

Ford 6.7 VWT

Fuel type discussion and Reference Test Data Review



Agenda

- Fuels task force recap
- Fuel sample comparison
- Reference oil results analysis (PCI0 vs D975)
- Statistical Analysis

Ford 6.7 Fuels Taskforce

- Created in 2020 and tasked to identify what requirements should apply to a fuel used for the Ford 6.7 test.
 - Involved all same companies as the Ford 6.7 development group
 - Met over a year to discuss the goal, review data, agree on preliminary target ranges/wording and complete a fuel type determination.
- Outcomes:
 - A preliminary fuel specification bracket was generated and agreed upon which would encompass the ability to use non-bio, non-winter D975 ULSD with a few other limiting parameters (of which PC10 qualifies) for the Ford 6.7 Test.
 - Procedure was updated to include Ford 6.7 D975 and the fuel spec was posted to the TMC site.

Ford 6.7 Allowable Fuels: PC-10 & Ford Test D975

- The below information lives on the TMC site with other fuel specifications

PC-10 Fuel Specification

Measurement	Units	ASTM Test Method	Spec
Distillation		D86	
Initial Boiling Point	°C		report
5% volume	°C		report
10% Volume	°C		report
20% volume	°C		report
30% volume	°C		report
40% volume	°C		report
50% Volume	°C		report
60% volume	°C		report
70% volume	°C		report
80% volume	°C		report
90% volume	°C		293-332
95% volume	°C		report
end boiling point	°C		report
loss	ml		report
residue	ml		report
API Gravity	°API	D4052	34.0-37.0
Cetane Index	unitless	D4737	report
Cetane Number	unitless	D613	43-47
Specific Gravity		D4052	0.8400-0.8550
Ramsbottom Carbon Residue on 10% Distillation	%	D524	max 0.350
Net Heating Value	MJ/kg	D4809	report
Composition, aromatics	mass %	D5186	28.0 - 33.5
Ash	mass %	D482	max 0.005
Flash Point	°C	D93	min 54
Pour Point	°C	D97	max -18
Cloud Point	°C	D2500	report
Strong Acid Number	mg KOH/g	D974	max 0.00
Total Acid Number	mg KOH/g	D974	max 0.05
Accelerated Stability	mg/100 mL	D2274	max 1.5

Revised 4-16-2019

Measurement	Units	ASTM Test Method	Spec
Copper Corrosion	classification	D130	max 1
Kinematic Viscosity	cSt	D445	2.0-2.6
Water and Sediment	volume %	D2709	max 0.05
Total Sulfur	mg/kg	D7039	7-15
Particulate matter	mg/L	D6217	report
hydrogen	wt %	D3343	report
carbon	wt %	D3343	report
Lubricity (HFRR)	µm	D6079	max 460
Bio fuel content	%	D7371	max 0.5%

ASTM D975 Fuel Limits for Ford 6.7L

Measurement	Units	ASTM Test Method	Spec
Distillation		D86	
Initial Boiling Point	°C		report
5% volume	°C		report
10% Volume	°C		report
20% volume	°C		report
30% volume	°C		report
40% volume	°C		report
50% Volume	°C		report
60% volume	°C		report
70% volume	°C		report
80% volume	°C		report
90% volume	°C		282-338
95% volume	°C		report
end boiling point	°C		report
loss	ml		report
residue	ml		report
API Gravity	°API	D4052	30.0-45.0
Cetane Index	unitless	D4737	report
Cetane Number	unitless	D613	40-63
Specific Gravity		D4052	report
Ramsbottom Carbon Residue on 10% Distillation	%	D524	max 0.350
Net Heating Value	MJ/kg	D4809	report
Composition, aromatics	mass %	D5186	13 - 43
Ash	mass %	D482	max 0.01
Flash Point	°C	D93	min 52
Pour Point	°C	D97	report
Cloud Point	°C	D2500	report
Strong Acid Number	mg KOH/g	D974	report
Total Acid Number	mg KOH/g	D974	report
Accelerated Stability	mg/100 mL	D2274	report
Copper Corrosion	classification	D130	max 1

Revised 5-13-2019

Measurement	Units	ASTM Test Method	Spec
Kinematic Viscosity	cSt	D445	1.9-2.9
Water and Sediment	volume %	D2709	max 0.05
Total Sulfur	mg/kg	D7039	max 15
Particulate matter	mg/L	D6217	report
hydrogen	wt %	D3343	report
carbon	wt %	D3343	report
Lubricity (HFRR)	µm	D6079	max 520
Bio fuel content	%	D7371	max 0.5%

- Fuel is to be purchased as a Summer Blend. No waivers from ASTM D975 Table 1 for Winter Blends are allowed for fuel for this test
- For a test that does not use a batched fuel, such as PC-10, measure D240, D445, D86, D4052, D613, D5186, D7371 and D7039 on the start of test sample and report values in the appropriate test forms



ULSD Fuel Property Ranges – Alternate Fuel Bracket

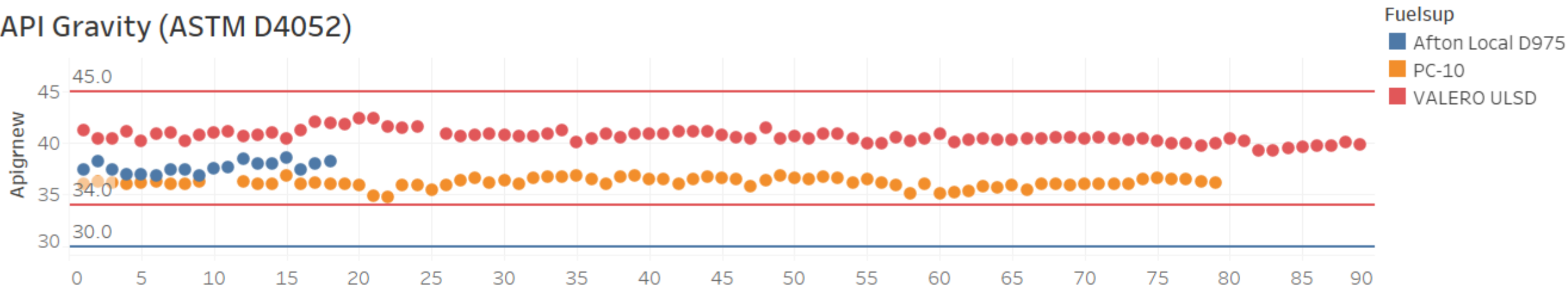
- ULSD Fuel Restrictions: B0, Summer Grade. **These Bracket fuels have been tested within prove out.**
- Some fuel sources below would not be covered by this bracket
- Highlighted parameters sit outside of the PC-10 current specification thus widening the fuel specification

Property	<u>TXLed</u> (Bracket Fuel 1)	PC-10 (Bracket Fuel 2)	Ford Source	Afton Source
API Gravity	39.5-43.0	34.0-37.0	32.2	37.8
KV40, <u>cSt</u>	2.2-2.9	2.0-2.6	2.7	2.4
Cetane number	53-63	43-47	40	47
Aromaticity, percent volume	12.0-18.0	28.0-33.5	40.9	20.3
90% Distillation, Deg C	313-335	293-332	320	326

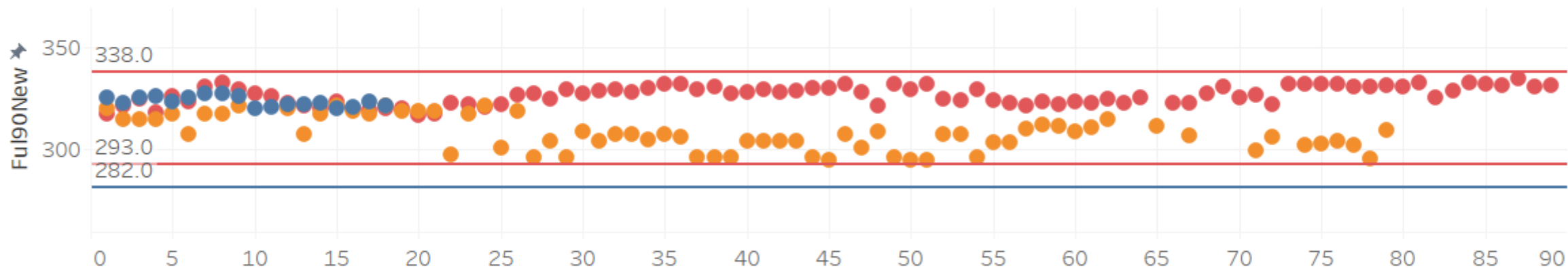
Parameter	D975 Spec	PC-10	Target Range (Full Bracket)	Target Range (<u>TXLed</u> – PC-10)
API Gravity		34.0-37.0	30.0-45.0	34.0- 45.0
KV40, <u>cSt</u>	1.9 – 4.1	2.0-2.6	1.9-2.9	1.9-2.9
Cetane number	40 min	43-47	40-63	43- 63
Aromaticity, percent volume	35 max or 40 Cetane Index	28.0-33.5	12.0-43.0	12.0-33.5
90% Distillation, Deg C	282 - 338	293-332	282-338	293- 338

*Selected target range in Aug. 2020

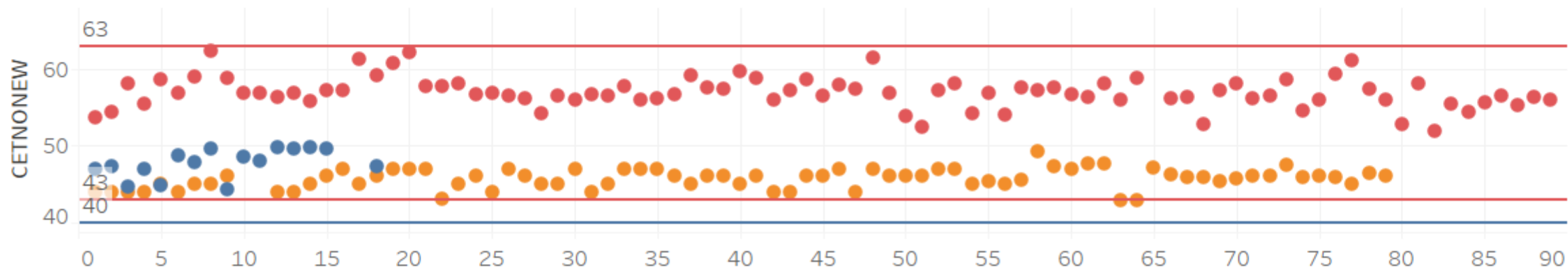
API Gravity (ASTM D4052)



90% Distillation, Deg C (ASTM D86)



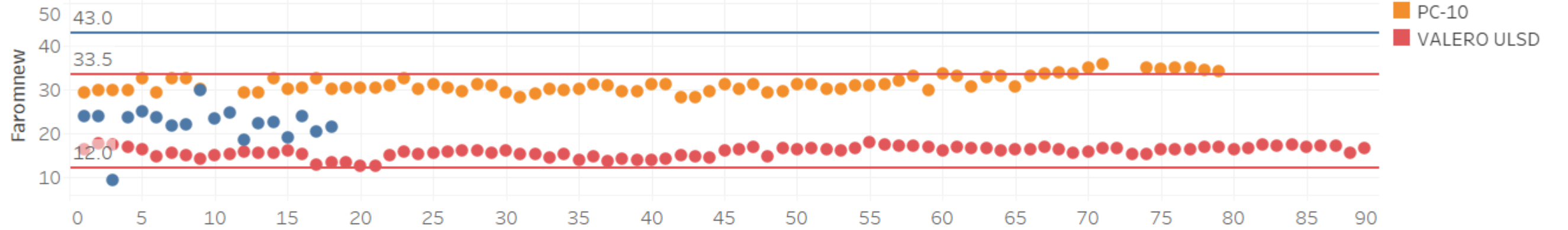
Cetane Number (ASTM D613)



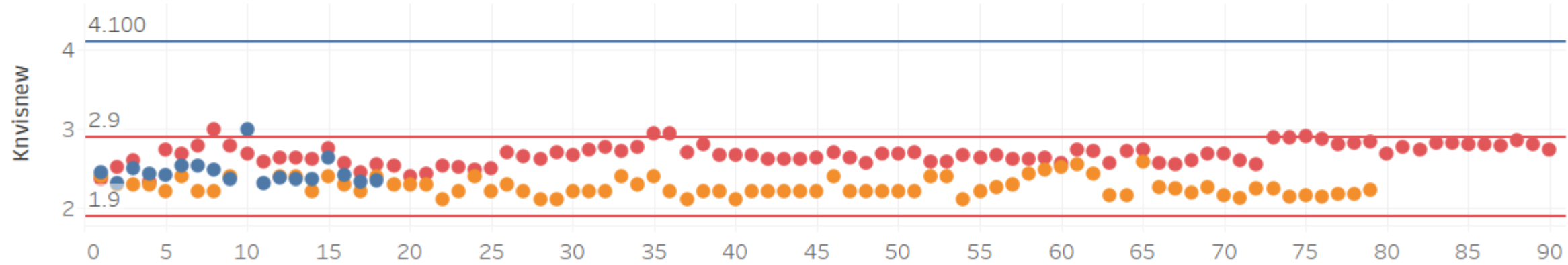
Target Range (Full Bracket)	Target Range (TXLed – PC-10)
30.0-45.0	34.0-45.0
1.9-2.9	1.9-2.9
40-63	43-63
12.0-43.0	12.0-33.5
282-338	293-338



Aromaticity, % Volume (ASTM D5186)



KV40 cSt (ASTM D445)



Parameter	D975 Spec	PC-10	Target Range (Full Bracket)	Target Range (TXLed – PC-10)
API Gravity		34.0-37.0	30.0-45.0	34.0- 45.0
KV40, <u>cSt</u>	1.9 – 4.1	2.0-2.6	1.9-2.9	1.9-2.9
Cetane number	40 min	43-47	40-63	43- 63
Aromaticity, percent volume	35 max or 40 Cetane Index	28.0-33.5	12.0-43.0	12.0-33.5
90% Distillation, Deg C	282 - 338	293-332	282-338	293- 338

*Selected target range in Aug. 2020

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Reference Results Slides



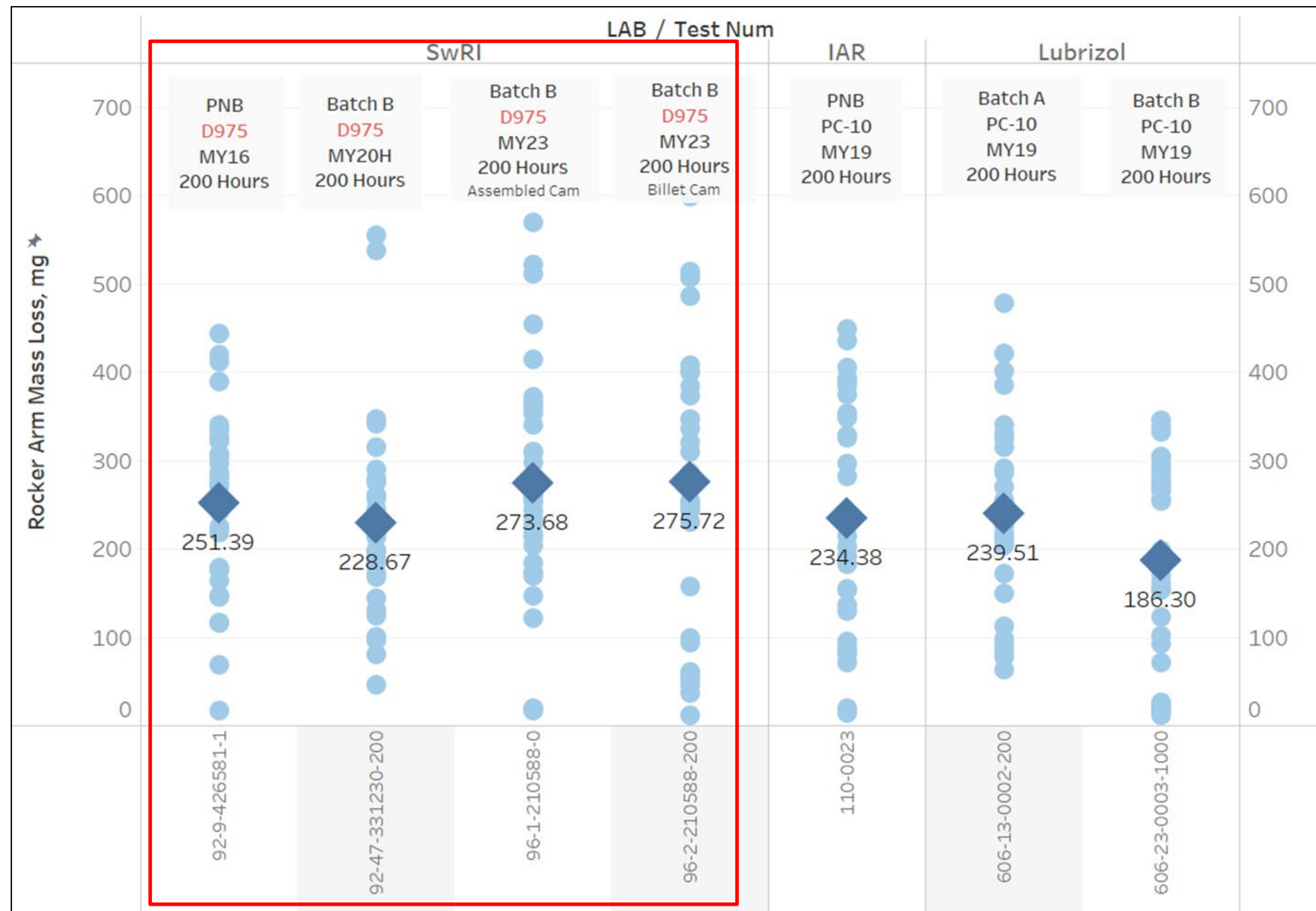
LWO (FVTW2) Reference Tests – 200 Hour Tests

- All Tests are 200 Hours
- SwRI Utilized D975 Fuel for all tests
 - Consistent results on D975 fuel despite MY and Batch Changes.
- IAR/LZ testing with PC-10
- No difference between D975 fuel and PC-10 fuel.



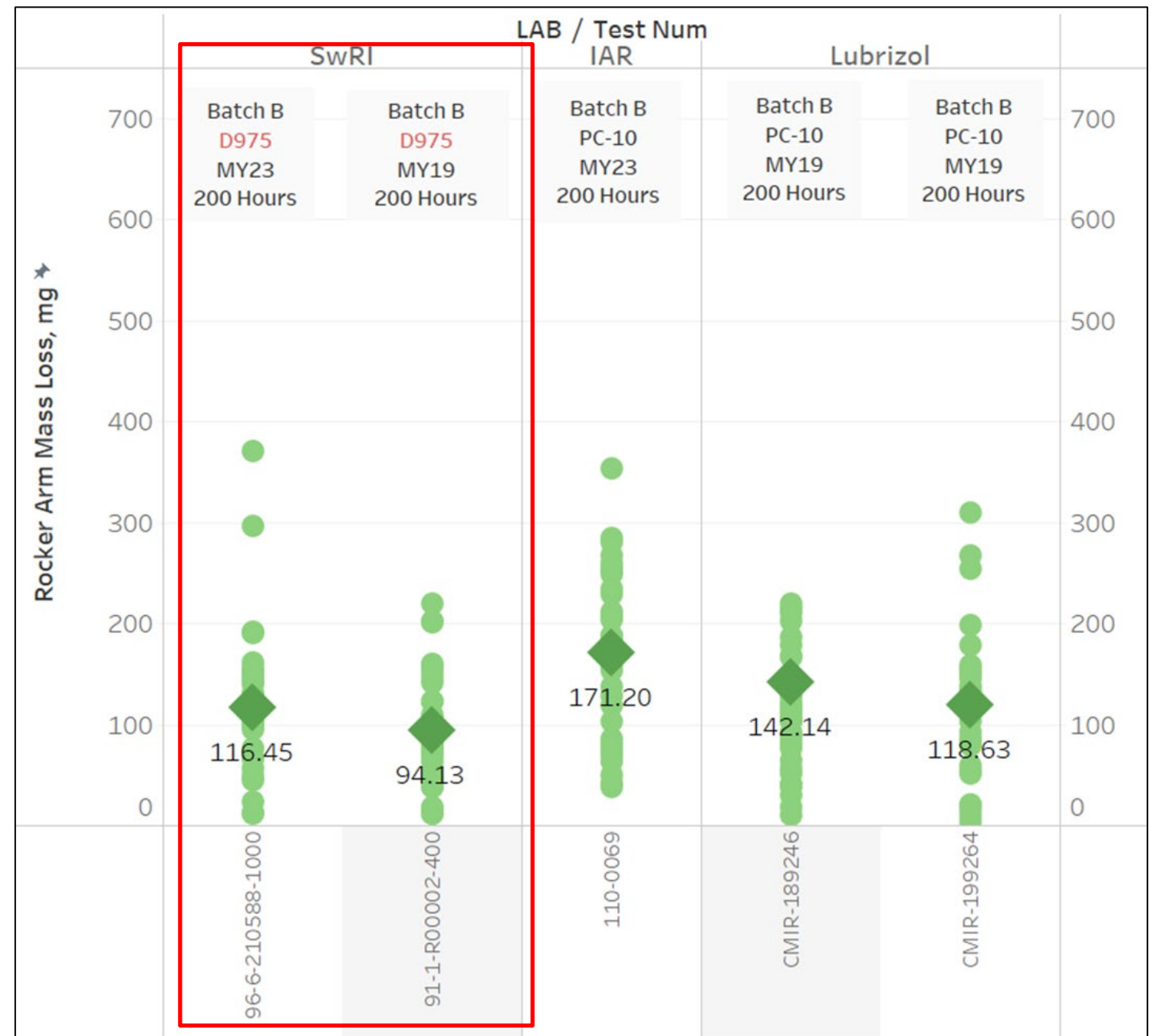
HWO (FVTWI) Reference Tests – 200 Hour Tests

- All tests are 200 Hours
- Higher variability observed on HWO at all labs
- SwRI Utilized D975 Fuel for all tests
- IAR/LZ testing with PC-10

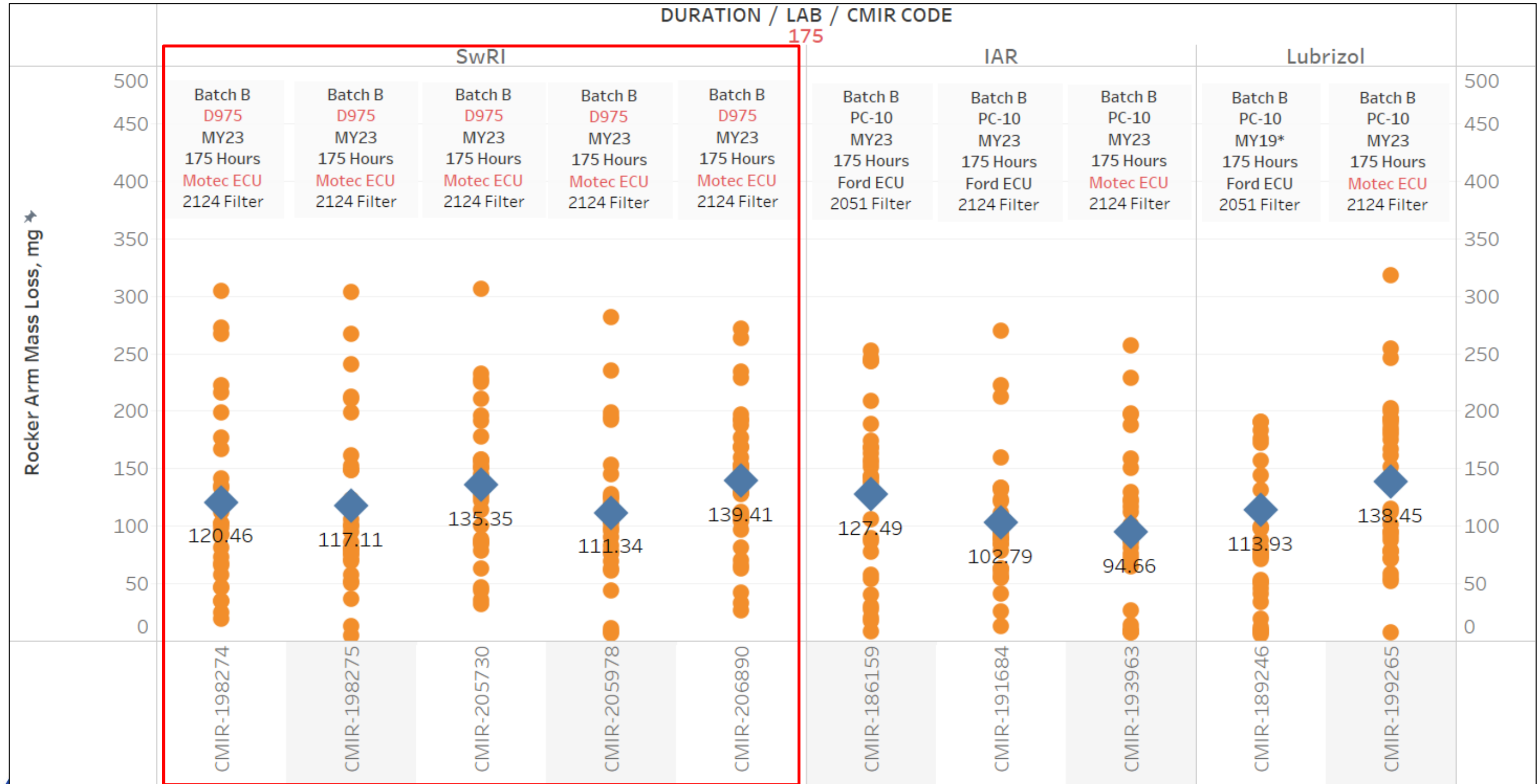


BLO (FVTW3) Reference Tests, 200 Hour Tests

- All tests are 200 Hours
- SwRI Utilized D975 Fuel for all tests
- IAR/LZ testing with PC-10
- Data set issues
 - IAR Test – May not be usable (Oil filter issue?)
 - LZ 142.1 mg run had a >1000 mg data point, if removed average is 109 mg.



BLO (FVTW3 & 3-I) Reference Tests, 175 Hours Only



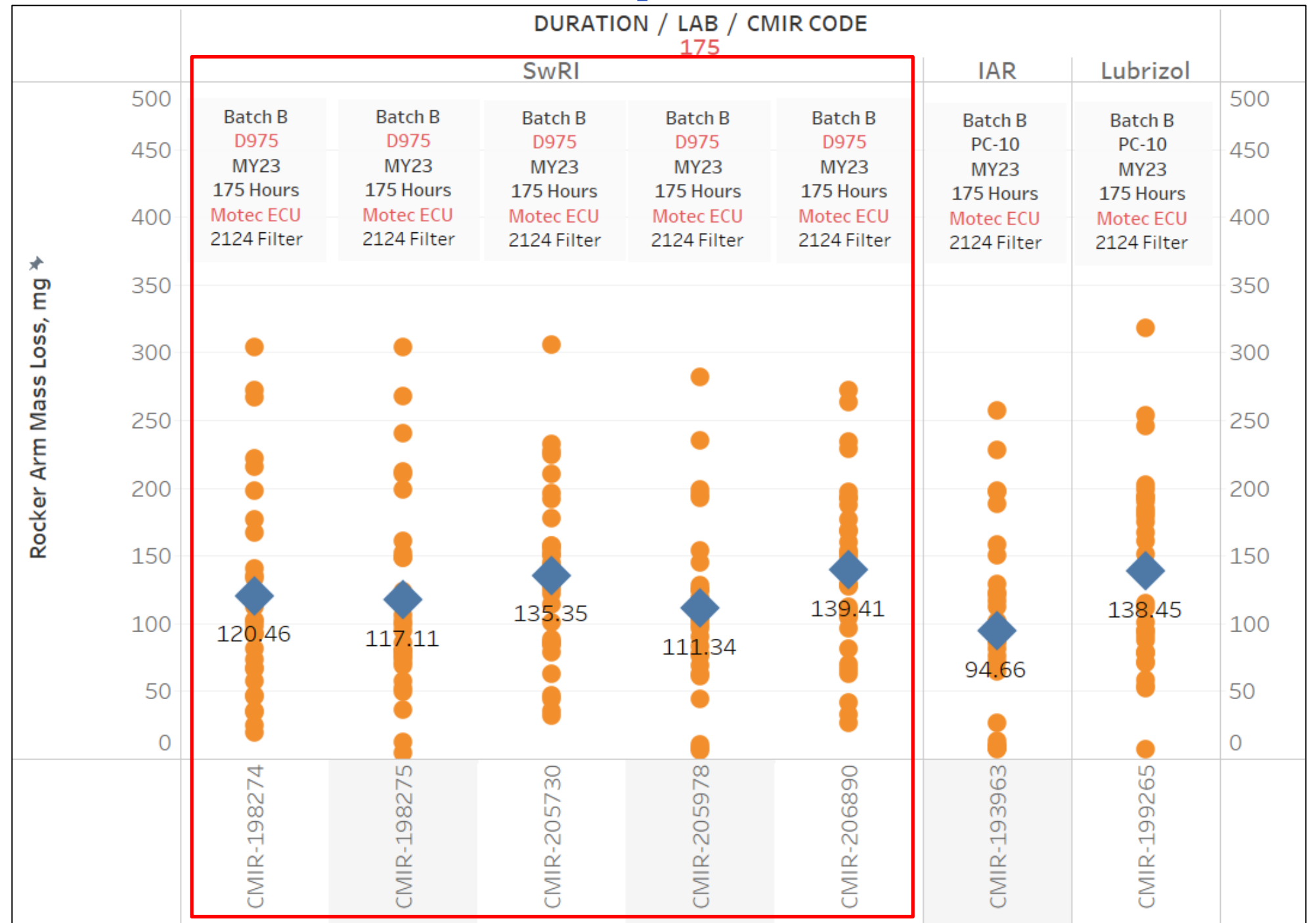
IAR “Severe” results in line with current testing?

- “Severe” tests run by IAR were thought to have been caused by an oil filter issue.
 - Current data shows that their results may have been in line with current results?

Industry Borderline Oil Reference Testing										
	Group 1 (On Target)							Group 2 (Severe of Target)		
200-hour Rocker Mass Loss (mg)	113.0**	132	116.6	94	116.5	N/A	N/A	203	171	153.7
175-hour Rocker Mass Loss (mg)	85**	N/A	N/A	N/A	N/A	102.8	137.9	N/A	127.5	134.1
Camshaft MY	2019 AF	2019 AF	2019 AG	2019 AG	2023 Billet	2023 Assembled	2019 AG	2023 Billet	2023 Billet	2023 Assembled
Engine MY	2019	2019	2020	2019	2023	2023	2023	2023	2023	2023
Test Lab	Lab B	Lab A	Lab G	Lab A	Lab A	Lab G	Lab G	Lab G	Lab G	Lab G
ECU	Ford	Ford	Standalone	Ford	Ford	Ford	Standalone	Ford	Ford	Standalone
Oil Filter	2051	2051	2051	2124	2124	2124	2051	2051	2051	2051

BLO Reference tests run on current procedure

- All 175 Hour Tests
- MY23 Engine & Motec ECU
- SwRI Utilized D975 Fuel for all tests
- IAR/LZ testing with PC-10



Statistical Analysis on data set

Determine if the data suggests there may be a difference in the results using D975 fuel vs. PC10 Fuel.

Two ways to look for differences

1. Using all data – Any factors that may have changed results over time (MY, batch, etc) are included in the model to not mask potential fuel differences.
2. Using only the most recent data with the current procedure

Either way Lab A is the only lab with D975 therefore any potential fuel differences would be included in the entire estimate of the lab as a whole.

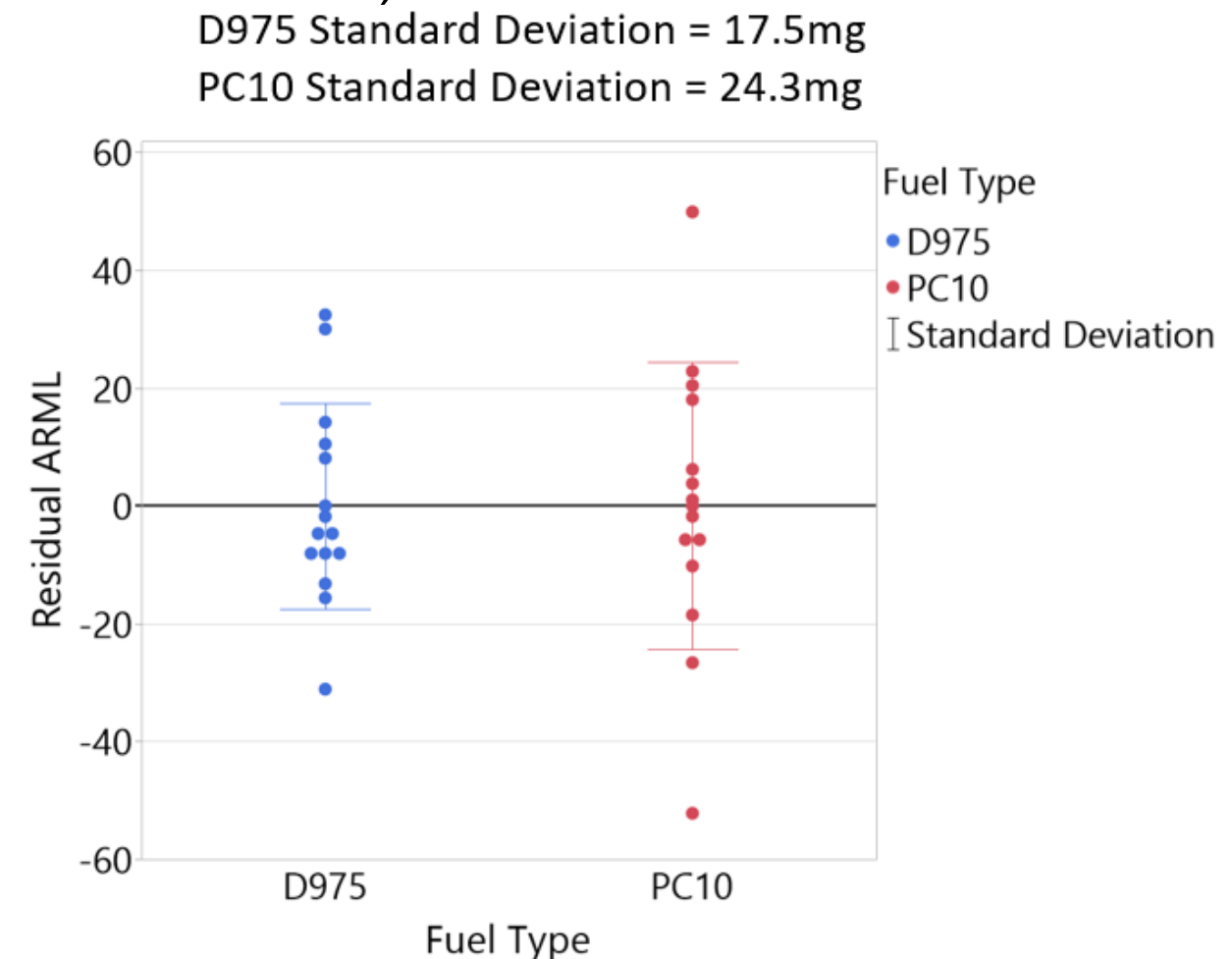
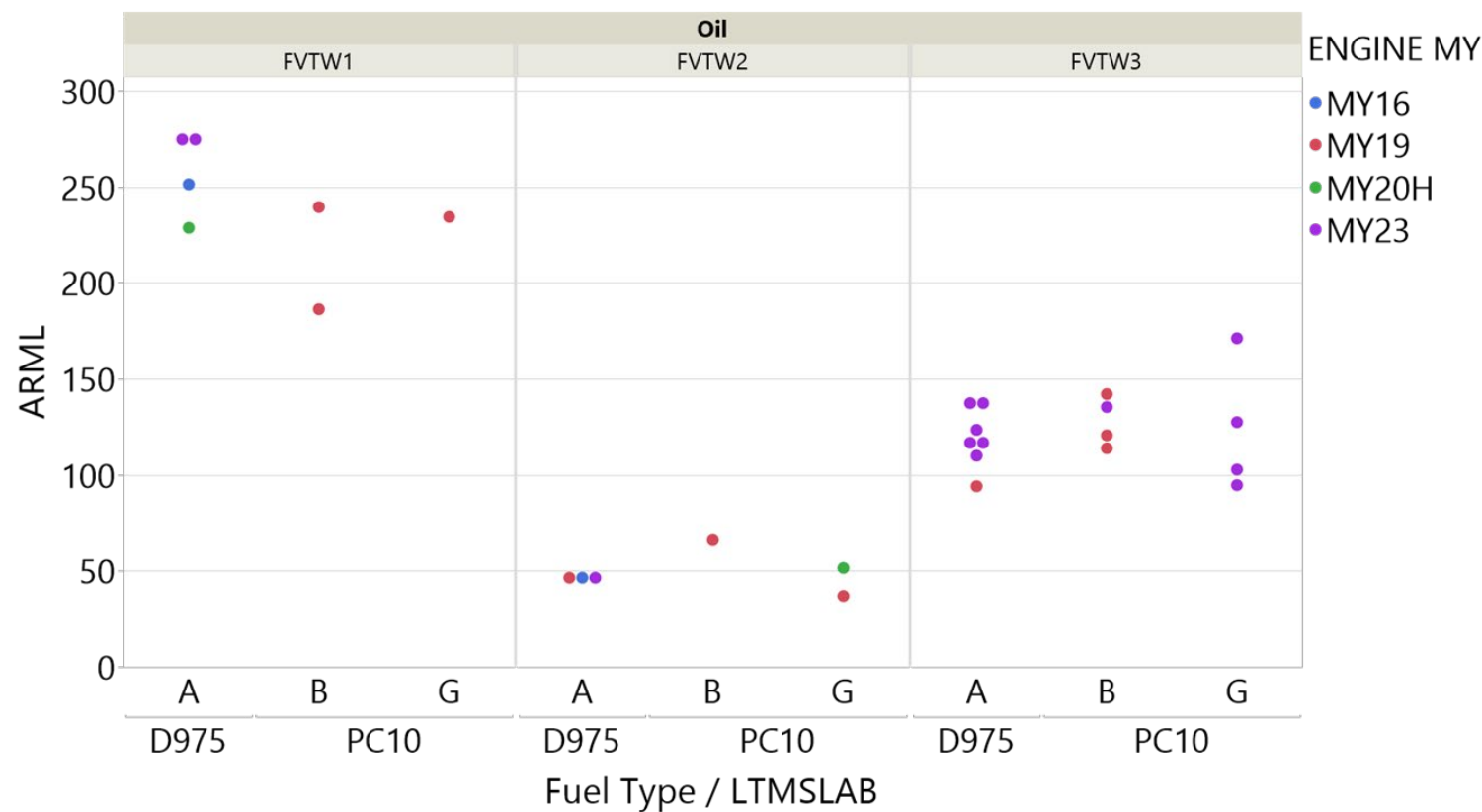
28 total tests:

- 3 labs (A, B, and G)
- Two Fuels (D975 and PC10)
- 3 Fluids (FVTW1 (high wear), FVTV2 (low wear), and FVTV3 (borderline))
- Two test lengths (200 hour and 175 hour).
- Mixed engine MY and ECU Type

Statistical Analysis on data set

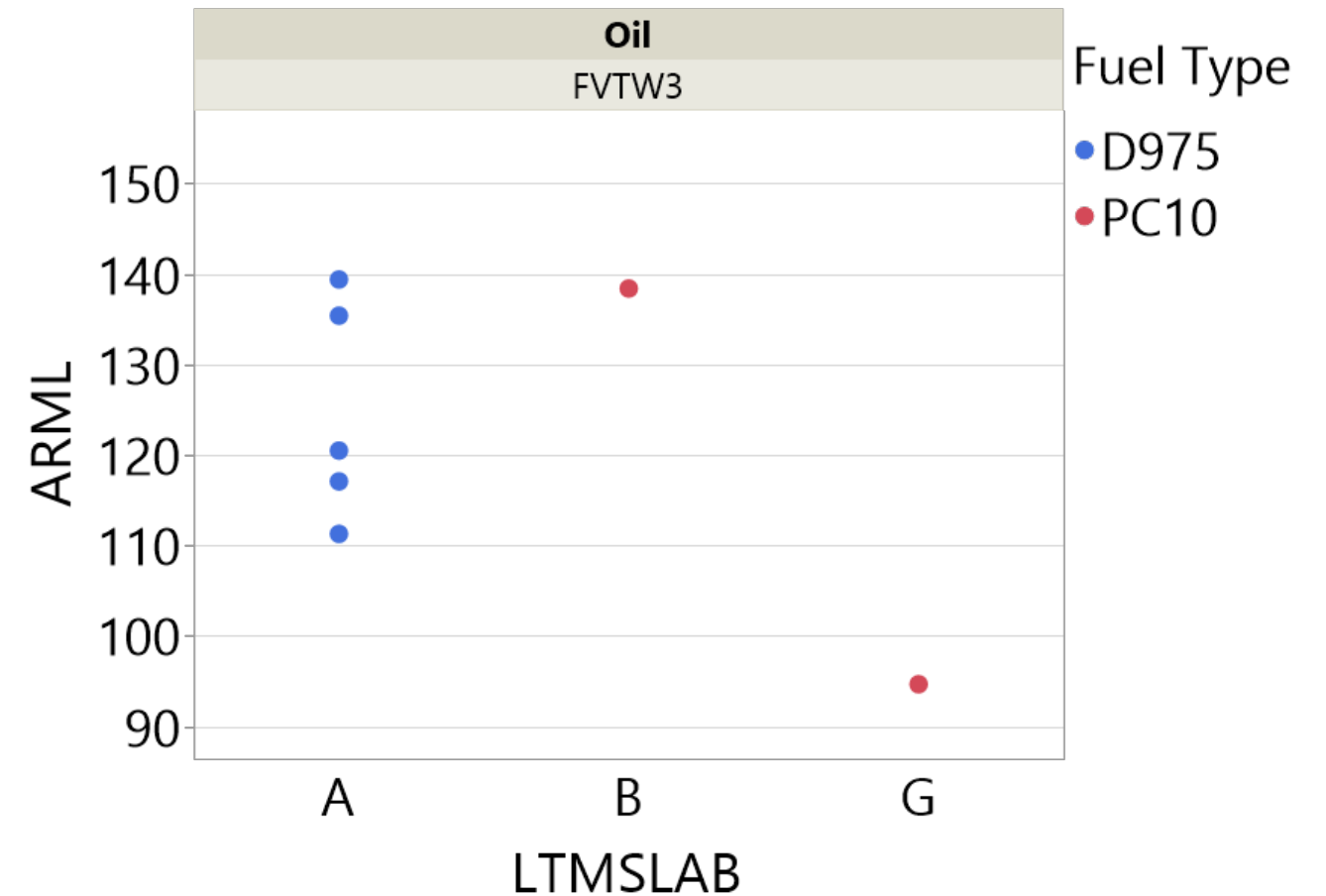
No statistical significance found due to fuel. The data did show a slight significance for the MY23 engine which was likely driven by the large variation in HWO results and limited data set.

Repeatability: Based on residuals from the model which only included variables for oil and lab, the D975 data has a slightly smaller standard deviation (limited data set).



Recent Data – Current procedure only

There is not enough data on the current procedure to draw many conclusions. However, the mean of the D975 data falls in between the other two labs, and based on the previous results, the spread of the data is expected to be similar with additional data.



Final Items

- SwRI stance based on data is that test is not fuel sensitive and test variability overshadows any minor impact fuel may have.
- SwRI suggestion is to proceed with current TMC hosted fuel specs
 - Revisit the aromatics and kv40 range for the D975 specification.
- Let the LTMS system handle any severity differences via the stand severity adjustment.
- Monitor data as additional references are conducted



End

