VH Operational Data Review | MINUTES

Revision Date *12/20/2016 1:18:00 PM*

Relevant Test:	Sequence VH
Note Taker:	CHTM
Meeting Date:	12-14-2016
Lubrizol Attendees:	Mileti, Brys, O'Malley
Comments:	Sequence VH operational data review in advance of Precision Matrix. This review focused on the Stage 1, Stage 2 and Stage 3 steady-state data.

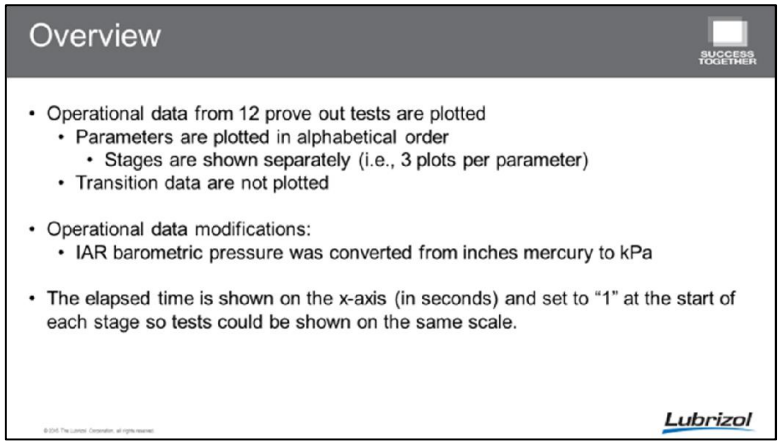
1. OPERATIONAL DATA REVIEW:

a) Presentation Used during Review:

i) The presentation used during the operational data review was distributed by Kevin O'Malley via email on 12-12-2016 at 8:50AM EST.
   (1) ***File:*** *VH Prove Out Operational Data Plots 12-12-2016.pptx*

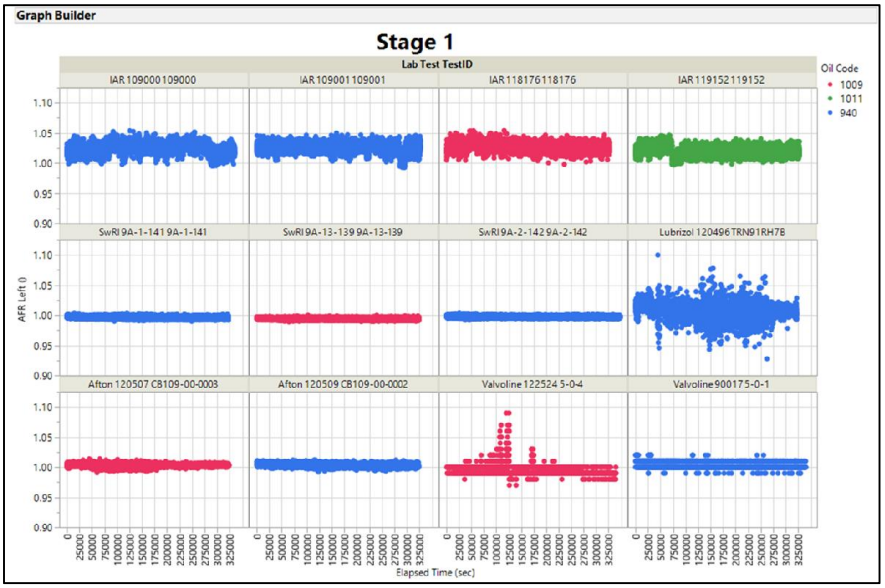
ii) O'Malley issued an updated version of this presentation after the meeting via email on 12-15-2016 at 12:01PM EST.
   (1) This updated presentation included data from test key 120505.
   (2) **File:** *VH Prove Out Operational Data Plots 12-15-2016.pptx*

b) Overview Slide:



c) AFR Left-Side:

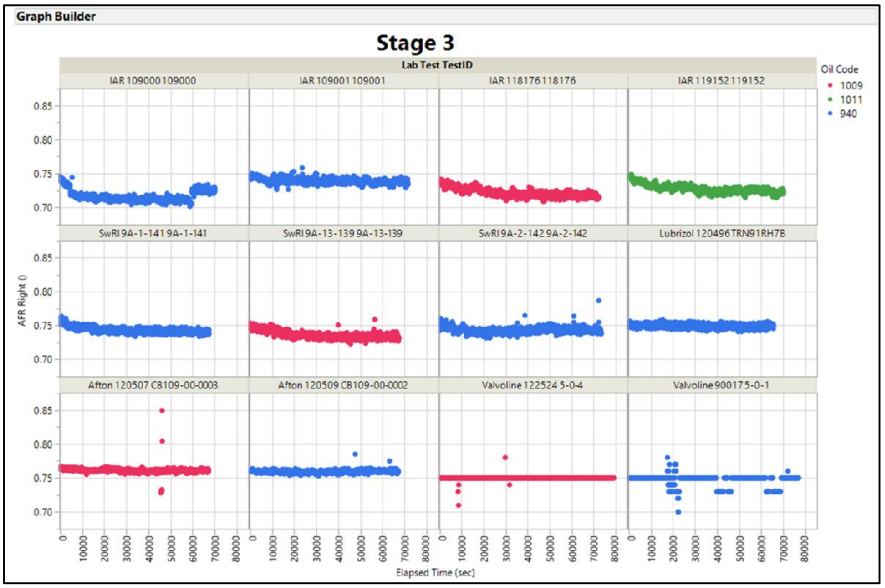
i) ***Stage 1:***



(1) SWRI is reporting data with a 30-second sampling rate while the other labs are reporting data with a 60-second sampling rate.
(2) One of the three SWRI tests used REO1006-2 (#9A-2-142).
  (a) This test is incorrectly labeled as a REO940 prove-out test.
  (b) The REO1006-2 test is not an official VH prove-out test.
(3) The quality of the Lubrizol AFR and speed data was negatively impacted by the ongoing AFR control problems with their stand.
(4) The IAR data is on the "lean" side of the AFR set-point.
  (a) IAR is using the MEXA-730 Lambda boxes.

d) AFR Right-Side:

i) ***Stage 3:***



ii) Afton is not surprised to see the AFR on one side of the engine run "rich" while the AFR on the other side of the engine runs "lean".
  (1) The test stand is controlling to an average of the two AFR values.
  (2) However, it is unusual to see a lab run with two "lean" cylinder banks or two "rich" cylinder banks.

iii) ***Intertek and SWRI:***

(1) These two labs control the AFR by manually modulating fuel flow.
(2) They are aware that there is a "drift" in their Stage 3 AFR values.
(a) They compensate for this "drift" by resetting the PCM during every oil check.

iv) ***Ashland Comments:***
(1) The fact that there are different AFR control strategies being used by the labs could be questioned by the Industry in the future.
(2) A memo was circulated several years ago regarding how the Sequence VG test stands were to use MAF to control AFR.
(3) Their Stage 3 AFR usually varies by approximately ±0.01 Lambda.

v) The VG procedure requires that the Stage 3 AFR (average of left-side and right-side) remain within 0.75±0.03 Lambda.

vi) Intertek and SWRI are willing to change their Stage 3 AFR control strategies to match the other three labs.

vii) SWRI noted that the Sequence VG test originally used a single O_2 sensor in the "Y" between the left-side and right-side exhaust pipes.

e) Coolant Temperature, Inlet:

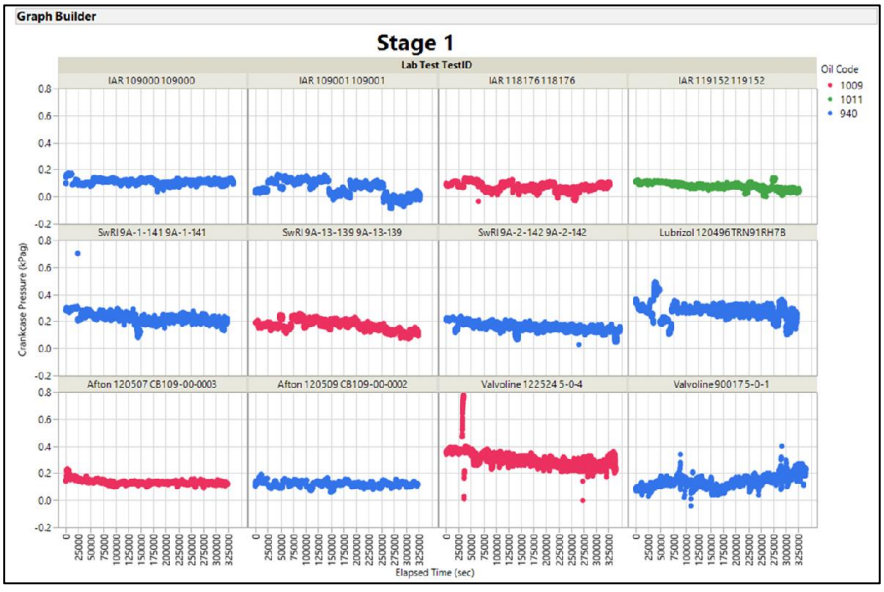
i) Ashland's inlet coolant temperature in all three stages is higher than those of the other labs.
(1) There is also considerable noise in their measurements (particularly in Stage 2).
(2) Some of this may be due to a calibration issue with their thermocouple or coolant flow meter.
(a) Ashland confirmed that the inlet temperature thermocouple for 900175-0-1 was not in the correct location.
(i) This was addressed during the recent Industry stand inspections.
(b) Ashland also said that they did not have their electronic coolant flow meter in place for 900175-0-1.

f) Coolant Temperature, Outlet:

i) The graphs in the presentation use very small y-axis scales, and this makes it appear as if there is more variation than there actually is.

g) Crankcase Pressure:

i) ***Stage 1:***



(1) The crankcase pressure measurements from all of the labs were surprisingly similar.

(2) Lubrizol comments:

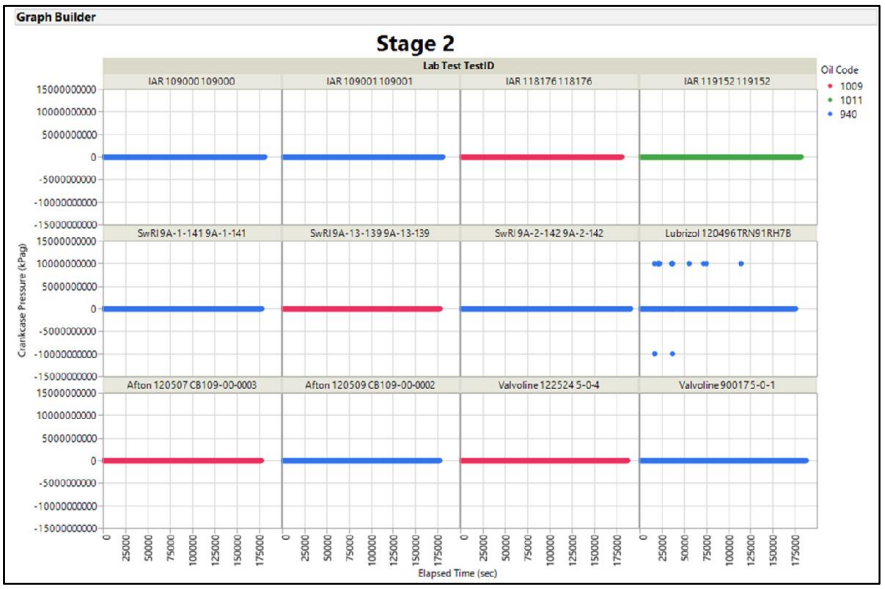
(a) The most important thing about the Stage 1 crankcase pressure is that no lab is maintaining a vacuum.

(b) Intertek gets close to 0kPa during one of their tests, but it is only for a few hours.

(i) This could be due to a fouled PCV valve, piston ring deposits or oil in the pressure transducer line.

(ii) Overall, this is not a concern.

ii) ***Stage 2:***



(1) Some of the labs may get unusual pressure spikes (such as with the Lubrizol test) if their pressure transducers continue to record data during the blowby checks.

(2) Afton has corrected this problem by installing a 3-way valve that isolates the pressure transducer during blowby checks.

(3) 2nd Intertek Test:

(a) The blowby dropped drastically during the second-half of this test.

(i) The blowby may have dropped as a result of deposits near the piston ring gaps.

(b) The fact that the crankcase pressure became negative may be due to the lower blowby flow.

iii) ***Fouled PCV Valves:***

(1) The Sequence VG procedure does not explicitly state how a lab is to deal with a fouled, stuck or malfunctioning PCV valve.

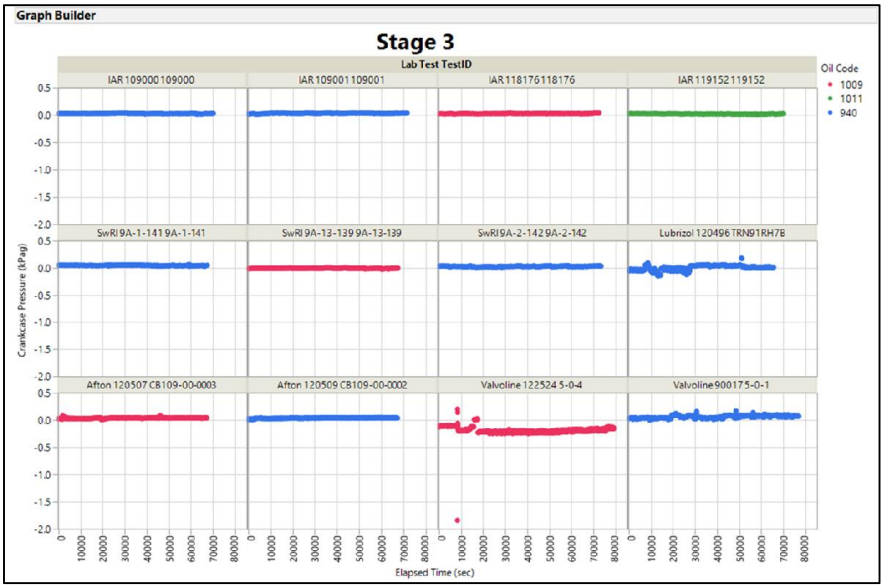
(2) On one hand, the valves could be replaced during the test.

(a) On the other hand, the PCV is technically a measured part.

(b) As a result, the argument could be made that they should not be replaced (even if they are malfunctioning).

(3) This issue should be clarified in the VH procedure.

iv) ***Stage 3:***



(1) Lubrizol comments:

(a) The crankcase pressure in Stage 3 should be right around 0kPag.

(b) It is also not unusual to see the crankcase pressure periodically become negative.

h) Coolant Pressure:

i) The coolant pressure limits, like many of the other limits for this test, are extremely narrow.

(1) TMC noted that all of the limits were established using VG Precision Matrix data.

(2) Both TMC and Ford are willing to revisit these limits after the VH Precision Matrix.

ii) ***Ashland comments:***

(1) Ashland plans to eventually switch from manual coolant pressure control to PID control.

(2) SWRI already uses a PID to control their coolant pressure.

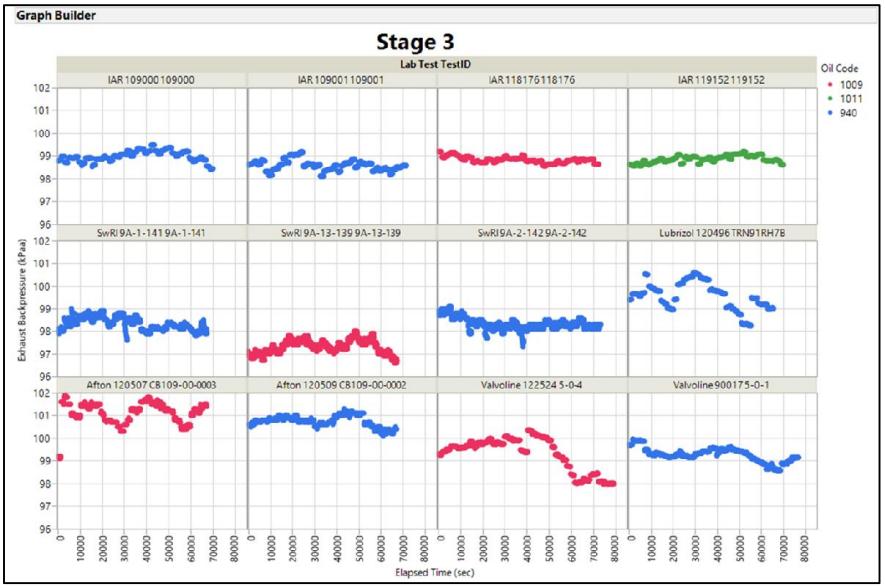
i) Speed

i) Almost all of the labs will have a negative Stage 3 speed QI.

ii) The group suggested widening the Stage 3 speed QI limits for the Precision Matrix.

(1) The limits can be tightened at a later time if the data permits.

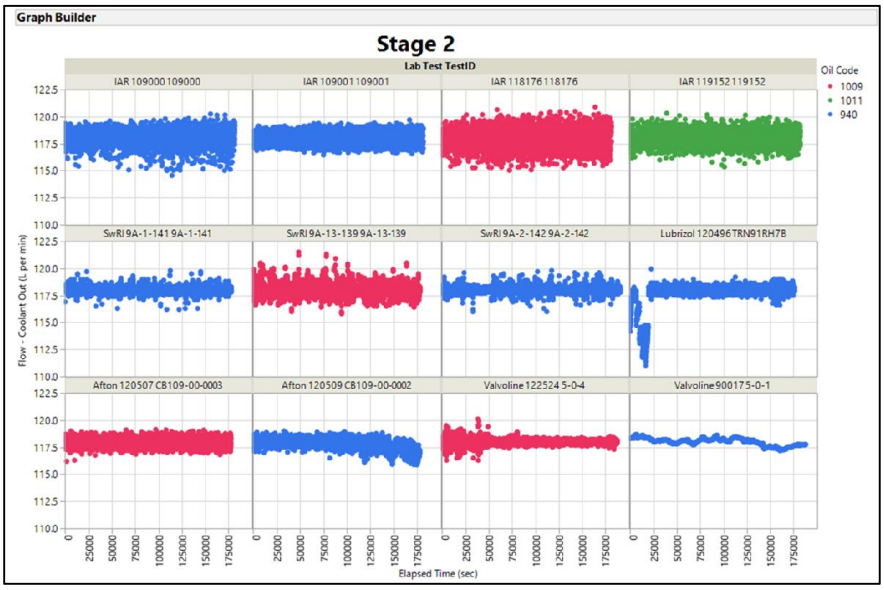
j) Exhaust Backpressure:



i) The fluctuations in the Stage 3 exhaust backpressure are due to changes in barometric pressure.

k) Coolant Flow at Engine Outlet:

i) **Stage 2:**



ii) ***Cobra High-Output Water Pump:***

(1) There was a substantial shift in engine coolant flow with the Lubrizol test at approximately 24HRS.

(2) Lubrizol was having difficulty achieving the Stage 2 coolant flow set-point of 118LPM with the stock Ford VG water pump.

(3) As a result, Lubrizol installed the optional Ford Cobra water pump in the engine.

(a) This new water pump (with vortex ring) generated the additional output needed to hit the Stage 2 flow set-point (as shown in the graph).

(4) Afton comments:

(a) Afton has also switched to the Cobra water pump.

(b) The Cobra pump does not generate as much cavitation as the original VG pump.

(c) Afton has noted that there is more variation with the Cobra pumps than there was with the VG pumps.

(d) Lubrizol believes this variation may be due to the fact that the vortex ring appears to be welded to the impeller by hand.

(5) Ashland comments:

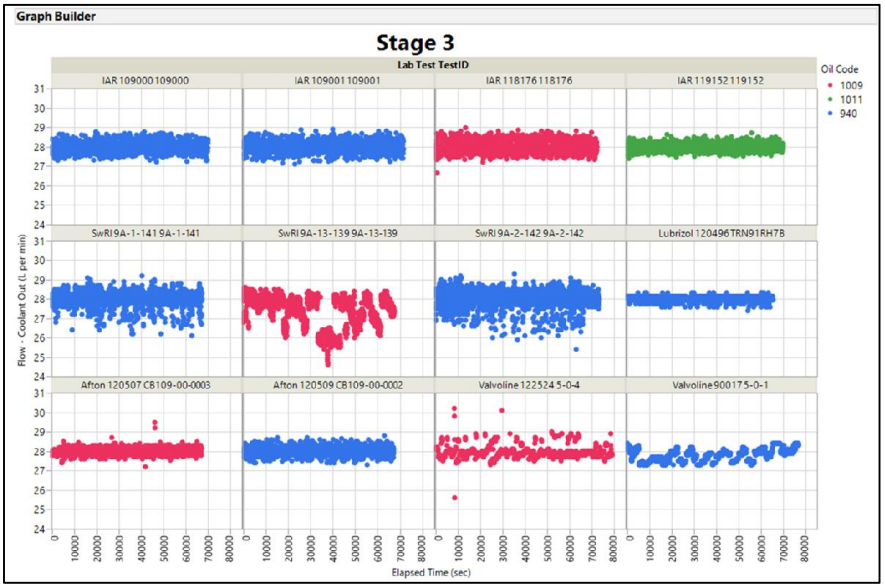
(a) Ashland found a particular Cobra water pump that has performed well and they are still using it.

iii) ***QI Limits for Stage 2 and Stage 3 Set-Points:***

(1) The Stage 1 coolant flow QI limits from the Sequence VG test are being applied to the Stage 2 and Stage 3 set-points for the VH test.

(2) This issue will need to be revisited after the Precision Matrix.

iv) ***Stage 3:***

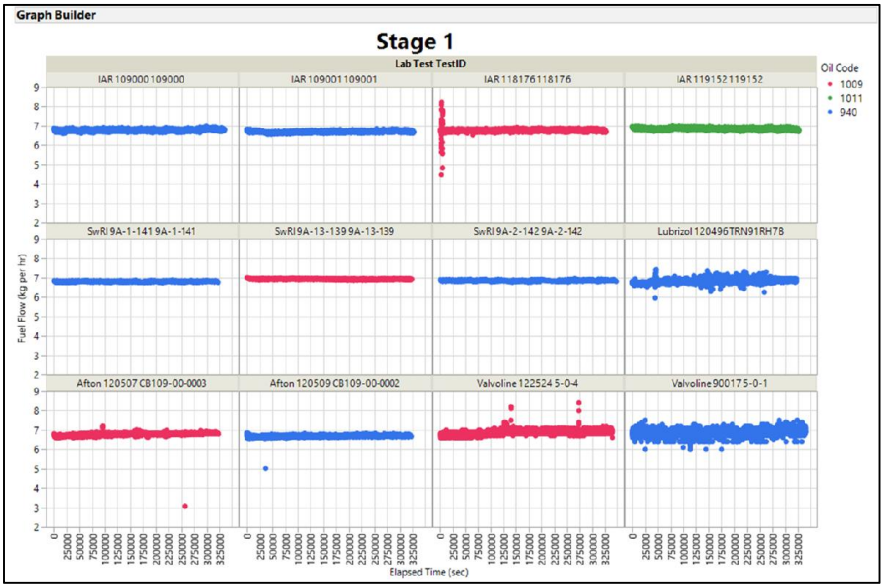


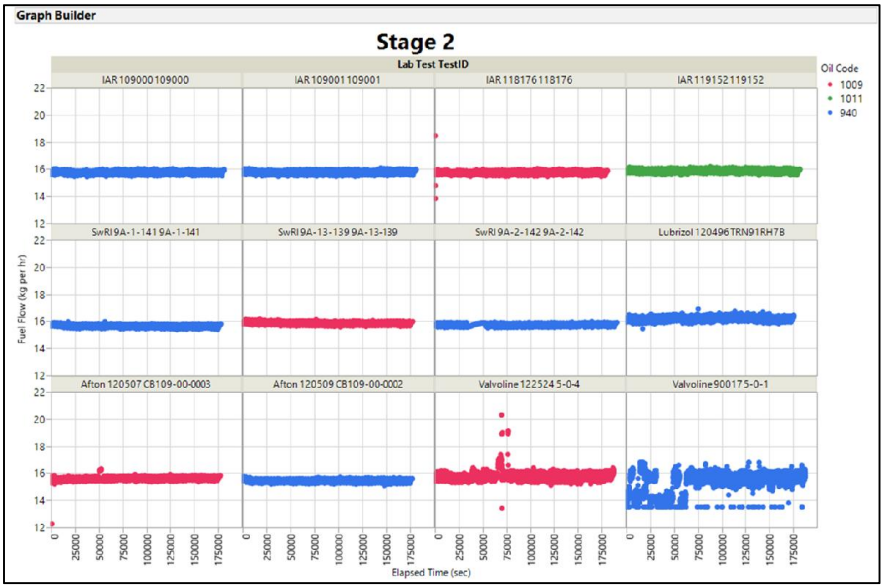
v) SWRI had a problem with their control valve in Stage 3.

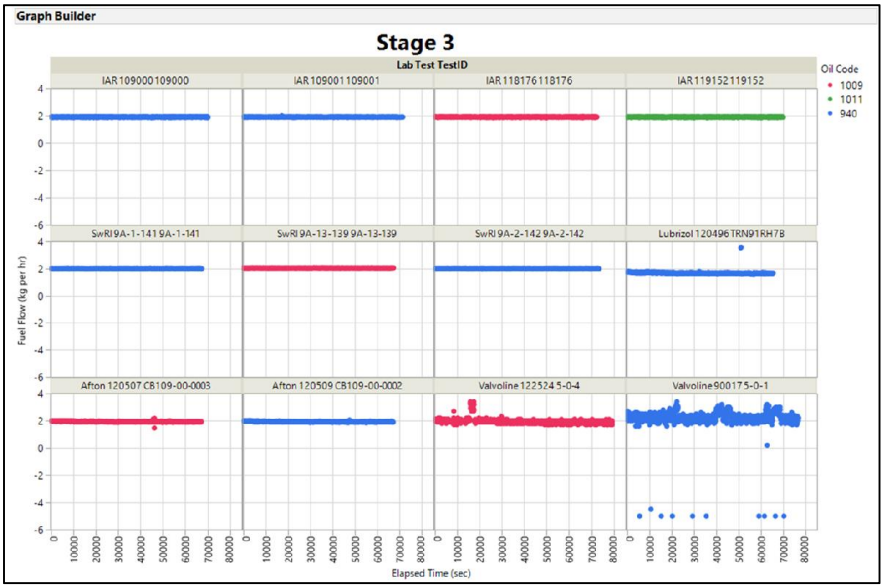
vi) This problem has been fixed.

I) Fuel Flow:

i) ***Stage 1 and Stage 2:***







ii) The Stage 1 and Stage 2 fuel flows for all five labs are remarkably similar.
   (1) The Stage 1 flow rates are all around 6.8-6.9 kg/hr.
   (2) The Stage 2 flow rates are all around 15.7-15.9 kg/hr.

iii) All of the labs are using Micro Motion flow meters except Lubrizol.
   (1) Lubrizol is using a Micro Oval flow meter (which is probably not as precise as the Micro Motion units).

iv) ***Excessive Noise in Ashland Measurements:***
   (1) Ashland had excessive noise/variability in its Stage 2 and Stage 3 fuel flow measurements.
   (2) This noise/variability was most likely caused by a problem with their O_2 sensors.

m) Fuel Pressure:

i) The decision was made earlier in the year (during the VG-A operational data review) to mandate a fuel pressure of 250±20kPa.

ii) Some of the data submitted by Intertek was generated before the group agreed upon this pressure set-point.
   (1) As a result, the corresponding fuel pressures are well above 250kPa.

iii) The Sequence VH procedure on the TMC website needs to be updated with this set-point.

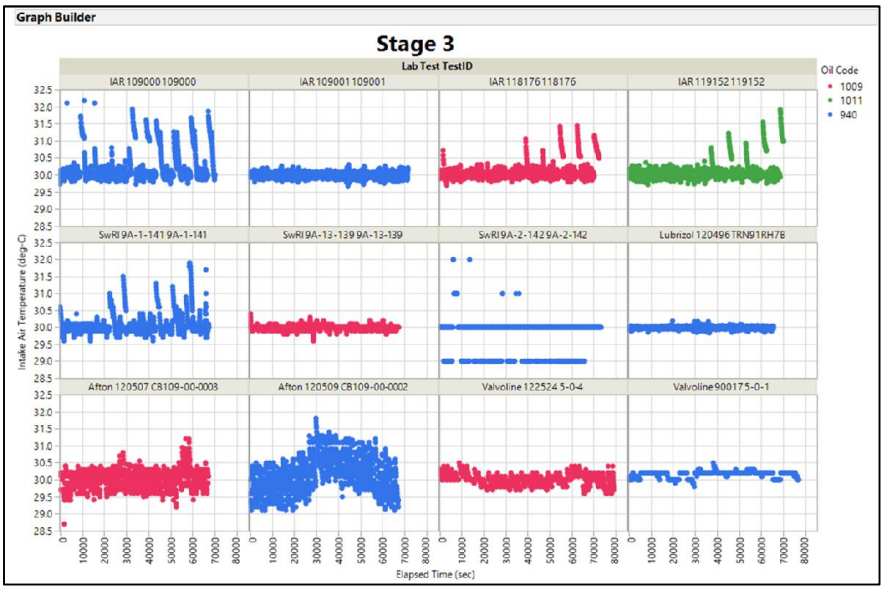
n) Intake Air Pressure:

i) The intake air pressure parameter should be revisited during the Precision Matrix.

ii) The pressure measurements are very sensitive to the orientation of the sample probe (particularly its angle to the incoming air flow).

o) Intake Air Temperature:

i) ***Stage 3:***

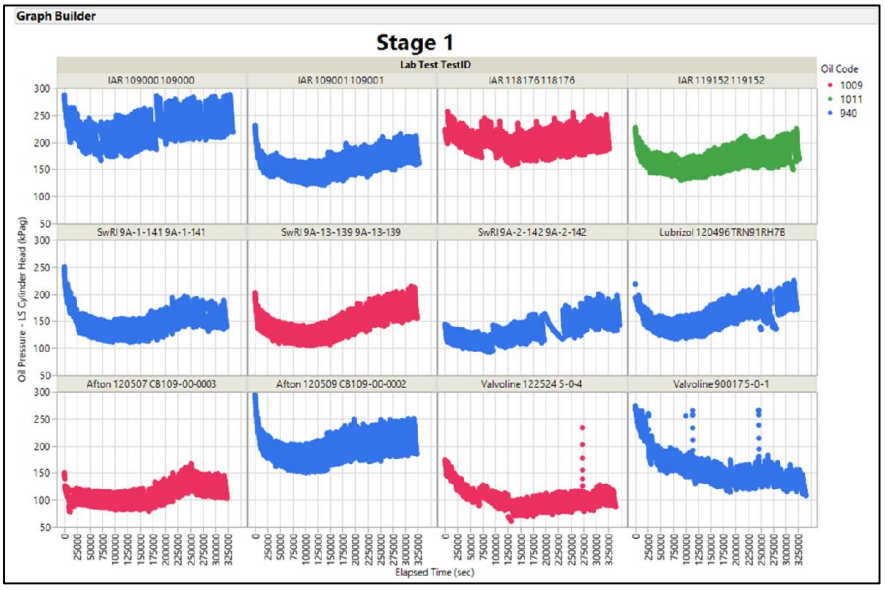


(1) Some of the labs struggle to control to the intake air temperature (particularly in Stage 3).

(2) All of the labs are using electric heaters to control this parameter.

p) Left-Side Cylinder Head Oil Pressure:

i) ***Stage 1:***

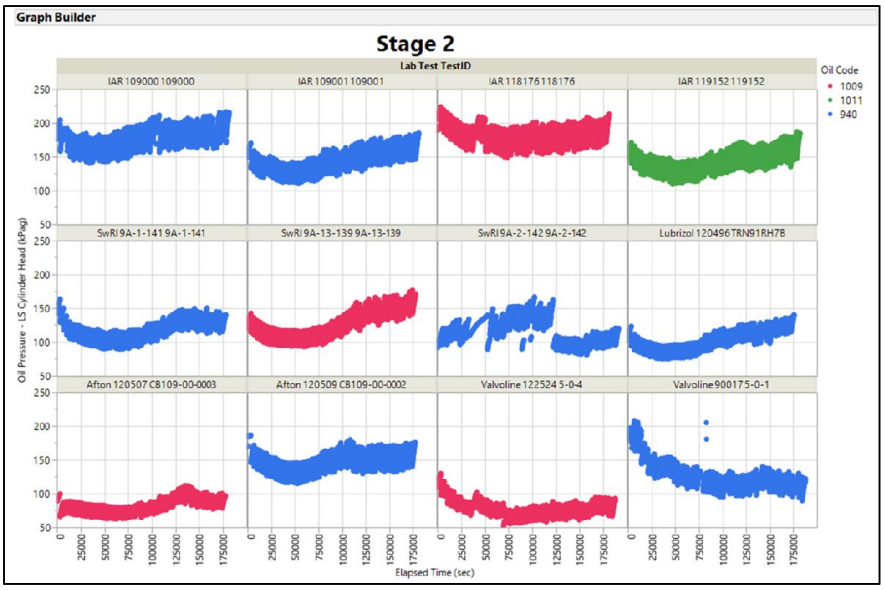


(1) Cylinder head pressures will obviously vary from oil-to-oil.

(2) Lubrizol comments:

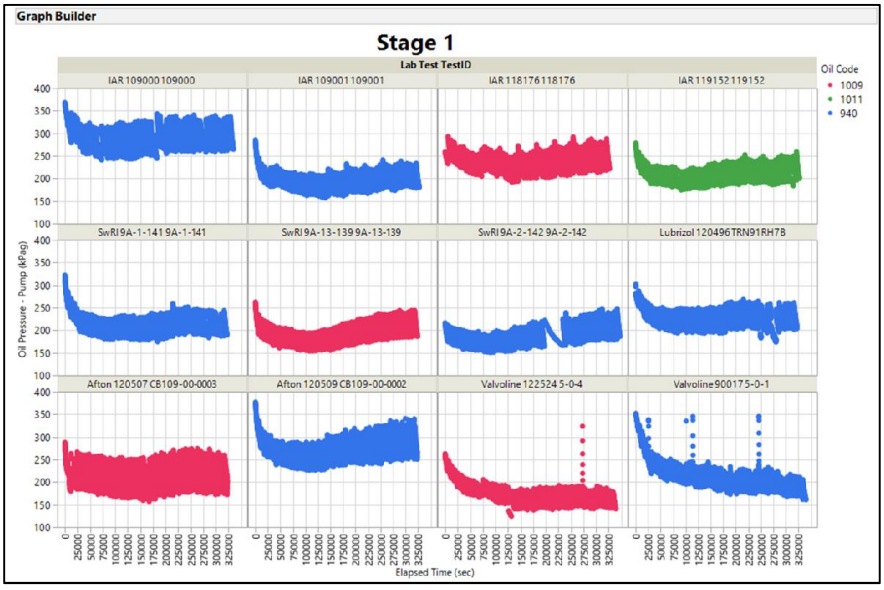
(a) Lubrizol has frequently seen shifts in cylinder head pressures with both the VG and VH engines that cannot be explained by oil viscosity or fuel dilution.
(b) Lubrizol unsuccessfully attempted to correlate these pressure shifts to dimensional differences in the cylinder heads or camshaft bearings.

ii) ***Stage 2:***



(1) Afton and Ashland both had tests in which their left-side cylinder head oil pressure dropped significantly below 100kPa.
(2) The consensus of the group is that these oil pressure anomalies are partially the result of engine-to-engine hardware differences.

q) Oil Pump Pressure:



i) The oil pressure for Ashland test #122524 is lower than the oil pressure for the remaining tests.

r) Oil Temperature at Outlet:

i) The last test for Ashland has an unusually high outlet oil temperature.
(1) This may be due to a calibration offset.

ii) The outlet oil temperature is an uncontrolled parameter.

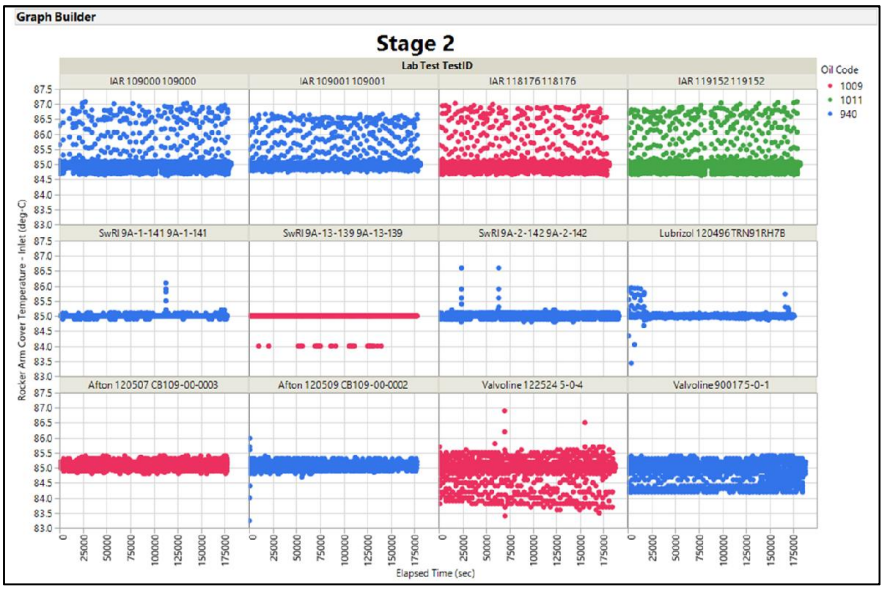
s) Power:

i) At one point, Ashland was dealing with an AFR control problem.
   (1) They fixed this problem by replacing the O_2 sensors and ignition wires.

ii) Lubrizol is also having AFR control problems.
   (1) Lubrizol has excused itself from the Precision Matrix because it has not yet been able to resolve these problems.

t) Rocker Arm Cover Coolant Temperature at Inlet:

*i) **Stage 2:***



(1) There is a lot of noise in the coolant temperature measurements at Intertek.
   (a) It appears as if there is an issue with the first data point recorded for each cycle.

Action Items	Person responsible	Completion Date
IAR and SWRI to change their strategy for controlling Stage 3 AFR to bring them in alignment with the other three labs.	IAR, SWRI	
The Sequence VH procedure needs to explicitly state how a lab should deal with a malfunctioning PCV valve.	Ford	
Widen the Stage 3 speed QI limits for the Precision Matrix.	Ford	
Revisit upper and lower QI limits for Stage 2 and Stage 3 coolant flow set-points.	Ford	
Update VH procedure with correct fuel pressure set-point.	Ford	

Follow-up Notes/Updates:	Initials	Date Added