Cummins Surveillance Panel Teleconference
October 21, 2016
10:30 a.m. EDT
Meeting Minutes

Attendance:
Intertek – Jim Moritz, Mey Dewey
SwRI – Jim McCord, Jose Starling
Afton – Bob Campbell
Lubrizol – Nick Secue, John Ahlborn, Kevin O'Malley
Oronite – Marnix Torreman, Mark Cooper, Jim Rutherford,
Infineum – Elisa Santos, Jim Gutzwiller
TEI – Dan Lanctot
TMC – Sean Moyer
Cummins – Christie Jackson, Ryan Denton
Volvo – Greg Shank

ISM Hardware Status
Kevin O'Malley reviewed the presentation: ***ISM Hardware Batch Change Analysis Oct 2016***

-Kevin pointed out that the soot adjustment was instituted as a balance among the oils that were tested but we currently only test on one reference oil. It's possible that the soot adjustment has changed over time and is also affecting results.

-The cylinder head change lines up with this hardware change and could also be impacting the data.

> -There was discussion about whether labs had to run the timing differently in order to get the same soot using the new cylinder head.
> -All labs indicated that there didn't seem to be any difference between these runs with the new head and previous runs.

Bob Campbell motioned and Jim McCord seconded that labs should be allowed to use the new scalloped cylinder heads going forward as needed but that the old cylinder heads are acceptable for use. The motion passed unanimously

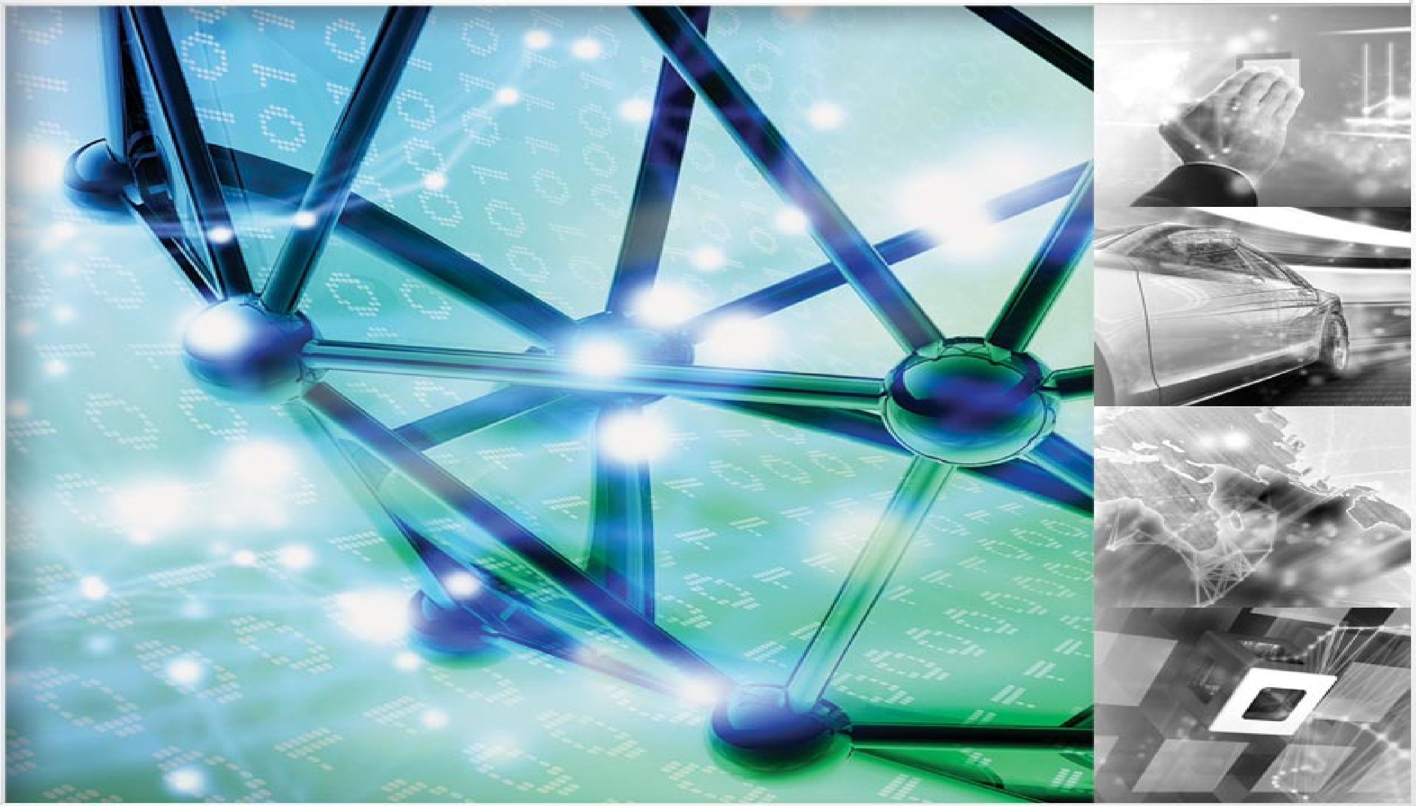
Bob Campbell motioned and Nick Secue seconded that the panel accept all the new hardware and adopt and new correction factor on SAIAS results of adding 0.41 to ln(SAIAS) for pushrod batch C that started at kit # 938. The motion passed unanimously

Labs will resubmit reference test results with the new correction factor and work with the TMC to adjust reference periods accordingly.

Labs will submit suggestions for data dictionary changes to Sean Moyer by October 28th, 2016. Sean will compile the suggestions and send them to the group as a motion.

Ryan Denton discussed a slide detailing the progress of the ISX replacement for the ISM:
ISM replacement test update

The meeting adjourned at 12:10 p.m.



ISM Hardware Batch Change Analysis

Kevin O'Malley
The Lubrizol Corporation

October 2016

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Overview

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- New hardware combination:

Crosshead Batch	Injector Adjusting Screw	Injector Push Rod	Intake/Exhaust Valves	Wire Mesh Test Filters
F	D	C	F	ISM ASTM 4th Batch

- Data included through 9/13/2016:
  - 82 tests with chart = Y (one of which has newest hardware combination)
  - 4 chart = N with newest hardware combination introduced

- Test results with new hardware combination appear close to prior results for filter plugging delta and average sludge rating

- Crosshead mass loss is slightly higher with new hardware, but more aligned with the oil target compared to prior hardware

- Various statistical models were investigated; models suggest current injector screw weight loss (SAIAS) correction factor may not be appropriate for newest hardware combination

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Overview

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Possible Options:

- Don't accept new hardware
- Accept new hardware with no modifications to current correction factors (CFs)
- Accept new hardware and modify SAIAS correction:
  - Correction factors can be calculated based on various hardware changes.
    Note: There is some overlap in how various hardware were introduced. The latest valve and filter batches have a few more reference results in addition to the latest coordinated reference tests.

Hardware specification	Correction
Hardware combination FDCF ISM ASTM 4th Batch	ln(SAIAS) + 0.410
Hardware combination FDCF ISM ASTM 4th Batch	ln(SAIAS) + 0.615
Crosshead Batch F	ln(SAIAS) + 0.564
Injector Push Rod Batch C	ln(SAIAS) + 0.548
Intake/Exhaust Valves Batch F	ln(SAIAS) + 0.396
Wire Mesh Test Filter Batch ISM ASTM 4th Batch	ln(SAIAS) + 0.269

Estimated using average of test results

Model based estimates containing Lab-Stand and hardware specification

  - CFs are the differences between 830-2 oil target = ln(29.5) and the estimated hardware average.

Additional comments:

- An indirect relationship exists between TGAAVG and crosshead mass loss & injector adjusting screw mass loss.
- You may recall at the test's inception that the soot adjustment was calculated as a balance among the oils tested at that time. We only test 830-2 now. Therefore, we don't know what's happening with the soot effect in the other oils.
- The effect of TGAAVG also corresponds to a change in time. Thus, we cannot say for sure whether changes in ACWL or SAIAS are related to the soot adjustment or industry corrections or both.

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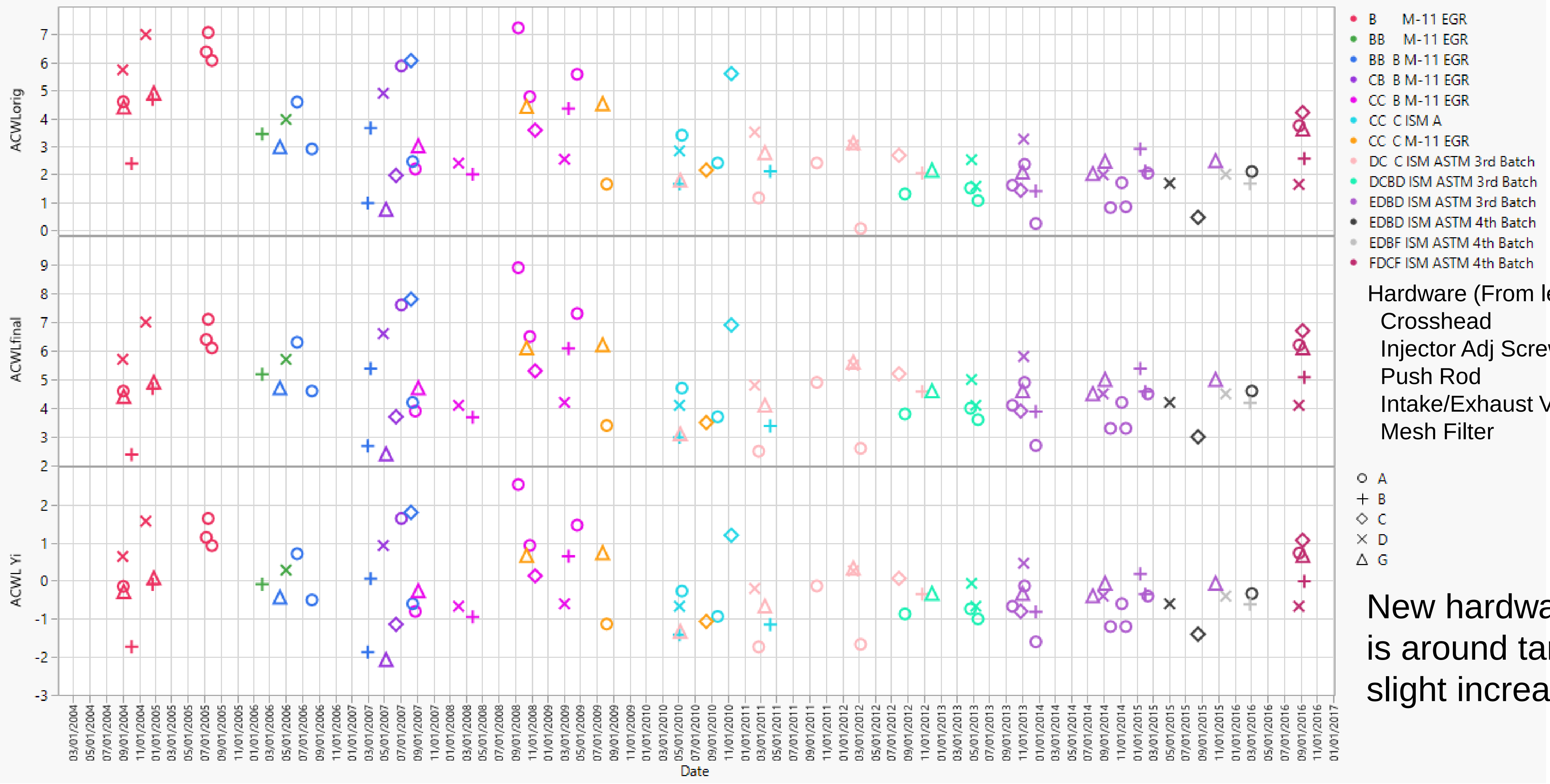
Crosshead Weight Loss



Hardware (From left to right)
- Crosshead
- Injector Adj Screw
- Push Rod
- Intake/Exhaust Valve
- Mesh Filter

New hardware combination is around target. This is a slight increase for some labs

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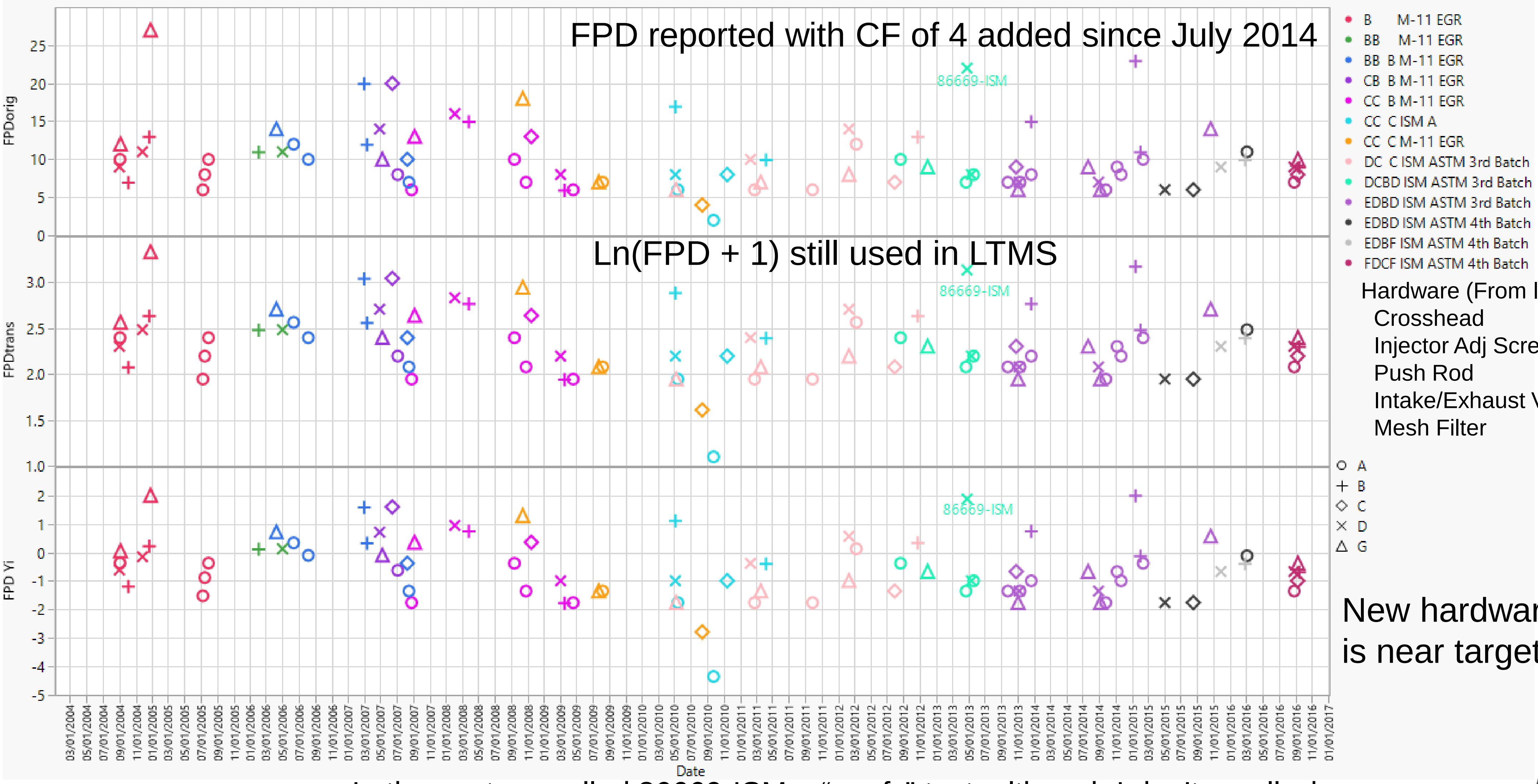
Filter Plugging Delta



Hardware (From left to right)
- Crosshead
- Injector Adj Screw
- Push Rod
- Intake/Exhaust Valve
- Mesh Filter

New hardware combination is near target.

In the past we called 86669-ISM a “goofy” test, although I don’t recall why.

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Average Sludge Rating

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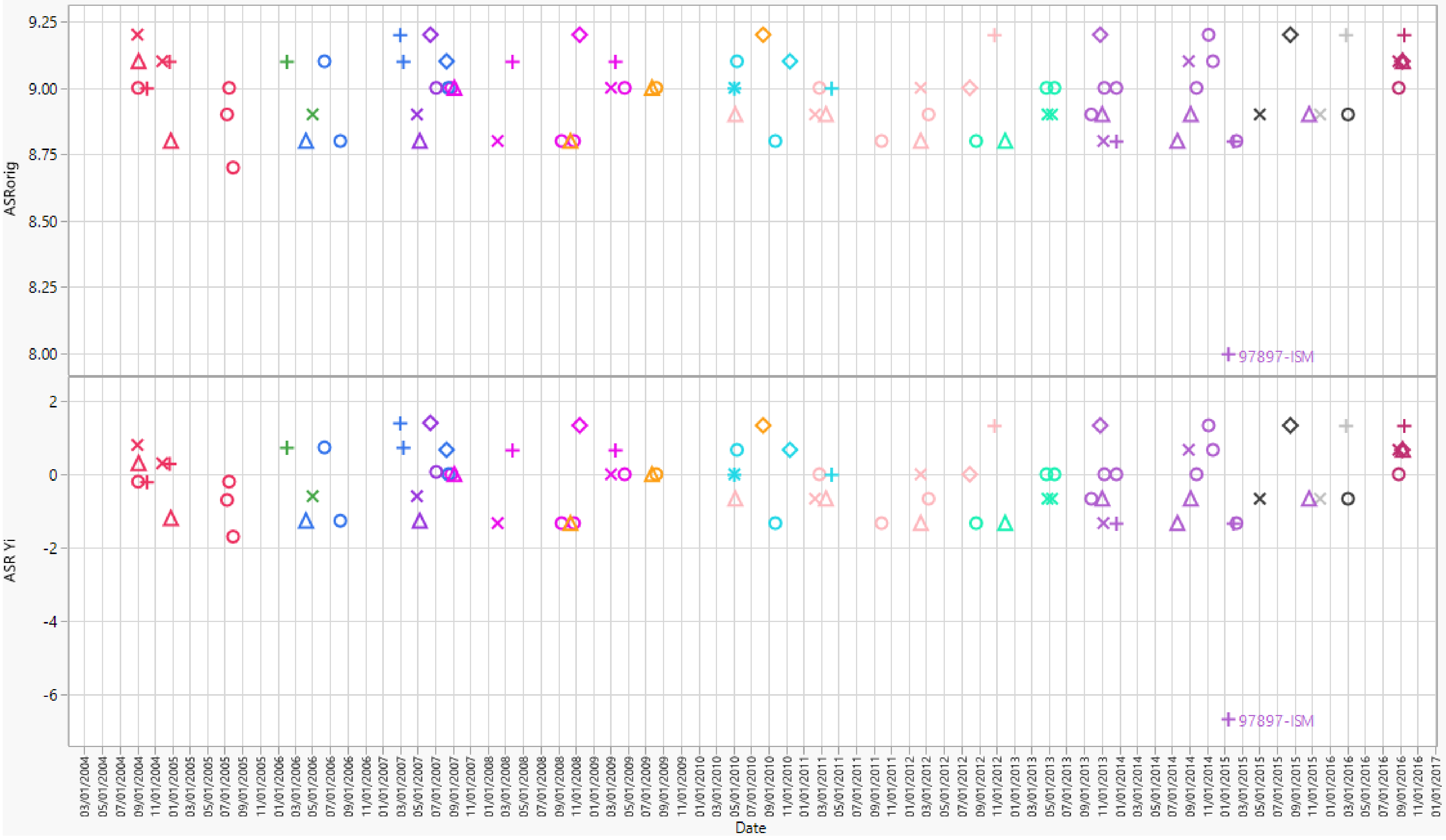

- B M-11 EGR
- BB M-11 EGR
- BB B M-11 EGR
- CB B M-11 EGR
- CC B M-11 EGR
- CC C ISM A
- CC C M-11 EGR
- DC C ISM ASTM 3rd Batch
- DCBD ISM ASTM 3rd Batch
- EDBD ISM ASTM 3rd Batch
- EDBD ISM ASTM 4th Batch
- EDBF ISM ASTM 4th Batch
- FDCF ISM ASTM 4th Batch

Hardware (From left to right)
- Crosshead
- Injector Adj Screw
- Push Rod
- Intake/Exhaust Valve
- Mesh Filter

- ○ A
- + B
- ◇ C
- × D
- △ G

New hardware combination is close to target.

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Injector Screw wt loss adj to 3.9% soot

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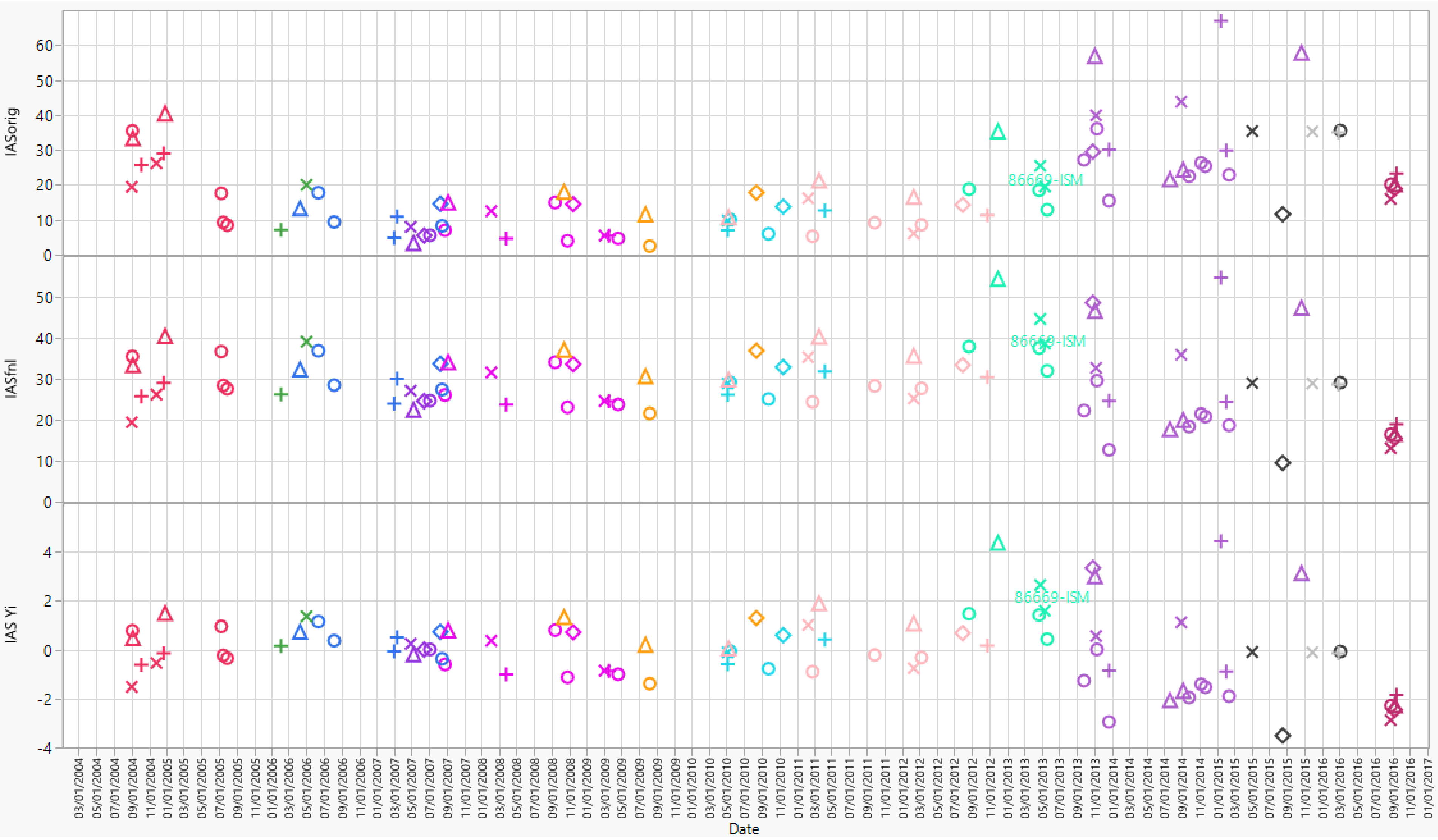

- B M-11 EGR
- BB M-11 EGR
- BB B M-11 EGR
- CB B M-11 EGR
- CC B M-11 EGR
- CC C ISM A
- CC C M-11 EGR
- DC C ISM ASTM 3rd Batch
- DCBD ISM ASTM 3rd Batch
- EDBD ISM ASTM 3rd Batch
- EDBD ISM ASTM 4th Batch
- EDBF ISM ASTM 4th Batch
- FDCF ISM ASTM 4th Batch

Hardware (From left to right)
- Crosshead
- Injector Adj Screw
- Push Rod
- Intake/Exhaust Valve
- Mesh Filter

- ○ A
- + B
- ◇ C
- × D
- △ G

New hardware combination appears to need a modified CF

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Injector Screw wt loss adj to 3.9% soot Example with a CF applied

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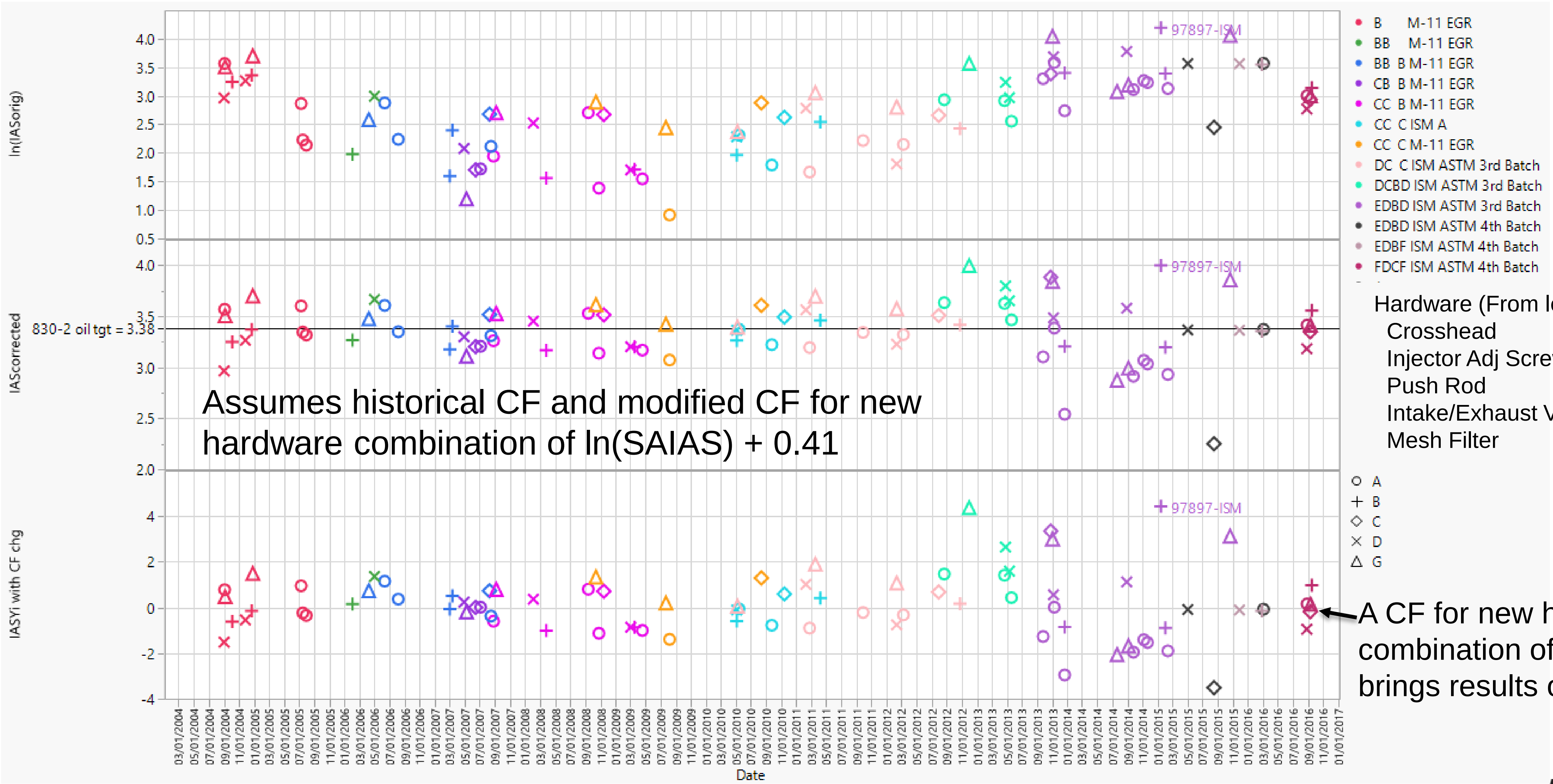

Assumes historical CF and modified CF for new hardware combination of ln(SAIAS) + 0.41

Hardware (From left to right)
- Crosshead
- Injector Adj Screw
- Push Rod
- Intake/Exhaust Valve
- Mesh Filter

A CF for new hardware combination of ln(SAIAS) + 0.41 brings results on target

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Working together, achieving great things

When your company and ours combine energies, great things can happen. You bring ideas, challenges and opportunities. We'll bring powerful additive and market expertise, unmatched testing capabilities, integrated global supply and an independent approach to help you differentiate and succeed.

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APPENDIX

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ISM Crosshead Mass Loss Calculations (D7468 – 15)

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11.1 Crosshead Mass Loss—Use the procedure shown in 8.1.6 to determine individual EOT crosshead mass.

11.1.1 Separate the crossheads into intake and exhaust groups.

11.1.2 Calculate the mass loss for each crosshead (pre-test - post test), and report the results. Calculate the average crosshead mass loss for the intake and exhaust groups.

11.1.3 Calculate the average mass loss, $\bar{x}$, and the standard deviation of the mass loss, s, for each group and report as *As Measured* in the *Intake/Exhaust Summary* section of Form 6 listed in Table A9.1.

11.1.4 Use Practice E178, two-sided test at a 95% significance level, to determine if any crosshead mass loss values are outliers. Determine outliers for the intake and exhaust groups separately. Remove a maximum of one outlier per group Calculate the average mass loss, $\bar{x}$, and the standard deviation of the mass loss, s, for each group and report as *Outlier Screened* in the *Intake/Exhaust Summary* section of Form 6 listed in Table A9.1.

11.1.5 Calculate the average and the standard deviation of all mass loss values combined (intake and exhaust). Report the average, minimum, maximum and standard deviation as *As Measured* in the *Overall Summary* section of Form 6 listed in Table A9.1.

11.1.6 Calculate the average and the standard deviation of each group (intake and exhaust) using all mass loss values with outliers removed. Report the average, minimum, maximum and standard deviation as *Outlier Screened* in the *Overall Summary* section of Form 6 listed in Table A9.1.

11.1.7 Calculate the following and report as *Adjusted to 3.9% Soot* in the *Overall Summary* section of Form 6 listed in Table A9.1:

$$\text{Crosshead Mass Loss Outlier Screened and Adjusted to 3.9\% Average Soot Mass} = \text{OSCHW} + 3(3.9 - \text{AVGSOOT}) \quad (1)$$

where:

OSCHW	=	Outlier Screened Crosshead Average Mass Loss value in the Overall Summary, and
AVGSOOT	=	mathematical average of the nine 25 h soot values (from 0 to 200) h, reported to one decimal.

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ISM Injector Adjusting Screw Mass Loss Calculations (D7468 – 15)

11.2 Injector Adjusting Screw Mass Loss—Use the procedure shown in 8.1.9 to determine individual EOT adjusting screw mass.

11.2.1 Calculate the mass loss for each injector adjusting screw (pre-test – post test), and report the results in the main section on Form 12 listed in Table A9.1.

11.2.2 Calculate the average mass loss, $\bar{x}$, and the standard deviation of the mass loss, s, for the injector adjusting screws. Report the average mass loss as *Average As Measured* in the main section of Form 12 listed in Table A9.1.

11.2.3 Use Practice E178, two-sided test at a 95% significance level, to determine if any injector adjusting screw mass loss values are outliers. Remove a maximum of one outlier. Calculate the average mass loss, $\bar{x}$, and the standard deviation of the mass loss, s, and report as *Outlier Screened* in the summary section of Form 12 listed in Table A9.1.

11.2.4 Calculate the following and report as *Average Adjusted to 3.9% Soot* in the main section of Forms 4 and 12 listed in Table A9.1:

$$SAIAS = \exp(\ln(OSIAS) + 1.7(3.9 - AVGSOOT)) \qquad (2)$$

where:

SAIAS	=	Injector Adjusting Screw Outlier Screened and Adjusted to 3.9% Average Soot Mass,
OSIAS	=	Outlier Screened Injector Adjusting Screw Average Mass Loss value in the Overall Summary, and
AVGSOOT	=	mathematical average of the nine 25 h soot values (from 0 to 200) h, reported to one decimal.

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Oil Targets and Correction Factors

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CROSSHEAD WEAR AT 3.9% SOOT
Unit of Measure: Milligrams
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
830-2	5.1	1.5

OIL FILTER ΔP
Unit of Measure: LN(OFDP+1)
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
830-2	2.5209	0.3274

AVERAGE SLUDGE RATING
Unit of Measure: Merit Rating
CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
830-2	9.00	0.15

INJECTOR ADJUSTING SCREW WEAR AT 3.9% SOOT
Unit of Measure: Milligrams
NON-CRITICAL PARAMETER

Reference Oil	Mean	Standard Deviation
830-2	29.5	5.7

ISM	June 28, 2007	***	All Tests	Add +1.7 to Crosshead Wear At 3.9% Soot Add +19.1 to Injector Adjusting Screw Wear At 3.9% Soot
	March 4, 2010	***	All Tests	Add +1.3 to Crosshead Wear At 3.9% Soot
	April 30, 2011	***	All Tests	Add +2.5 to Crosshead Wear At 3.9% Soot
	November 19, 2013	***	All Tests	Add -0.200 to ln(SAIAS)
	October 1, 2014	***	All Tests	Add 4 kPa to Oil Filter Delta Pressure

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Hardware Batch Changes

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Cummins ISM Critical Parts Batch Changes

Part	Batch	Date	Starting Kit Number	Comments
Crossheads	C	Nov-2006	201	Prior batch was M-11 EGR Batch B
"	D	Apr-2010	425	
"	E	May-2013	673	
"	F	July-2016	938	
Injector Adjusting Screws	B	Jun-2005	75	
"	C	Jul-2007	235	
"	D	May-2013	673	
Injector Push Rods	A	?	?	No record of exact Date or first Kit use
"	B	Apr-2012	571	
"	C	July-2016	938	
Intake/Exhaust Valves	B	Nov-2005	111	
"	C	Aug-2008	301	
"	D	Mar-2012	562	
"	F	July-2015	901	
Wire Mesh Test Filters	M11 EGR-3	Dec-2003	1	1st Batch Wire Mesh Filters
"	ISM ASTM	Aug-2009	375	2nd Batch Wire Mesh Filters
"	ISM ASTM	Apr-2010	425	3rd Batch Wire Mesh Filters 901 Media
"	ISM ASTM	Jan-2015	844	4th Batch Wire Mesh Filters 901 Media

ZRB ISM Parts Batch Info updated on 7/28/2016

At one time these were labeled “ISM A”

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ISX replacement test

- Rail pressure and timing can be adjusted to hit soot loading
- Duty cycle still being ironed out but likely will include soot loading phase and a more transient wear phase
- Most measured parts will carry forward except injector adjusting screw
- Valve adjusting screw may take the place of this
- Test will include a reporting of piston deposits