DD13 Scuffing Task Force Meeting Minutes – 8/28/2013

IAR - San Antonio, Texas

Attendance:

Brad Carter – IAR
Greg Shank – Volvo
Jim Rutherford – Chevron Oronite
James Pearce – SwRI
Martin Thompson – SwRI
Pat Fetterman – Infineum
Bob Salgueiro – Infineum
Elisa Santos – Infineum
Sean Moyer – TMC
Mark Sutherland – TEI
Bob Campbell – Afton
Mark Cooper – Chevron Oronite
Riccardo Conti – Exxon Mobil
Jim Gutzwiller – Infineum
Jeff Clark – TMC
John Cruz – Detroit Diesel
Jim Carter – Haltermann
Christian Porter – Afton
Chris Castanien – Lubrizol
Michael Conrad – Lubrizol
Nick Secue – Lubrizol
Andy Broff – IAR
Jim Moritz – IAR

The meeting started with a tour of the DD13 test stand at IAR.

Jim Matasic opened the meeting with a call for any questions from the group about the lab visit.

Brad Carter indicated that Jim Matasic provided engine and instrumentation instructions to IAR. Jim said that the next steps were to work with SW to provide the same support in setting up their test stand.

Jim Matasic presented to the group an update on test development status. See Attachment 1.

Presentation: (ATTACHMENT 1)

Jim discussed test results up to this point

-2 test results on a “poor” 2.9 HTHS formulation
-1 result on “good” HTHS formulation

The method for scuffing verification is to monitor crankcase pressure. Once a CCP increase of 3 kPa is seen, an oil sample is taken and ICP analysis done looking for elevated levels of Cr and Fe. The other option is to use a borescope to physically inspect the cylinders for scuffing once the CCP increases.

Jim showed a plot of crankcase pressure showing spikes in pressure after scuffing events. The pressure spikes are consistent and repeatable no matter how many cylinders scuff.

Plots of TGA...not controlling for soot but useful to show soot that is being generated

Plots of chromium and iron...increase in Cr and Fe are an indicator of scuffing and measuments are used after crankcase pressure spikes to verify a scuffing event

-top rings are uncoated stainless steel...other rings are production coatings

Bob Campbell asked what the definition of hours to scuff is. Jim said that hours to scuff would most likely be the hours until crankcase pressure reaches 3 kPa. Bob Campbell's concern is there is a six hour spread between two failing oils and then another 20 to good oil. Is it really discriminating?

Wear results on all three oils was presented. “Poor” oils had 3 cylinders that scuffed and not less than 100% scuffing on each. The actual scuffed cylinders varied from test to test. The “good” oils only had 1 scuffed cylinder. Ring weight losses consistent with scuffing. Liner wear as well although measurement is difficult due to scuffing.

Martin Thompson asked if you can see scuffing on individual cylinders or is it that all cylinders scuff nearly simultaneously. Exhaust temps could potentially show individual cylinders scuffing but necessary to review data.

Other cylinders show no evidence of debris from scuffed cylinders. Cylinders that don’t scuff look like new

The test is currently running 200hrs but that is subject to change. There needs to be a discussion about how to determine what a passing test is and what is a failing test. Pat asked if there was any thought on running TMC-821 to compare to T12 liner wear data. The group seemed to think this was a good idea.

Jim said that the first step is to get discrimination in one lab and move to reproducibility at multiple labs.

There has been no scuffing in any segment other than 100% load. It was posed to the group whether there was any value to running strictly at 100% and bypassing 50% and 75% test steps.

Bob Campbell asked how we can be sure that this test solves the field issues seen without testing the oils that have performed poorly. Detroit responded that they have plenty of internal data on poor oils that they have run and they are concerned that certain oils have a propensity to scuff. They would like to build margin to protect against warranty issues in the future.

Pass fail parameters were discussed-

Test operational data was presented and reviewed. It was pointed out that controller voltages are locked at the end of warm up phase. Jim indicated that those voltages are very repeatable after any shutdown events. There has been some discussion about how to handle test cycle when there are emergency shutdowns. Scuffing events have typically occurred soon after a soak event so it is important to establish a procedure to handle shutdowns.

The status of test kits was presented. TEI is working on assembling kits and ordering parts. 3000 rings have been ordered. 429 builds worth were actually produced by supplier and in order to maintain a single batch the order was reduced. Jim went over the list of parts that are being changed at each build. 6 builds per lab are currently on order and should be available after about 2 weeks. Rings should be here within a week.

The rebuilds are not being done as a fresh build. The crank isn't being pulled. The rebuild process is basically pulling engine modules, cleaning and then reinstalling. Cylinder heads are not being rebuilt.

Engine modifications were highlighted

There is no break in oil flush. Oil charged right after build and cycle is started. There is a need to discuss a potential flush method and how to account for oil hang up.

Path Forward:
-Run good HTHS oil at Lubrizol once rings are available.
-Continue to work with Intertek and SwRI on stand installation.
-Intertek is running stand shakedown using one of the poor HTHS oils. Their first test will also run on poor HTHS formulation.
-Continue to pursue parts supply
-Start to work on a data dictionary
-Schedule a build workshop potentially at SwRI in the September timeframe.

The presentation ended here and general Q&A and group discussion ensued.

The flush procedure was discussed again. Jim indicated that Lubrizol is potentially looking at a 15 minute flush like the T11.

A question was asked about oil consumption and it was stated that has not an issue at this point.

The group decided to add a solvent flush at EOT. This will be added to the procedure for future tests.

A question was asked whether there is active oil pressure control and there is not.

A question was asked about what compensation is being done for aftertreatment system removal. The ECU SW has been altered to account for the removal of all aftertreatment components.

It was asked whether there is any indication that the engine is operating at the edge of controller maps. Jim indicated that they have seen nothing to suggest that they are.

The meeting was adjourned at ~11:30am. No details for the next meeting were established.

ATTACHMENT 1

DD13 Scuffing Test

Latest Results and Procedure

8-28-13

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Topics

SUCCESS TOGETHER

- Test Results
- Current Procedure
- Current Hardware
- Next Steps
- IAR Lab Visit

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Test Results

Test Results

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- 3 complete tests on current procedure
  - 2 results on the “Poor” 2.9HTHS formulation
  - 1 result on the “Good” 2.9HTHS formulation
- Positive results for repeatability and discrimination at LZ
- Important to note that the “Good” 2.9HTHS is not necessarily a passing formulation, but intended to be better performance than the poor formulation

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Scuff Verification

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- Steps to verify scuffing

1) Increase in Crankcase Pressure above 3kPa

2) Take sample and run ICP to look at Cr and Fe levels

AND/OR

3) Borescope engine to see visual scuffing

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Operational Data

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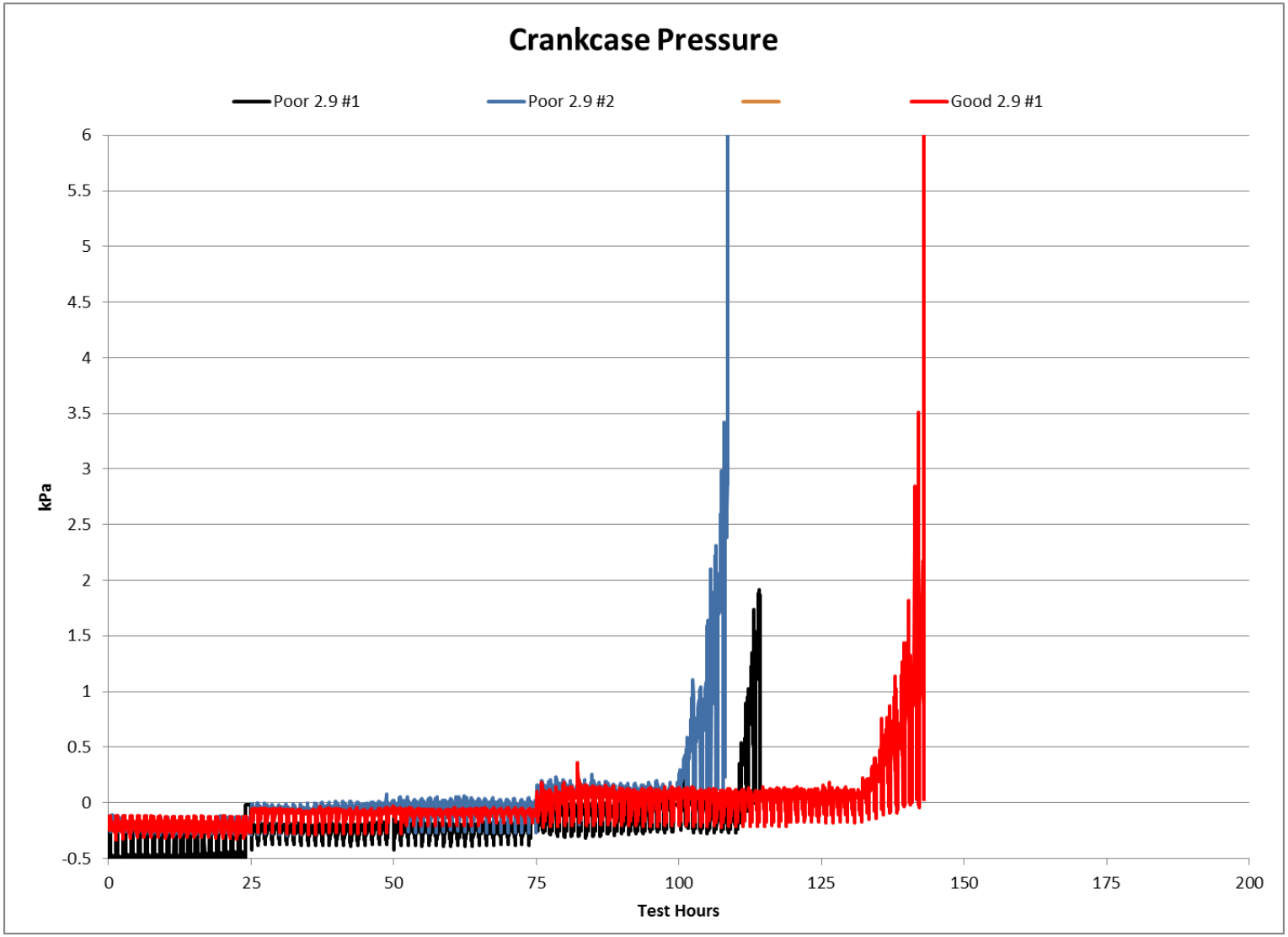

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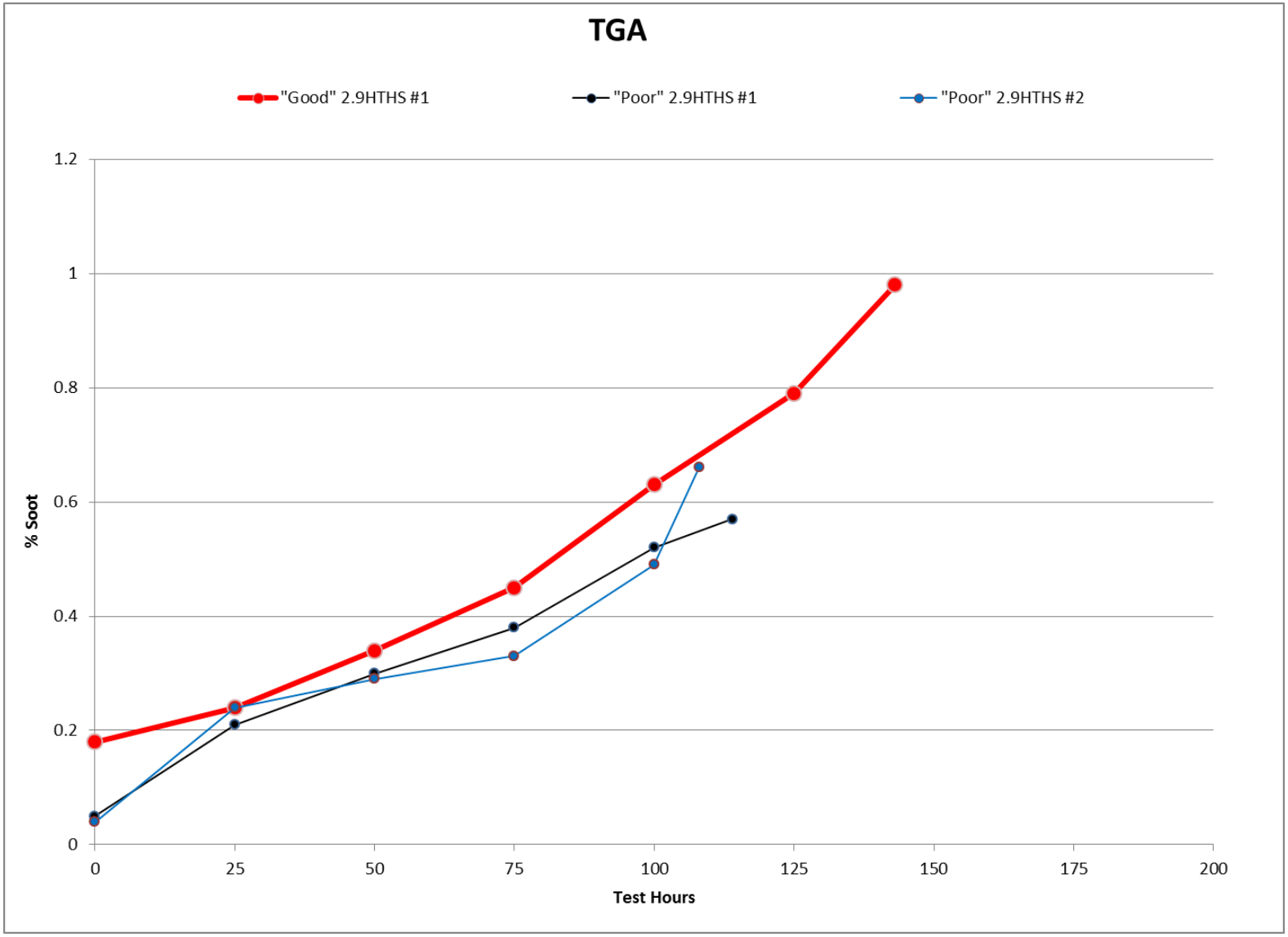
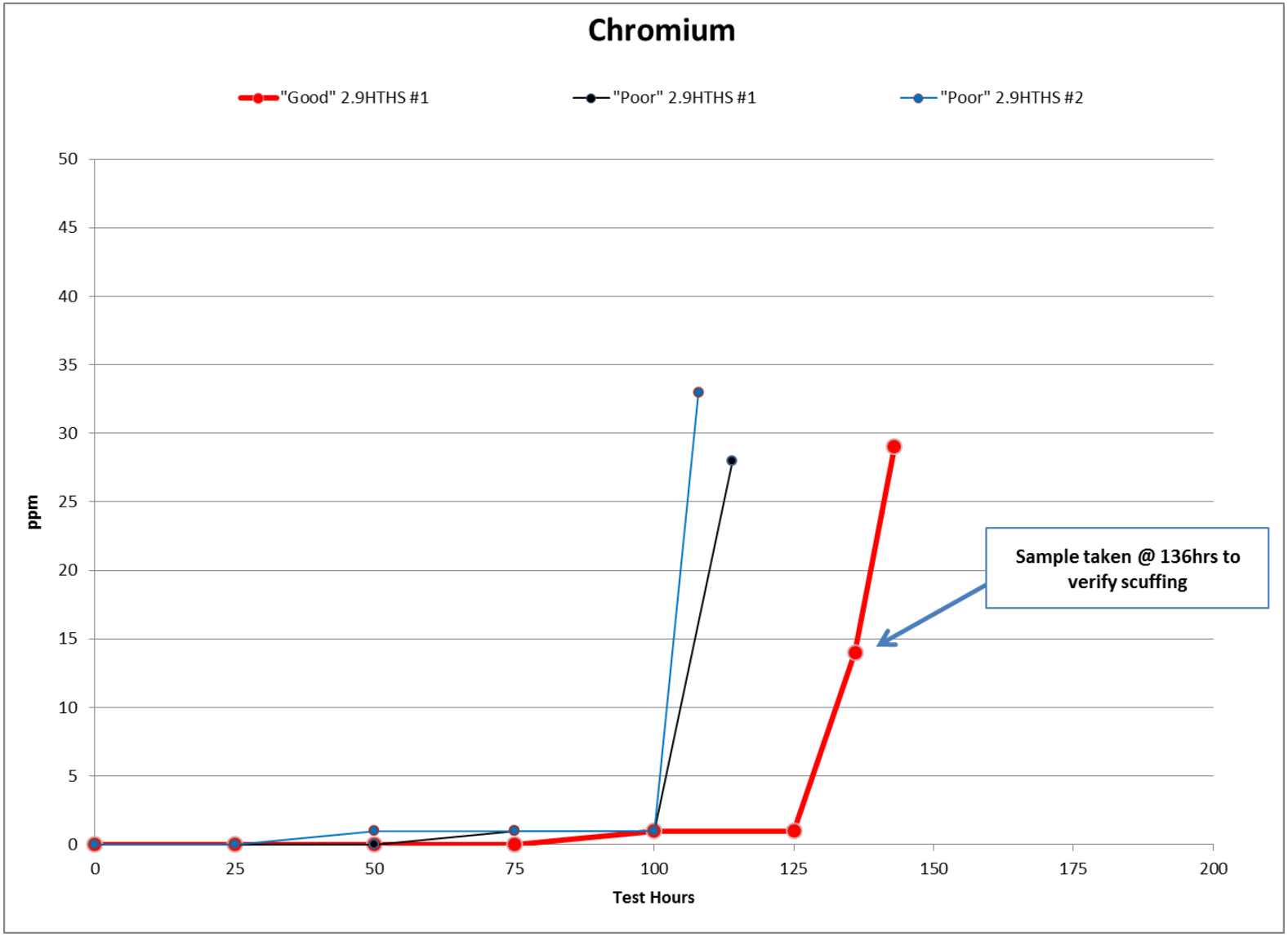
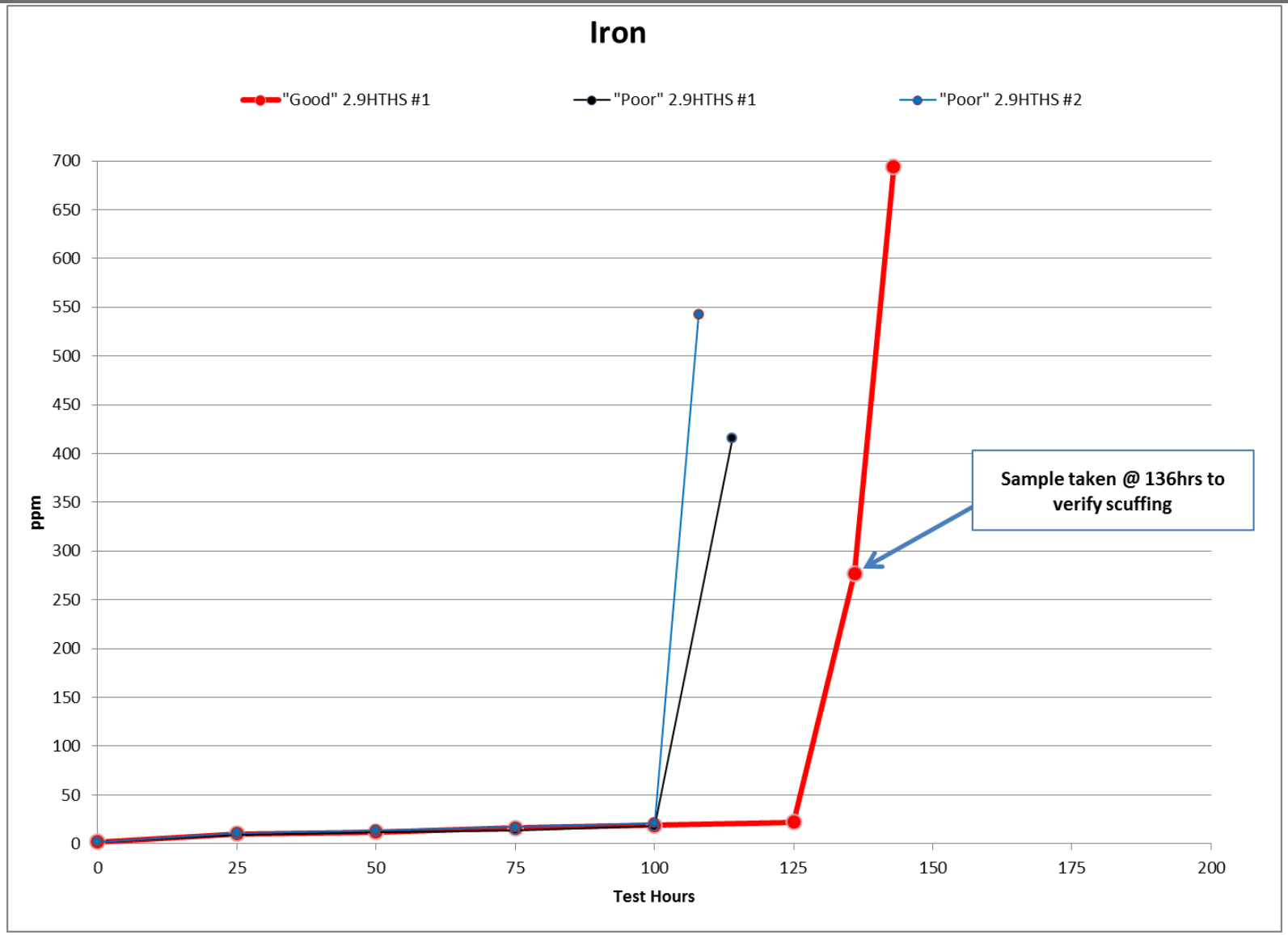
Analytical Data



Analytical Data



Analytical Data



Measurement Data

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- "Poor" 2.9HTHS #1 (114hrs)

Scuffing			
1	100%	4	0%
2	0%	5	0%
3	100%	6	100%

	1	2	3	4	5	6	avg
TRWL	4768	7.7	6081	4.5	5.3	5643	2752
2RWL	36.8	1.7	33.7	1.1	1.7	50.3	20.9
ORWL	27.5	0.6	27.6	0.3	0.1	32.2	14.7
CLW	87.6	2.21	109	2.86	2.81	105	51.7

- "Poor" 2.9HTHS #2 (108hrs)

Scuffing			
1	0%	4	100%
2	0%	5	0%
3	100%	6	100%

	1	2	3	4	5	6	avg
TRWL	5.2	2.5	3742	8721	11.5	9399	3647
2RWL	1	3.8	9.5	45.2	1.6	69.6	21.8
ORWL	2.2	1	16.9	37.7	2.5	59.4	20
CLW	3.68	3.31	96.8	169	4.42	177	75.6

- "Good" 2.9HTHS #1 (143hrs)

Scuffing			
1	0%	4	0%
2	0%	5	0%
3	0%	6	100%

	1	2	3	4	5	6	avg
TRWL	6.4	4.8	1.7	3.2	5.2	10003	1671
2RWL	2.2	0.4	1.4	0.8	0.3	46.2	8.6
ORWL	1.7	0.4	1.5	0	0.5	40	7.4
CLW	3.943	2.703	2.611	3.527	2.753	176.6	32.0

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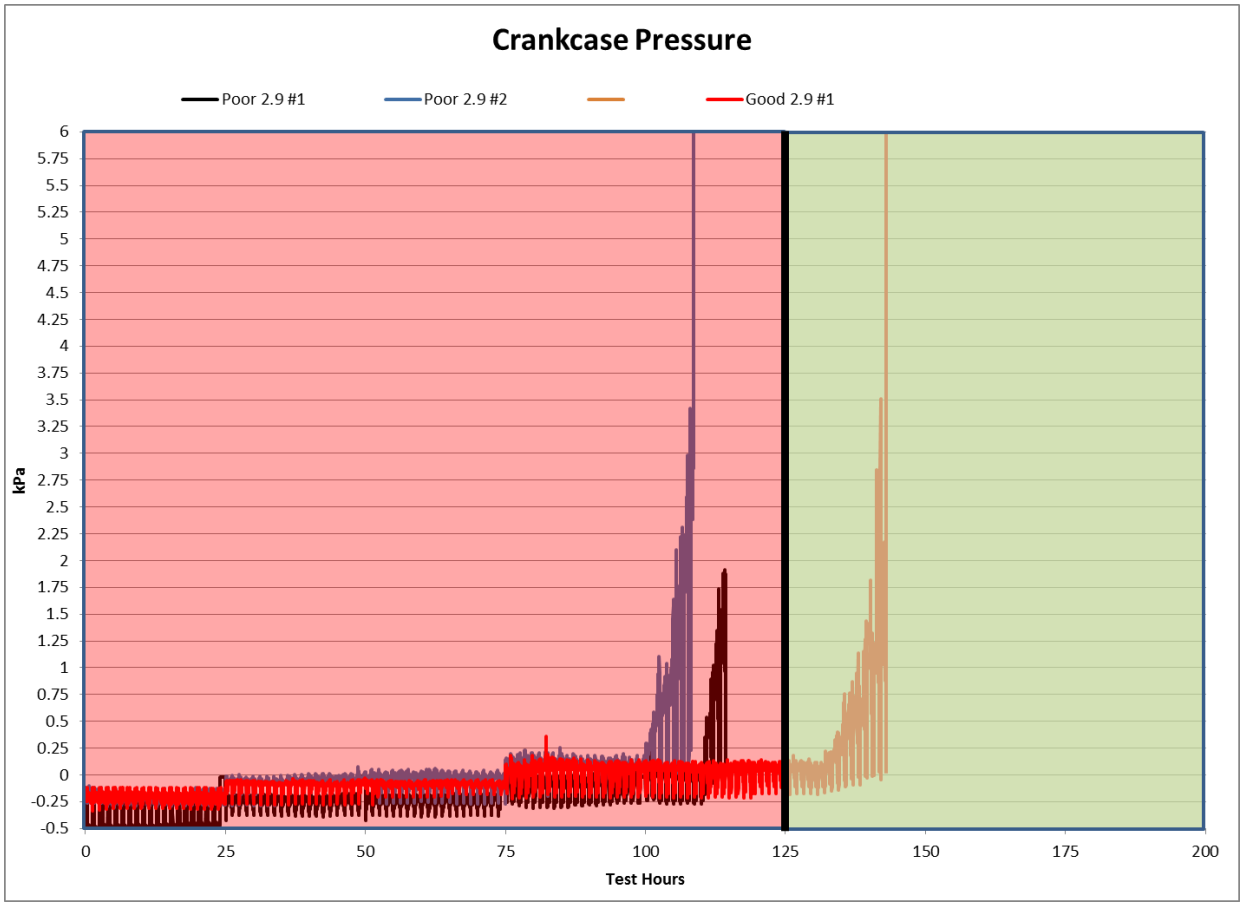
Current Procedure

Procedure

- Test Length
  - 200HR
    - Subject to change



Potential P/F Parameters

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- **Piston Ring / Cylinder Liner Scuffing**
  - % scuffing on liner

- Other items being monitored
  - Top Ring Weight loss
  - Connecting Rod Bushing Wear
  - Rocker Arm Bushing Wear
  - Rocker Shaft Wear
  - Cam Wear
  - Main Bearing Weight loss
  - Rod Bearing Weight loss
  - Piston Rating

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Operational Specifics (1 of 3)

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	Step	Time (min:sec)	Total Time (hr:min:sec)	Speed (RPM)	Speed Ramp (min:sec)	Torque (Nm)	Torque Ramp (min:sec)	Throttle (%)	Throttle Ramp (min:sec)	Coolant Pressure (kPa)
Test Warm-up	1			600		*Throttle Controlled*		0		70 ± 3
	2	05:00	00:22:00	1800	03:00	1200	03:00	*Torque Controlled*		
	3	05:00		1800		1800	03:00	*Torque Controlled*		
	4	10:00		1800		2032	03:00	*Torque Controlled*		
	5	02:00		600	02:00	*Throttle Controlled*		0	02:00	
Test	1	02:00	*25:00:00	600		*Throttle Controlled*		0		70 ± 3
	2	15:10		1800	00:10	*Throttle Controlled*		**	00:10	
	3	02:20		900	00:10	*Throttle Controlled*		35	00:10	
	4	02:20		600	00:10	*Throttle Controlled*		0	00:10	
	5	21:00		1100	00:10	*Throttle Controlled*		**	00:10	
	6	28:00		2000	25:00	*Throttle Controlled*		**		
	7	04:00		1800	02:00	*Throttle Controlled*		**		
	8	00:10		600	00:10	*Throttle Controlled*		0	00:10	
Cool Down	1	02:00	00:02:00	600	02:00	*Throttle Controlled*		0	02:00	70 ± 3
Soak	1	240:00	04:00:00							

* each cycle is 1hr 15min

*** Varies depending on test hours*

0-25 = 50%

25-75 = 75%

75-200 = 100%

Only "Test" segment counts for Test hours. Engine shutdowns down every 25 hours for soak. Total test length is 200 hours.

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Operational Specifics (2 of 3)

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	Step	Time (min:sec)	Total Time (hr:min:sec)	Intake Air Temperature (°C)	Coolant Outlet Temperature (°C)	Oil Gallery Temperature (°C)	Fuel Temperature (°C)	Exhaust Back Pressure (kPa)	Exhaust Back Pressure Ramp (min:sec)	CAC Delta Pressure (kPa)	Intake Air Restriction (kPa_{vac})	Intake Air Restriction Ramp (min:sec)	CAC Out Temperature (°C)
Test Warm-up	1			35	110	118	38	0		1	0.5		73
	2	05:00	00:22:00					10	02:00	6	1	02:00	
	3	05:00						20	02:00	10	3	02:00	
	4	10:00						30 ± 1	02:00	12 ± 1	3 ± 1		73 ± 2
	5	02:00						***Controller voltages locked at end of Step 4 of warm-up. Voltages will be reset following any warm-up event during the test.***					
Test	1	02:00	*25:00:00	35 (varies)	110 (varies)	118 (varies)	38 (varies)						
	2	15:10											
	3	02:20											
	4	02:20											
	5	21:00											
	6	28:00											
	7	04:00											
	8	00:10											
Cool Down	1	02:00	00:02:00	35	110	118	38	0	00:00	1	0.5	00:00	73
Soak	1	240:00	04:00:00										
			* each cycle is 1hr 15min										

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Operational Specifics (3 of 3)

SUCCESS TOGETHER

	Step	Time (min:sec)	Duration (hr:min:sec)	Notes
Warm-up	1			- Step 1 (idle) time should be minimized. - Samples are taken at Step 1. - This warm-up is used following any shutdown.
	2	05:00	00:22:00	
	3	05:00		
	4	10:00		
	5	02:00		
Test	1	02:00	25:00:00	- If a shutdown occurs during the cycle restart at Step 1 following warm-up. - Cycle will repeat for 25hrs
	2	15:10		
	3	02:20		
	4	02:20		
	5	21:00		
	6	28:00		
	7	04:00		
	8	00:10		
Cool Down	1	02:00	00:02:00	- Turn off engine at end of cooldown to begin soak - Same cooldown is used for any shutdown
Soak	1	240:00	04:00:00	- Restart engine at end of soak and procede to warm-up

This is one 25HR segment of test

Analyticals	
Test Hour	Description
NEW FUEL	Sulfur/Gravity
EOT FUEL	Sulfur/Gravity
NEW, 25, 50, 75, 100, 125, 150, 175, 200EOT	TGA Soot
	100KV
	40KV
	150HTHS
	100HTHS
	IR oxidation
	ICP
	TBN
	TAN
	90pass orbahn (only new)
	Fuel Dilution

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Current Hardware

Test Kits

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- TEI is assembling test kits with the following hardware
  - This will also include the Top Ring which is a special order from Federal Mogul (2576 rings/429 builds are shipping today)

Part Number	Definition (DIBS)	QTY
A4710302217	Piston Assembly	6
A4710380110	Upper Con Rod Bearings	6
A4710380111	Lower Con Rod Bearings	6
A4710330101	Upper Main Bearing	6
A4710330202	Lower Main Bearing	6
A4710300020	Connecting Rod	6
A4710112010	Liner	6
A4710110259	CSR	
A0249943945	Top Liner Seal	
A0239975545	Bottom Liner Seal	
A4710161120	Cylinder Head Gasket for CSR	1
A4710507	Upper Thrust Bearing	2
A4710508	Lower Thrust Bearing	2
A4719940241	Piston Pin Retainer	12
EA4710501231	Intake Rocker Shaft	1
A4729920350	Intake Rocker Shaft Narrow Spacer	6
A4729920650	Intake Rocker Shaft Wide Spacer	6
A4710500033	Intake Rocker Arm	6
EA4710500831	Exhaust Rocker Shaft	1
A4710550151	Exhaust Rocker Shaft Spacer	6
EA4720501334	Exhaust Rocker Arm	6
A4720501634	Exhaust Rocker Arm	6
EA4710500034	Exhaust Rocker Arm	6

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Engine Modifications

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- We have made several modifications for the test
  - External oil temperature control loop (details in following slides)
  - Block the coolant thermostat open
  - External oil weigh system
  - Modified belt tensioner to eliminate the compressor
  - Remove aftertreatment components

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Oil Cooler Modifications

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- Thermostat in housing is blocked as it would be if oil temperature was low and it by-passed the production heat exchanger

- The production heat exchanger is removed and a flat plate is in it’s place.

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Oil Cooler Modifications

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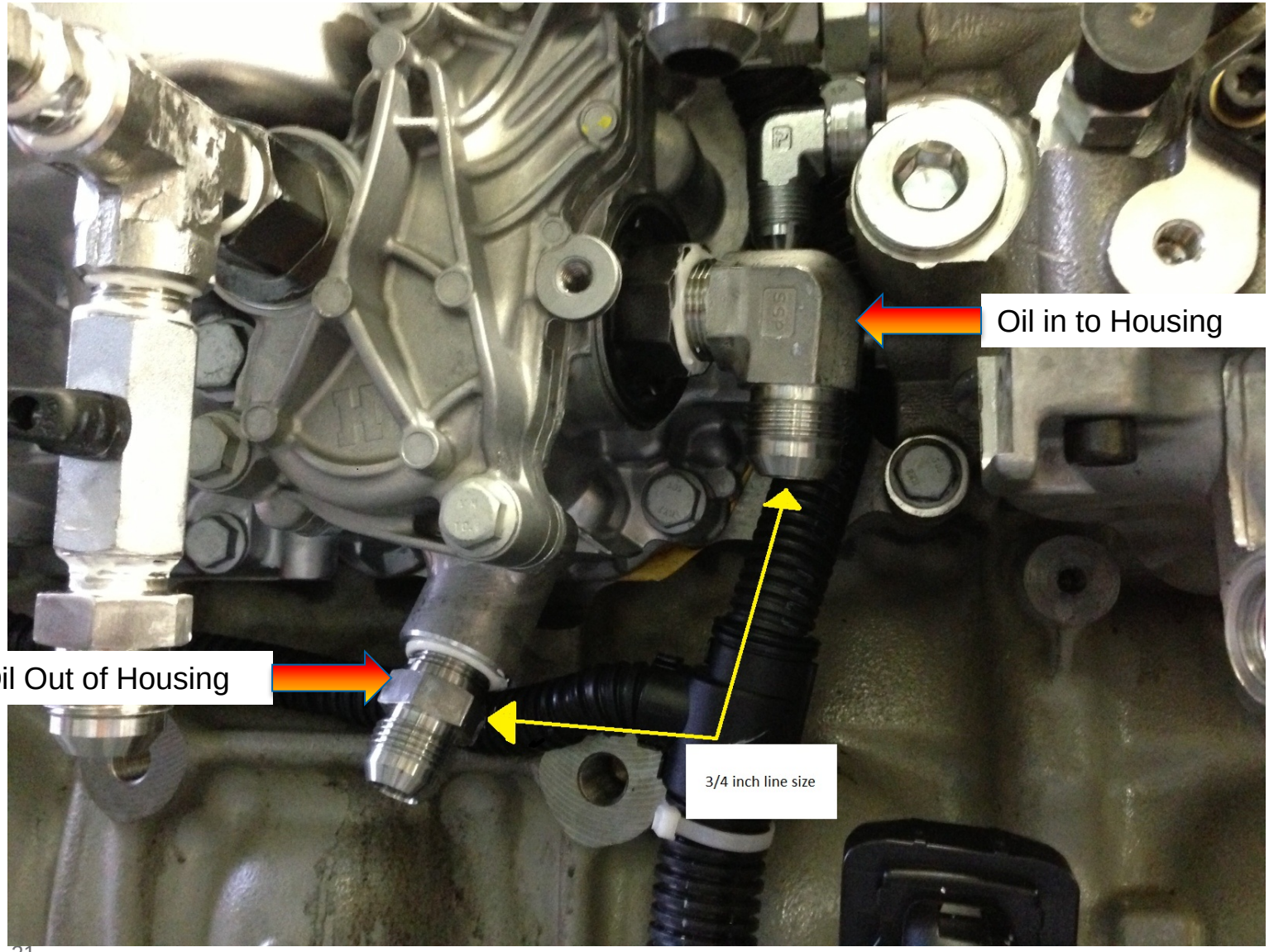

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Oil Cooler Modifications

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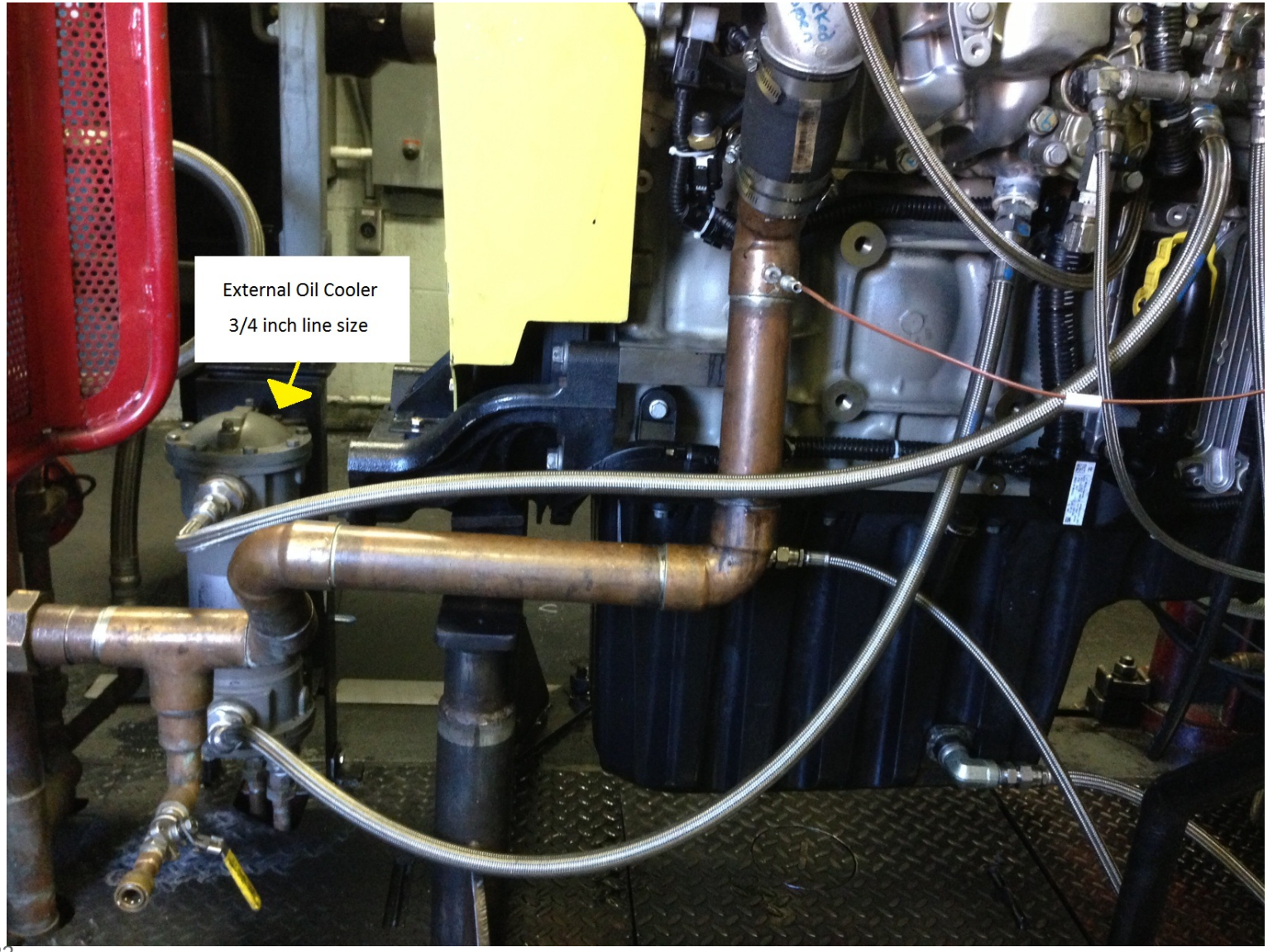

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Oil Cooler Modifications

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Oil Cooler Modifications

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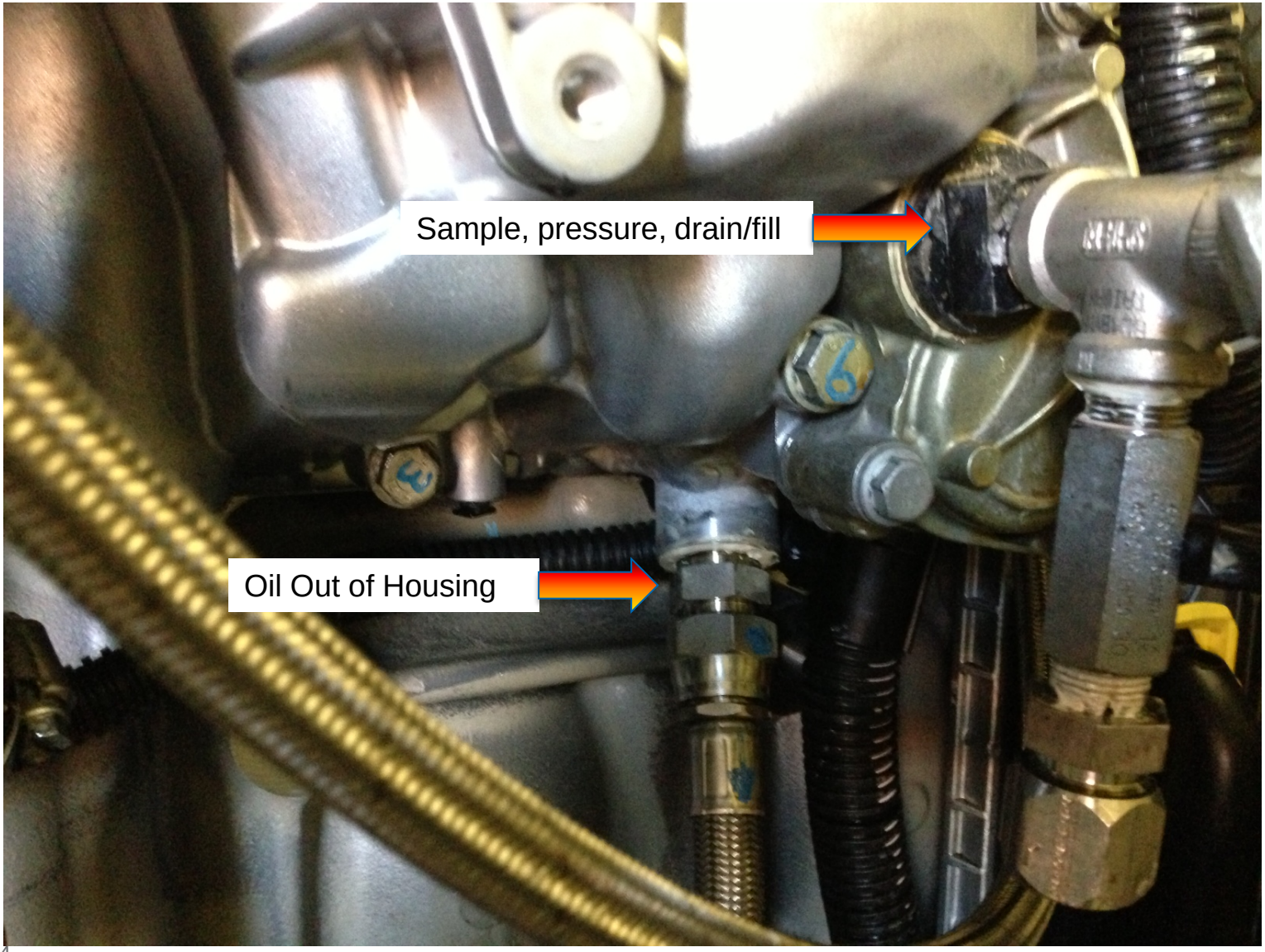

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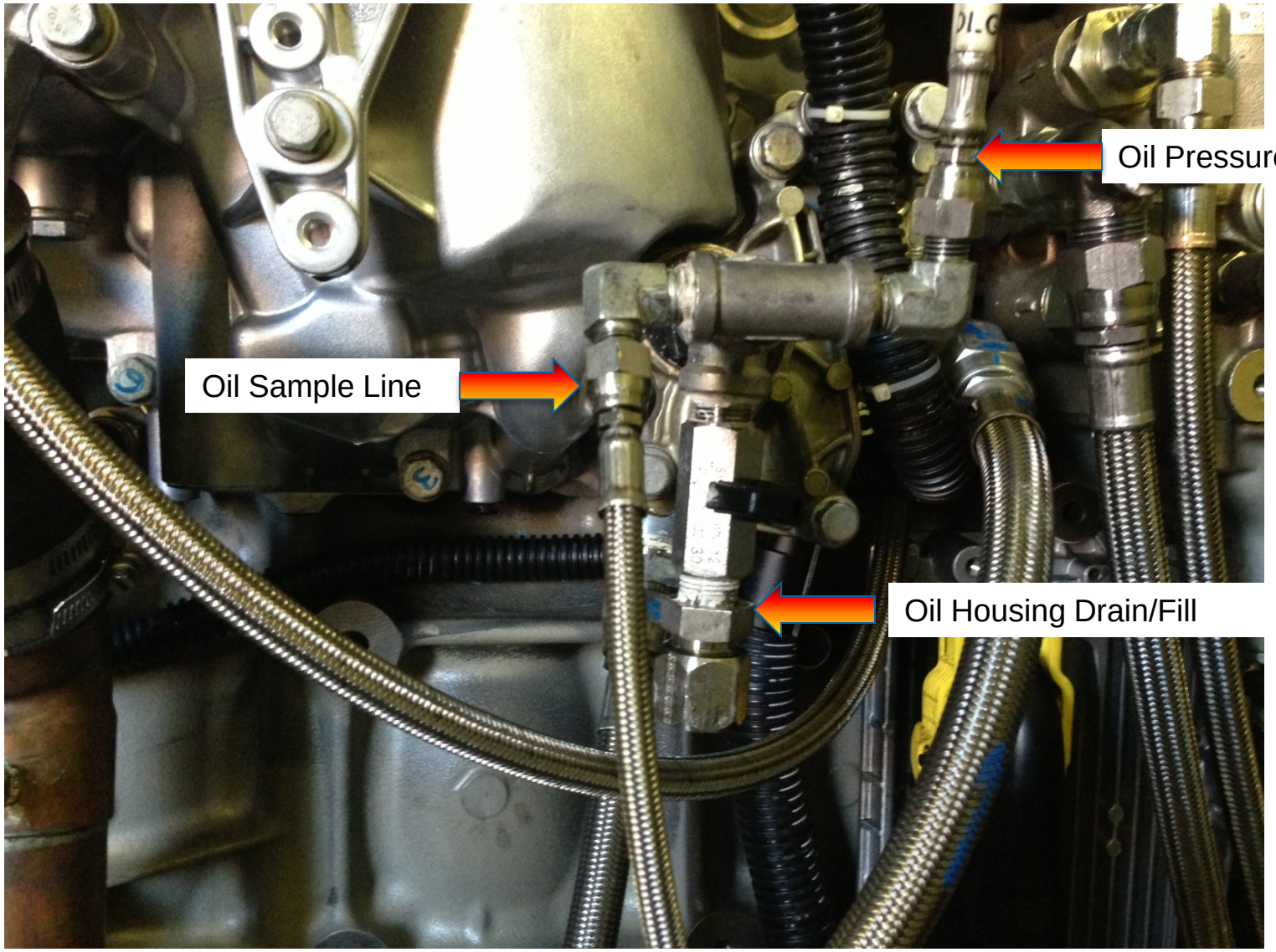
Oil Cooler Modifications

SUCCESS TOGETHER



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Next Steps

Next Steps

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- Run 2nd "Good" 2.9HTHS @ LZ
  - Run will commence once rings are available
- Continue to work with Intertek/SwRI on stand installation
  - SwRI install in progress
  - IAR shakedown in progress
    - Using "Poor" 2.9HTHS as shakedown oil
      - Potential data point if shakedown goes well
      - IAR will run their first actual test on the "Poor" 2.9HTHS oil
- Continue to work with TEI on parts supply
- Data Dictionary
- Schedule a DD13 build workshop @ LZ
  - September 2013?

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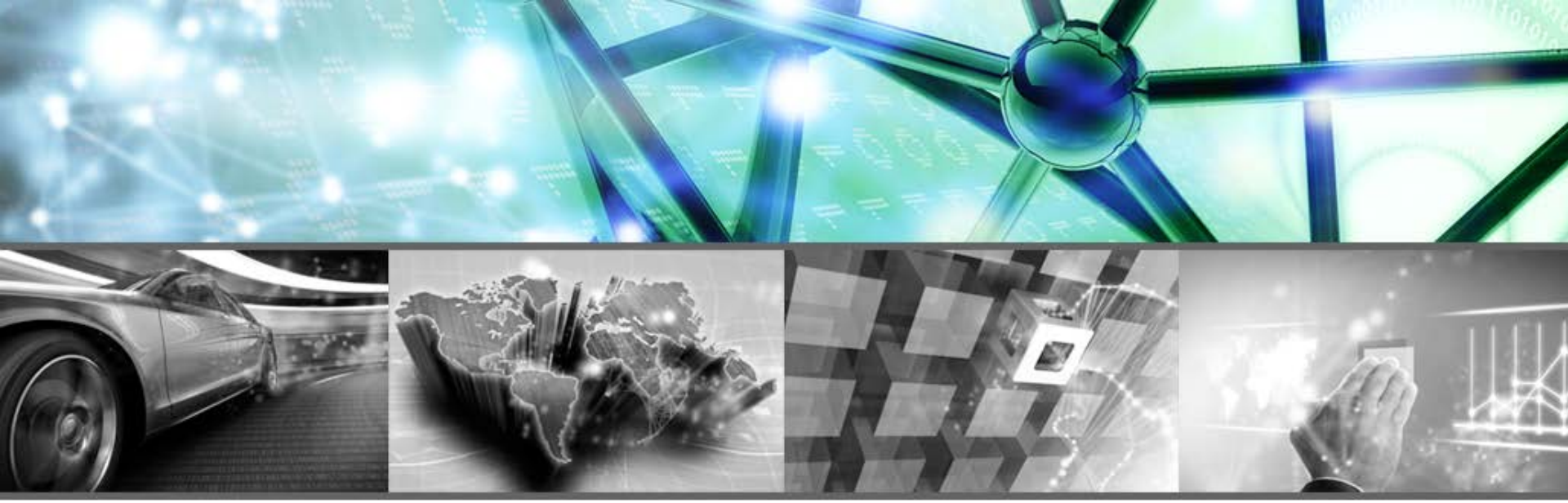

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Working together, achieving great things

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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