		1	2	3
Technology	X	A	B	C
	Y	D	E	F
	Z	G	H	J
		Group II	Group II	Group I

Outliers/missing data

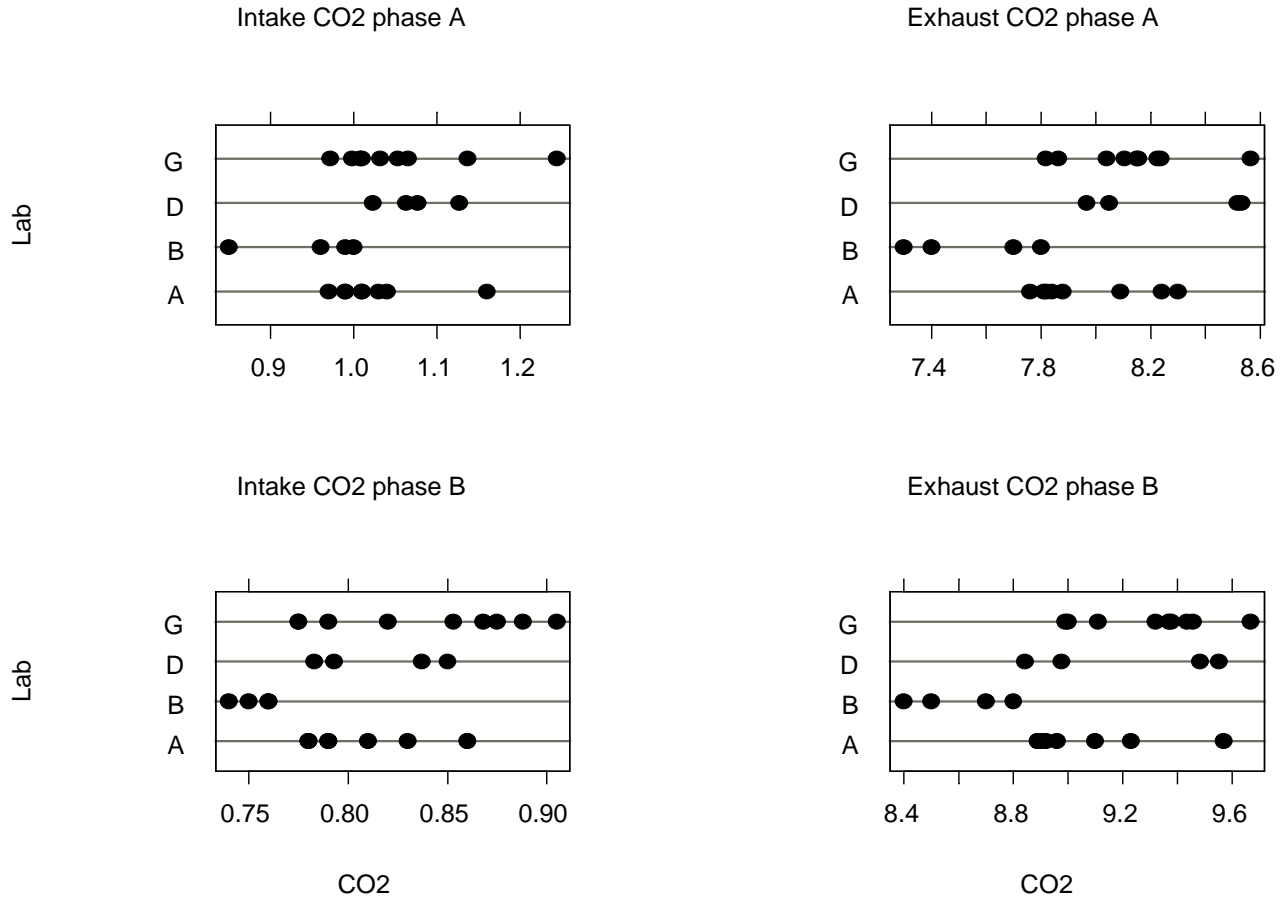
- Possible Outliers

- CMIR 38958 OC = 0 XHDW = 7.7
- CMIR 38931 TBN @ NEW = 7.7
- CMIR 38964 TBN @ NEW = 2.1
- CMIR 38929 ASWL = 404
- CMIR 38965 ASWL = 33

- Missing data

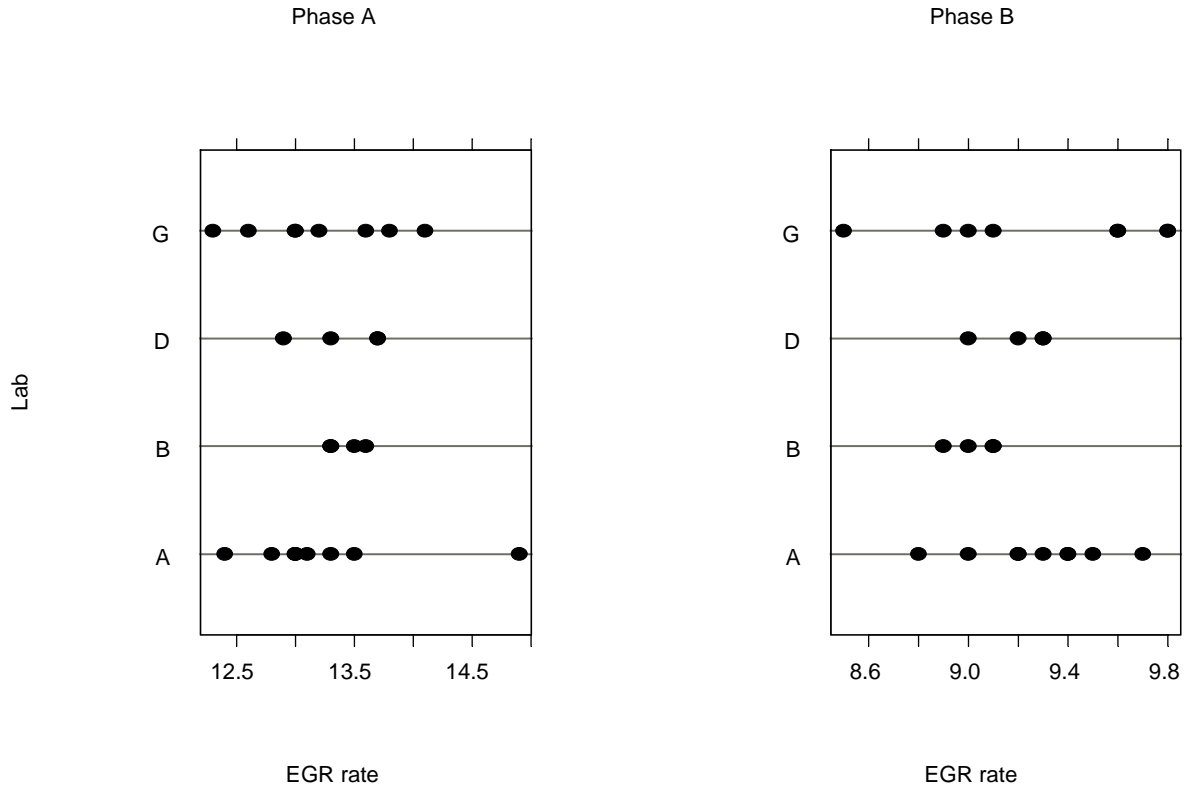
- CMIR 38963 TBN @ EOT,
- CMIR 38930 TBN @ EOT,
- CMIR 38958 Several missing values (due to termination)
- CMIR 38960 TBN @ NEW
- CMIR 38934 CO2
- Liner Wear Step Missing for all but 2 tests

Lab differences - CO₂



- Lab B has significantly lower CO₂ (both intake and exhaust) than Labs A, D, & G

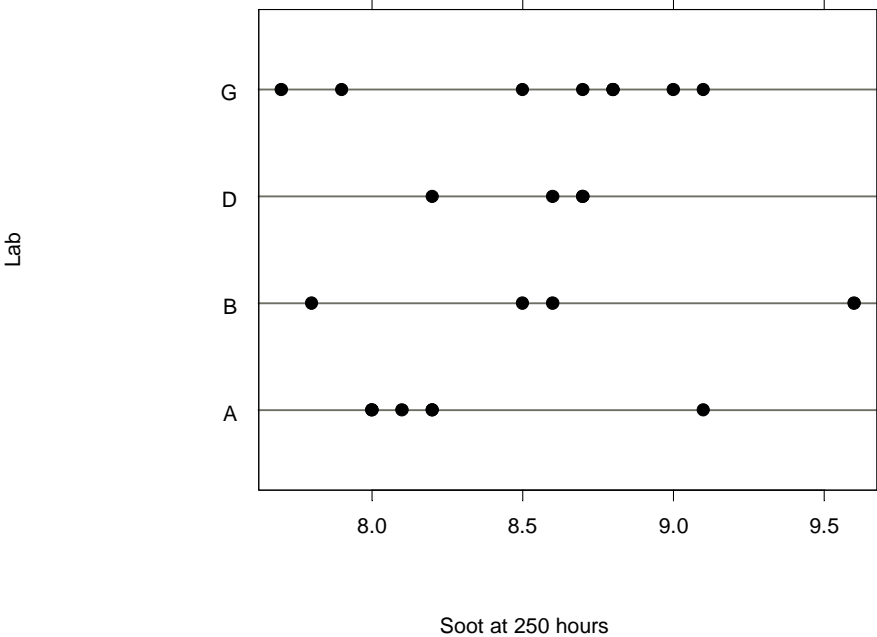
Lab differences - EGR rate



- No significant EGR rate differences by lab

M11EGR

Lab differences - Soot

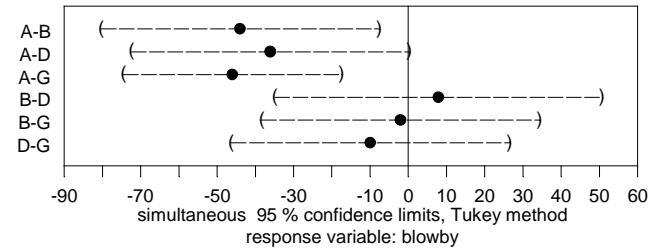
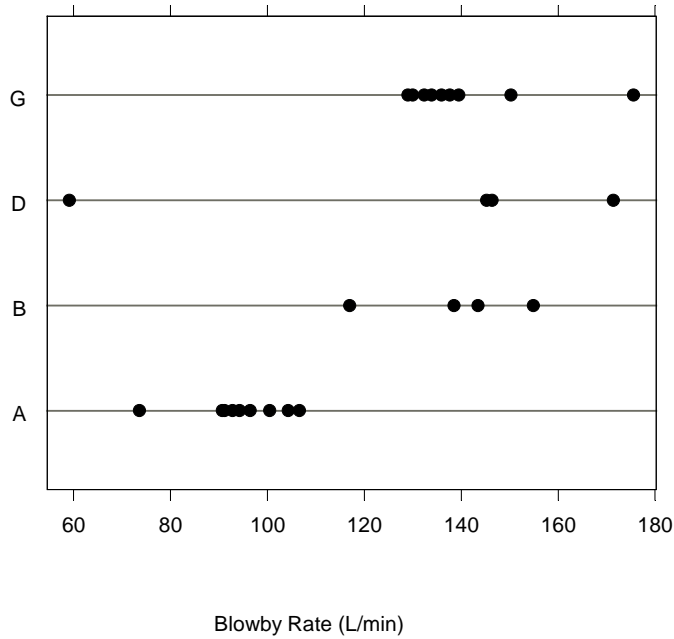


- No significant soot differences by lab

M11EGR

Lab differences - Blowby

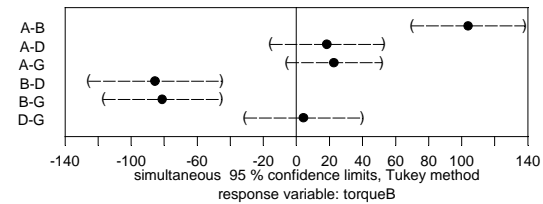
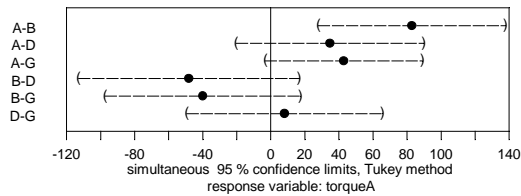
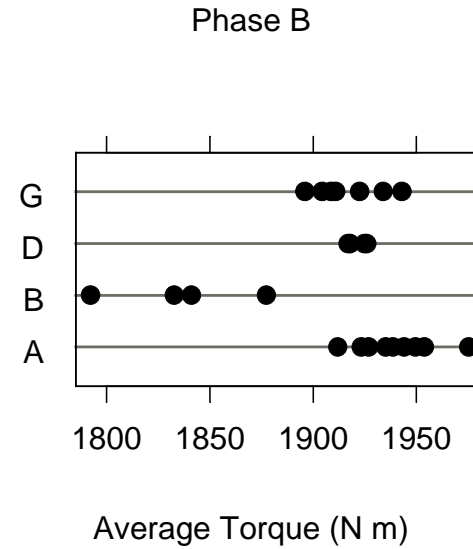
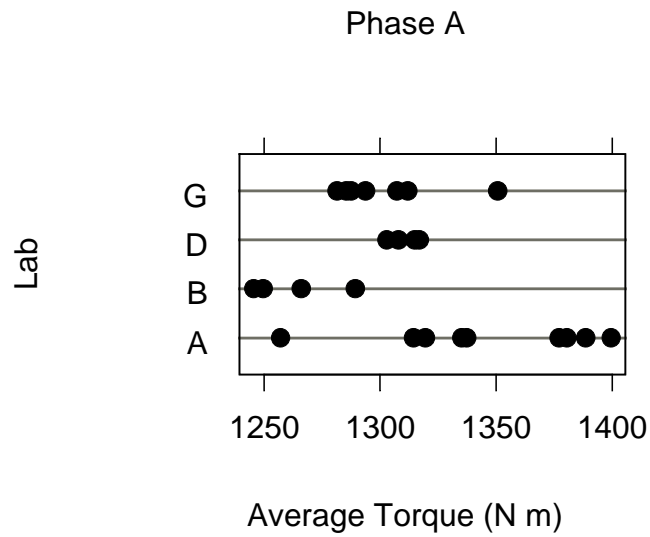
Lab



- Lab A has a significantly lower blowby rate than all other labs

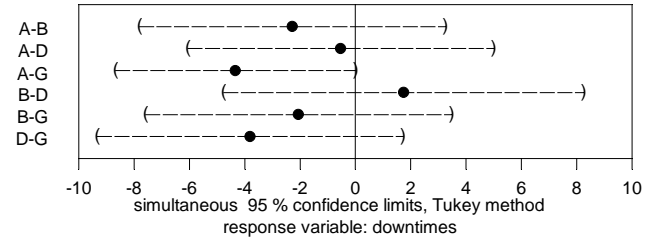
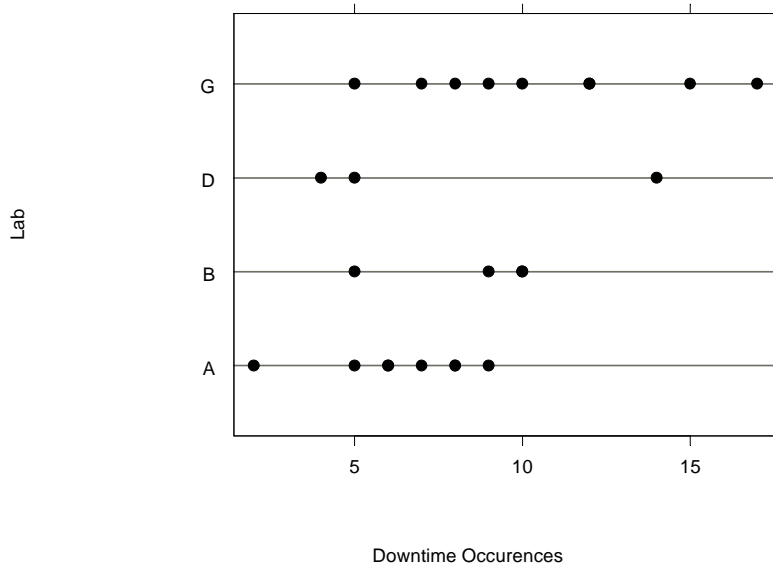
M11EGR

Lab differences - Torque



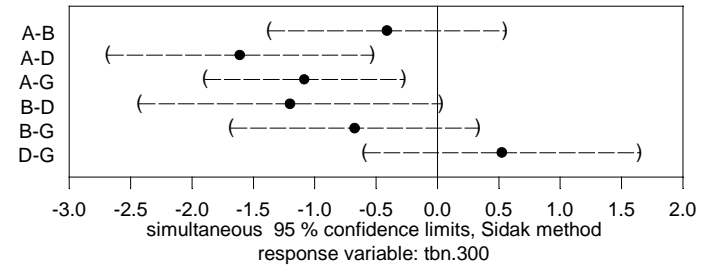
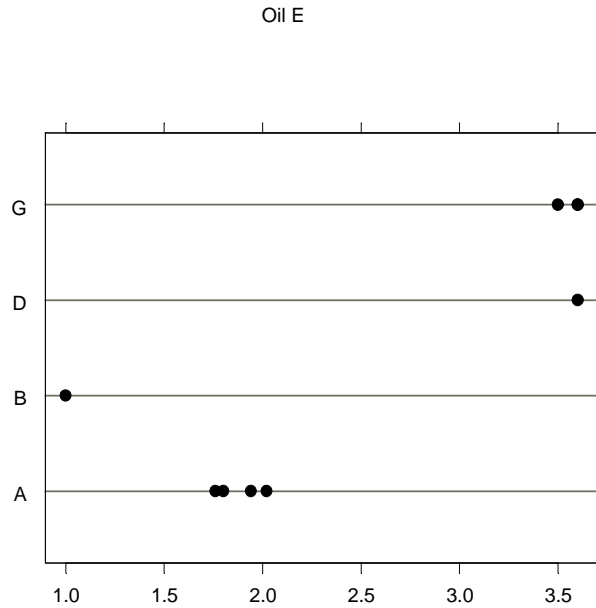
- Lab B runs at significantly lower torque than other labs

Lab differences - Shutdowns



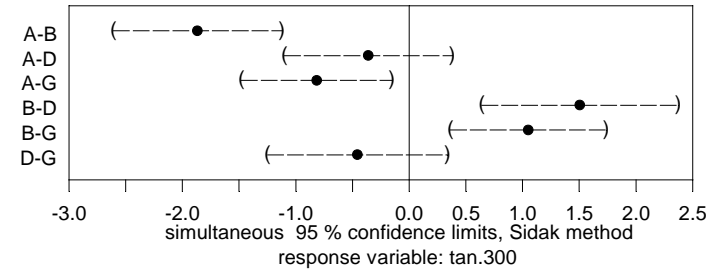
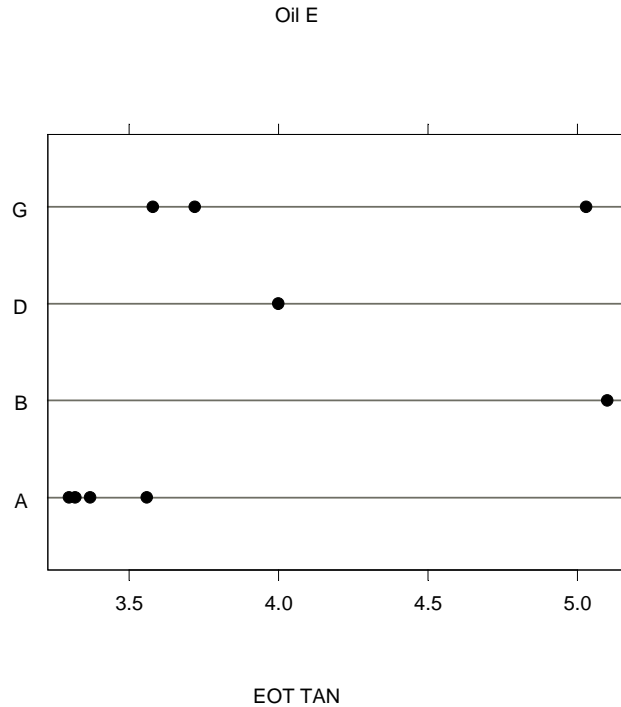
- Lab A has fewer shutdowns than Lab G

Lab differences - EOT TBN



- Lab A has lower EOT TBN than labs D and G
- Lab B appears not to belong to either group

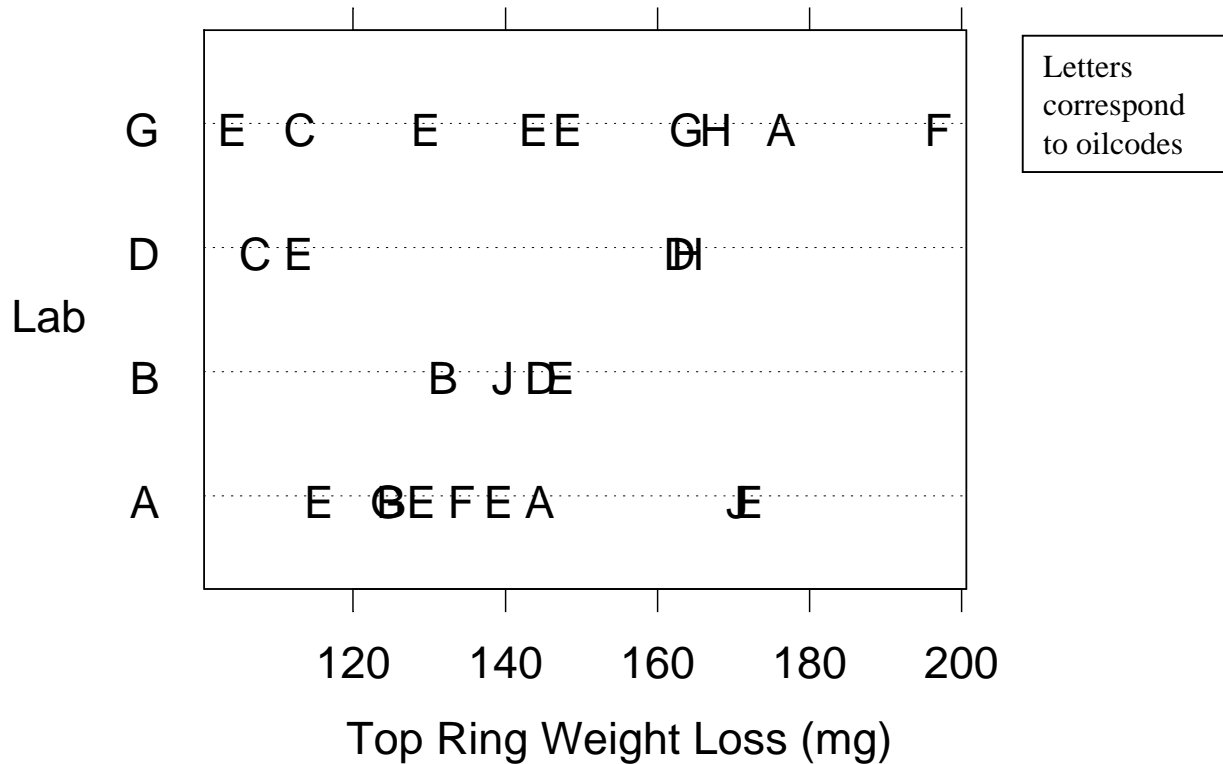
Lab differences - EOT TAN



- Lab B has higher EOT TAN than all other labs
- Lab A has lower EOT TAN than labs B and G

M11EGR

Top Ring Weight Loss

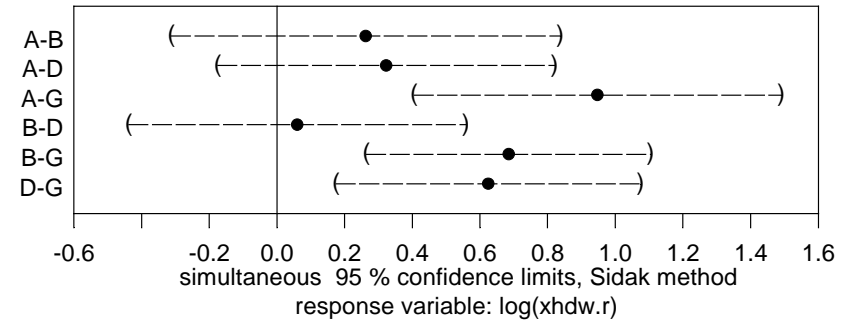
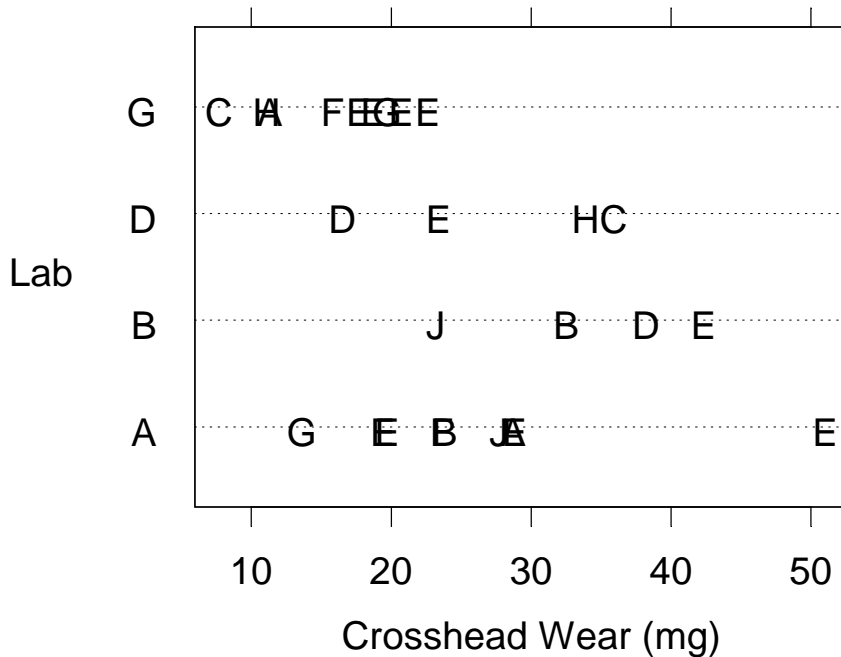


- No significant lab, base stock, or technology effect
- Excluding CMIR 38958 (TRWL=113) makes no difference

Crosshead Wear

- Significant lab effect
- Crosshead wear increases with increasing
 - Average soot (argument for soot correction)
 - Blowby rate
- No technology or base stock effect
- Log transform gives a better fit

XHDW - Lab differences



- Lab G has lower crosshead wear than the other labs
- Therefore Labs are combined into two groups: Lab G and Labs A, B, and D
- CMIR 38958 (XHDW = 7.7) and CMIR 38932 (XHDW = 51) do not effect conclusions

M11EGR

XHDW statistical model

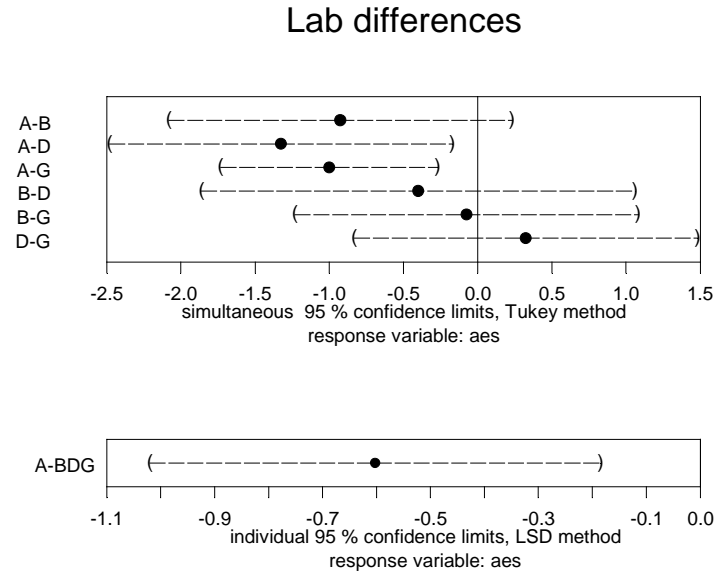
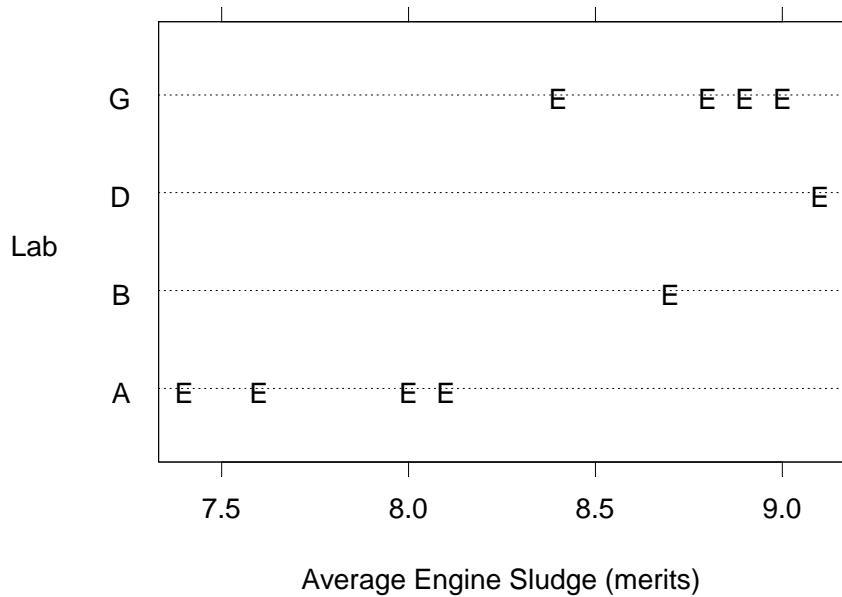
$$XHDW = e^{-0.83 LabG} e^{0.52 avSoot} e^{0.0047 Blowby}$$

- Lab G results in $e^{-0.83} = 0.43$ times as much wear as the other labs
- An increase in average soot by one TGA unit gives $e^{0.52} = 1.7$ times as much wear
- An increase in blowby rate of 10 L/min gives $e^{0.047} = 1.1$ times as much wear

Average Engine Sludge

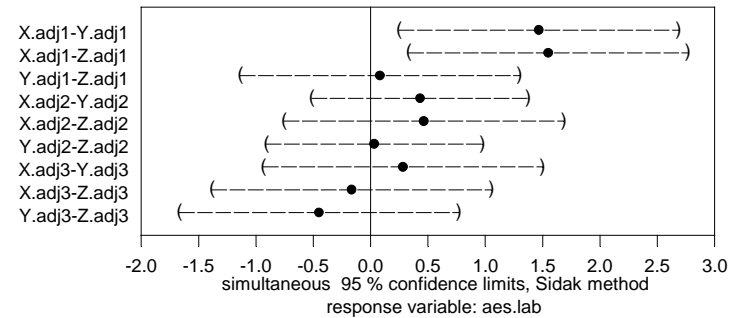
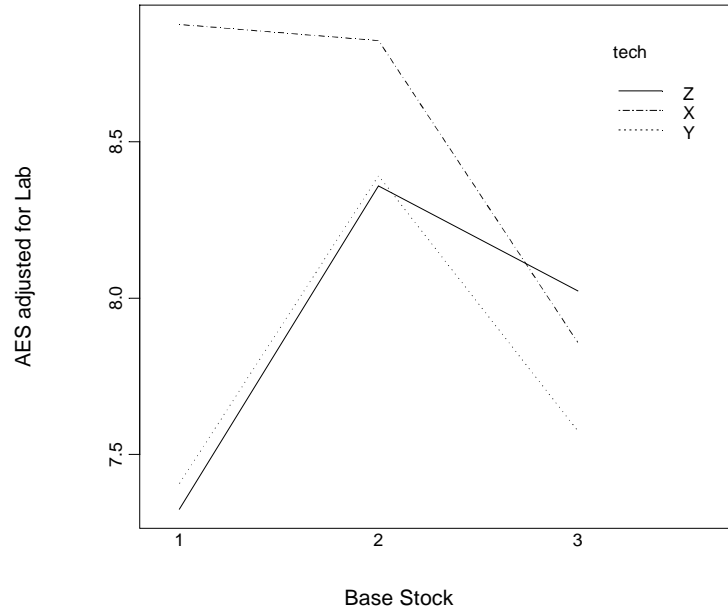
- Significant lab effect
- Two lab populations: A and BDG
- Technology / base stock interaction
- No transformation necessary
- CMIR 38958 is included (AES = 8.5)

AES - Lab differences



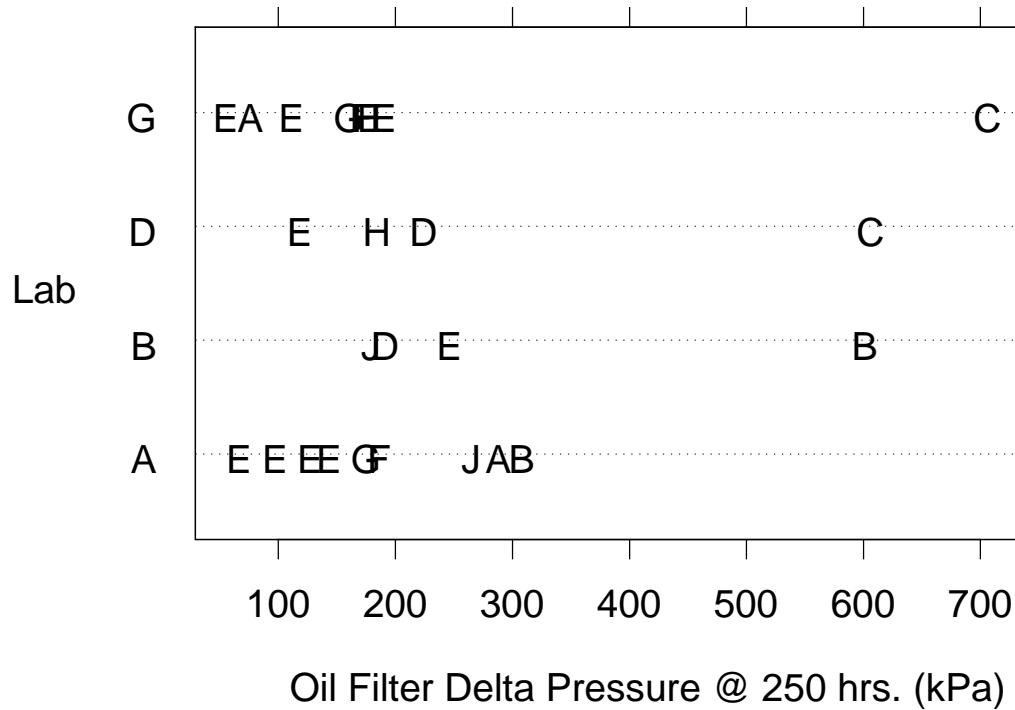
- Two lab populations: A and BDG
- CMIR 38958 is included (AES = 8.5)

AES - Base stock/Technology interaction



- Technology X has better sludge performance than technologies Y and Z, but only in base stock 1
- Base stock 2 is has better sludge performance than base stock 3 for all technologies

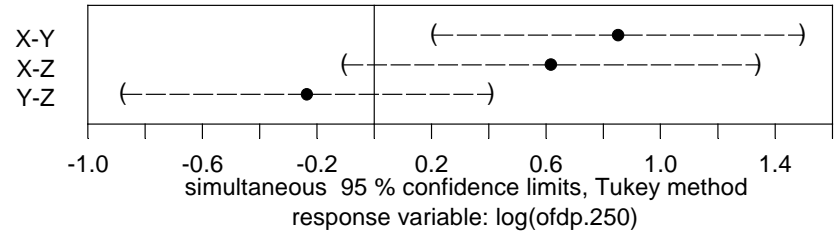
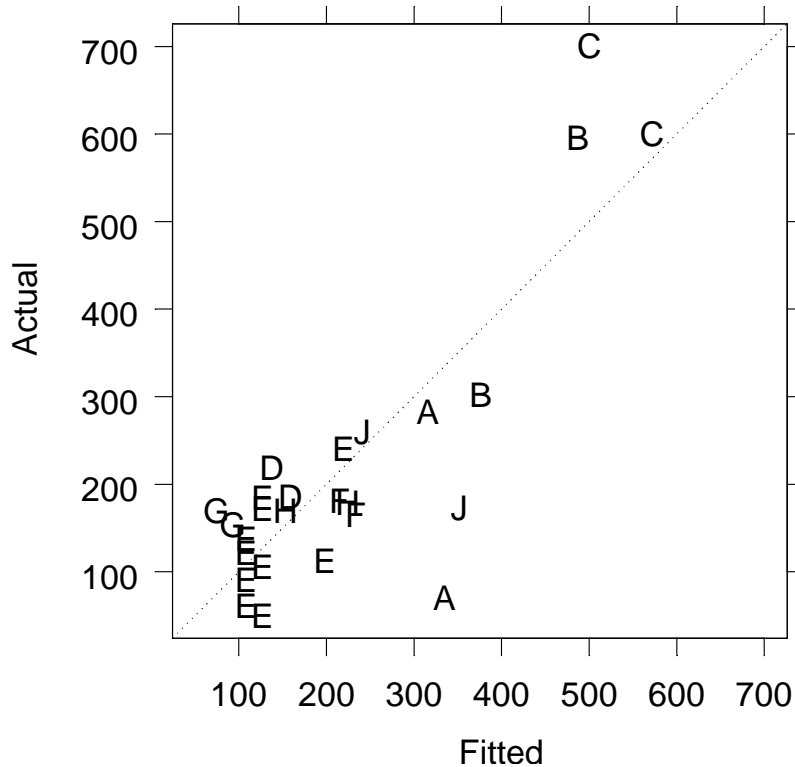
Oil Filter Delta Pressure @ 250 hrs.



- Three extreme values
- This includes CMIR 38958 OFDP = 706 @ 228 hrs.

M11EGR

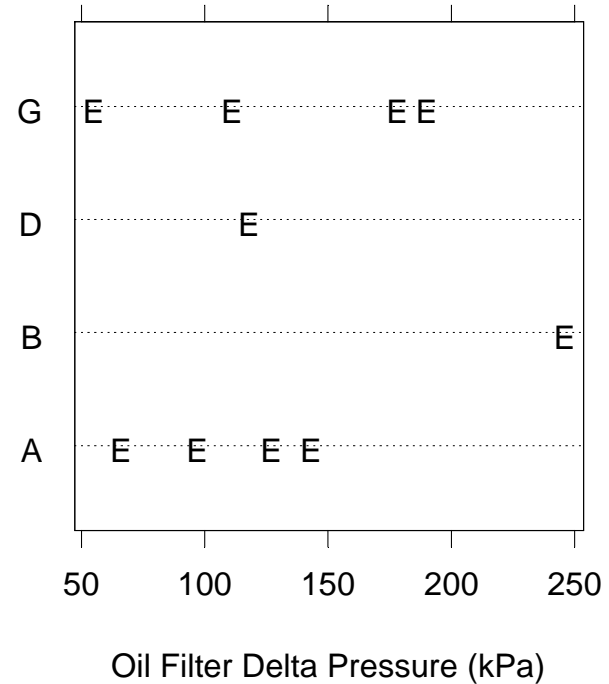
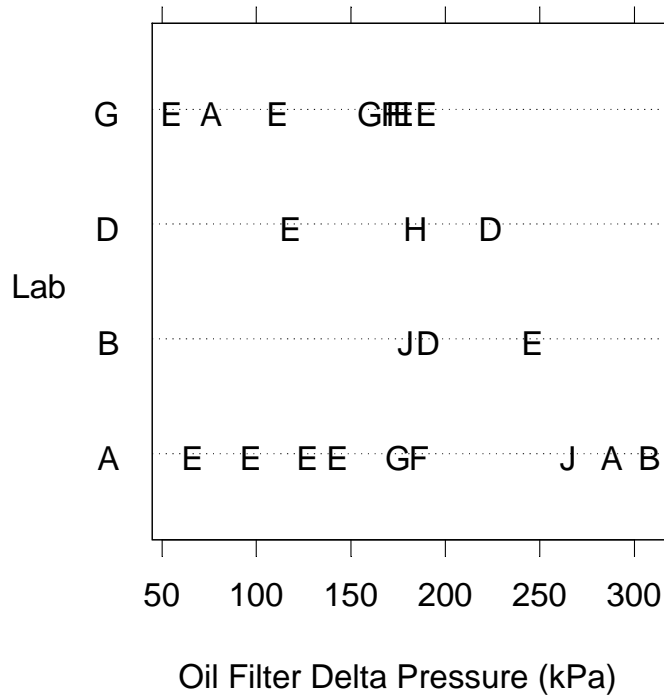
OFDP @ 250 hrs. (including extreme values)



- Technology X has higher OFDP than technologies Y and Z
- No lab or base stock effects
- Diagnostic plots show these points are highly influential

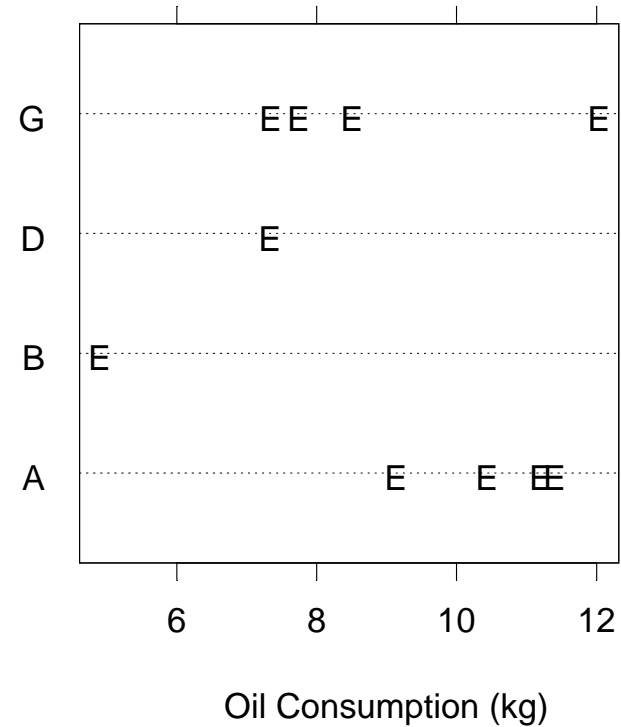
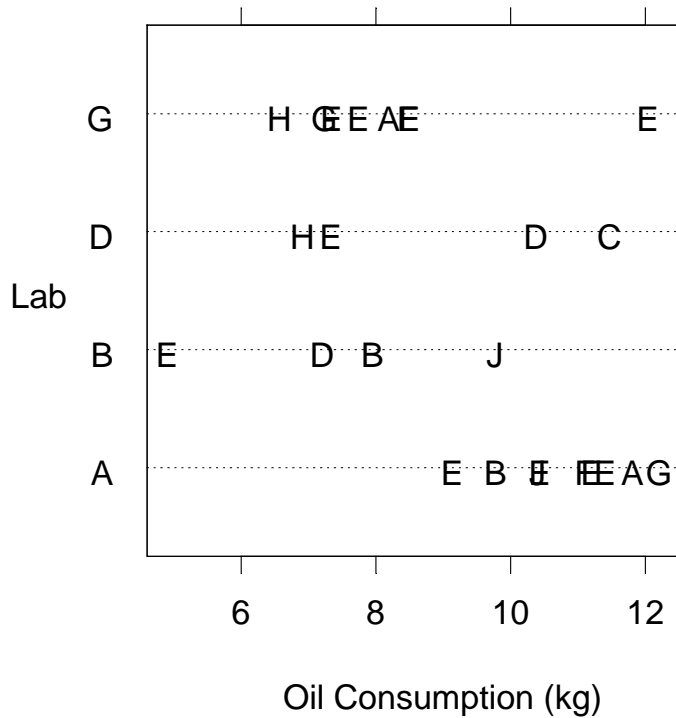
M11EGR

OFPD @ 250 hrs. (excluding extreme values)

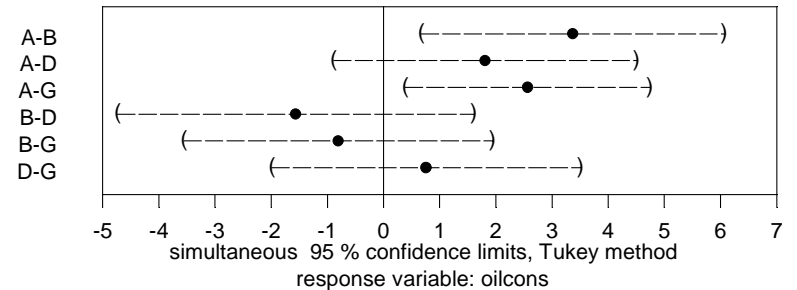


- No significant lab differences
- No significant base stock or technology effects
- However all information on oil C (Technology X in Base stock 3) is missing

Oil Consumption

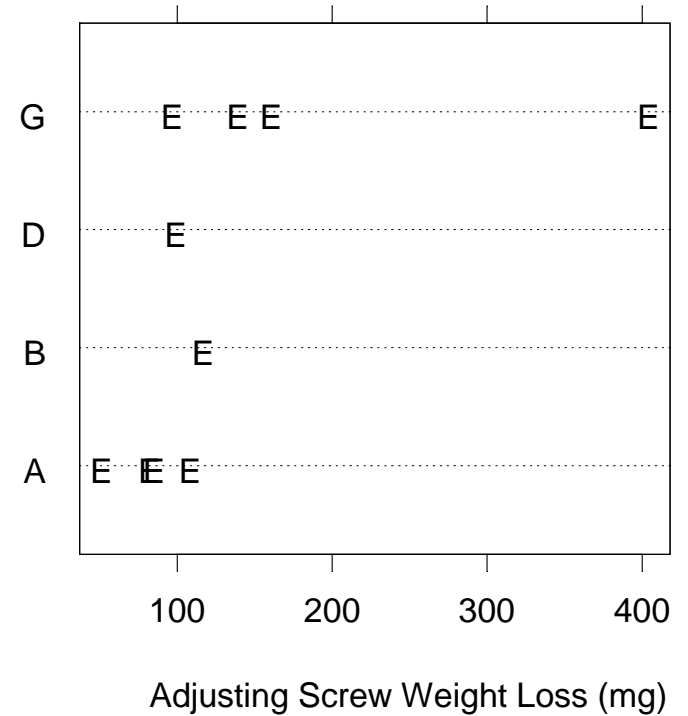
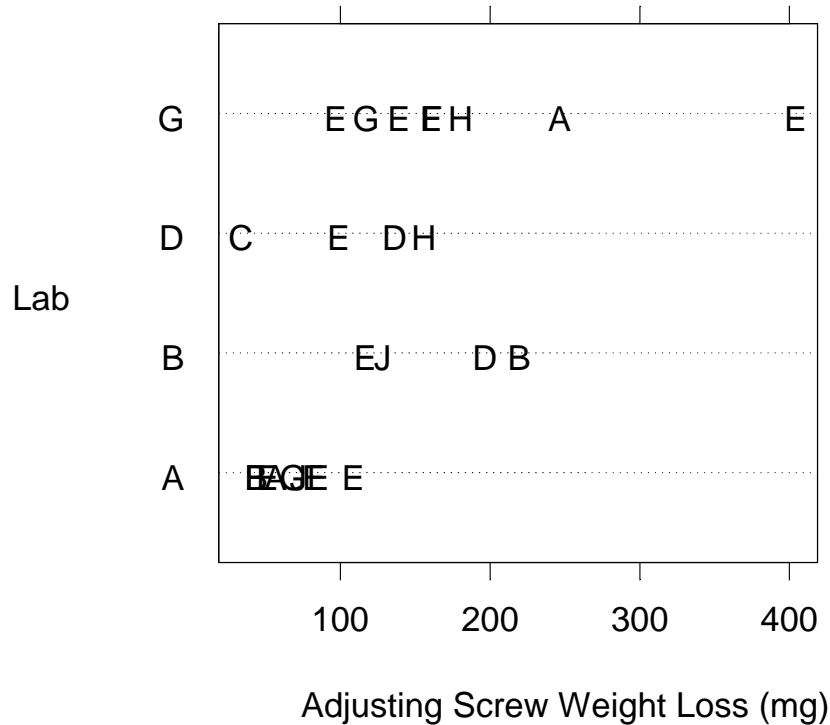


- Lab A has higher oil consumption than the other labs
- No technology or base stock effects

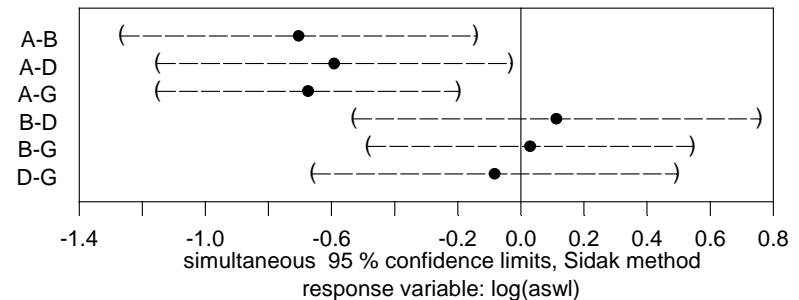


M11EGR

Adjusting Screw Weight Loss



- Lab A has lower ASWL than the other labs
- Technology and Base stock are not significant
- Log transform improves fit
- Excluding CMIR 38958 (ASWL = NA) & CMIR 38929 (ASWL = 404)



M11EGR

Precision estimates

Precision estimates

Parameter	AES	TRWL	XHDW	ASWL	OC	OFDP
Mean	8.40	134	26	134	9.0	133
Stand sd	0.36	24	12	97	1.6	36
Total sd	0.60	24	12	100	2.3	58
Repeatability	1.01	67	34	272	4.5	101
Reproduciblty	1.68	67	34	280	6.4	162
Coef Var (%)	7.14	18	46	75	26	44

- All on oil E because only oil E had repeat runs in a lab

Parameter Correlations

TRWL	0.14	-0.10	-0.11	0.37	-0.31
-0.09	XHDW	-0.05	0.20	-0.16	-0.33
-0.10	-0.22	AES	-0.01	-0.01	-0.08
-0.22	0.34	-0.08	OFDP	-0.42	0.07
0.21	-0.13	0.31	-0.21	ASWL	-0.24
-0.35	-0.13	-0.30	0.03	-0.21	OC

- The upper triangle shows the partial (adjusted) correlations
- The lower triangle is the raw (unadjusted) correlations
- No significant correlations among the parameters (using 0.85 as the significance criterion)