Sequence VH O&H Meeting + Sequence VJ Working Group
July 8th, 2026 at 3:00 PM EST via MS Teams

Attendees: Rob Zdrodowski, Christian Exposito, Tony Catanese, Joe Anthony, Dylan Beck, Angela Willis, Bill Du Chene, Jason Soto, Ben Maddock

Overview:

1. Hardware
2. Operation
3. VJ Working Group

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1. **Hardware**
    a. Inventory Life (as of December 2025)
        i. Lab A = ~2028
        ii. Lab B = ~2030
        iii. Lab D = ~2030
        iv. Lab G = ~2028

    b. Various hardware orders – FCS orders will be placed through TEI…. more details as they're available
        i. **Bishop Order 2026**
            1. Reached out to Adrian Ramirez to better grasp supply availability
        ii. **FCS Order 2026**
            1. TEI is working to populate the list with costs, lead times and minimum quantities.
        iii. **FCS Oil Pump order** in progress
            1. Afton supplied some to Intertek while TEI works on larger order

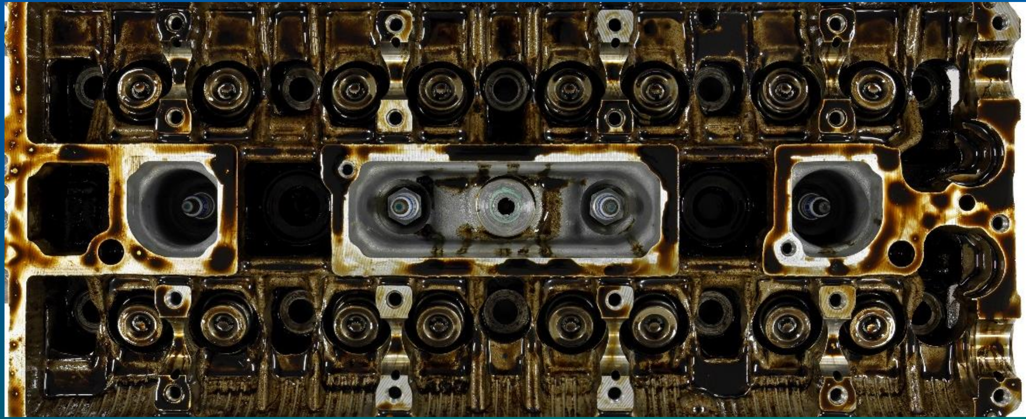
2. **Operation**
    a. ON HOLD until after M-000054-3 stats review - Tightened piston to bore clearance
        - Current: 0.020 to 0.046 mm
        - Proposed 0.030 to 0.038mm, average of all eight cylinders

3. **VJ Working Group**
    a. Ford announcement
    b. Lab updates
    c. Presentation
    d. Actions:
        i. Ben to create tracking sheet with topics
        ii. Ben to create stand configuration sheet with options to be discussed at next meeting
        iii. Labs to review ltms document and send any revisions or updates to Ben
            1. If available, please send your prelim sheets. I would like to expand the "ltms" document

O&H Historical Logbook

Date	Topic	Description	Comments
2/12/24	-	O&H formed.	
2/29/24	Hardware	Cam cap anaerobic sealant	IL24-1
3/5/24	Hardware	Cam bearings resolved with King Bearing supply to TEI.	Incl. SwRI bearing analysis
3/12/24	Fuel	N-000010-1+ CofA data integrity review.	Included lab samples to Saybolt
3/26/24	Fuel	Quarterly samples now from test cell	
4/9/24	Hardware	Piston oil hole size differences by piston size not statistically significant to APV	
4/16/24	Operation	Build Workshop conducted	IL24-3 and IL24-4
5/21/24	Fuel	AO content depletion in transit	
5/21/24	Operation	Honing data analysis uninterpretable due to measurement differences	This will be revisited after 2025 fuel approval matrix
6/4/24	Hardware	OHT3G-096-1 brushes explained	IIIG efforts
7/9/24	Operation	OSCR raters group imprecision reviewed	
8/27/24	Hardware	FCS order placed on pistons and rings	
8/27/24	Operation	N-10-1 approval vs PM statistical analysis	
1/7/25	Fuel	RVP adjustments vs fuel dilution	
4/29/25	Operation	Blowby Cart Questions - 5/16” orifice	Equation difference, ~0.1 L/min
8/19/25	Hardware	2024 FCS order has completed	
9/16/25	Operation	Engine Swap experiment Lab A & G	Fuel dilution moves with build
10/28/25	Fuel	M-000054-3 fuel batch approved.	
12/17/25	Operation	Updated report form to capture piston dia.	Version: 20251222
2/17/26	Operation	Severity alarms discussed ahead of Stats review	Some indication of RAC ICF. Other parameters are lab issues
2/17/26	Fuel	Fuel supplier feedback on ethanol, distillation and oxidation stability	O&H needs to summarize and create action plan
5/19/26	Fuel	Preliminary review of updated M-000054-3 stats analysis	No ICF is still appropriate

Sequence VJ

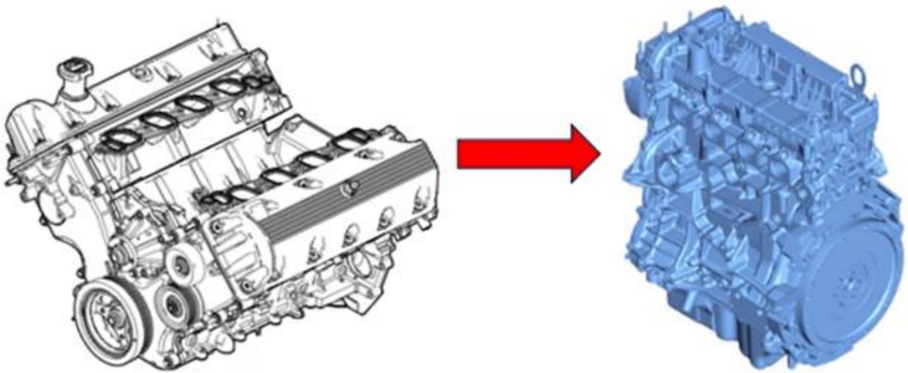


July 8th, 2026

Sequence VJ

Objective: Develop a replacement sludge and varnish test with the Ford 2.5L Maverick engine by December 2026. A successful completion includes adequate sludge severity, discrimination, and reproducibility across multiple labs.

- How did we get here?
- What are the current problems?
- Next steps



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Sequence VJ – Research Phase

- 7 results on RO 940 average 8.39 merits at 6.1% fuel dilution
- Test severity levers:
  - Test Cycle: Stage length, test duration, temperatures, loads, speeds, flows, lambda
  - Fuel type: Two suppliers
  - Engine & Stand Hardware: Pistons, oil squirters, PCM, blowby stack, fill volume
  - Build & Configuration: Cam timing, cylinder surface finish, ignition timing, injection timing, ring gaps

Lab	Batch	EOT	Duration	AES	RAC	AEV	APV	Ind	Average Fuel Dilution	Severity	Comments
Intertek	N-000010-18	4/22/2025	288	7.9	8.92	8.42	9.68	940	5.0%	Too mild	Extended due to mild 216h
Afton	N-000010-19	8/18/2025	216	9.02	9.1	9.27	8.62	940	12.0%	Too mild	Modified Stage 1, high fuel dilution but low NC
Intertek	E10	10/22/2025	126	6.89	7.8	8.51	-	940	4.5%	Concerning severe	Camshaft journal wear, terminated due to der
Lubrizol	N-000010-14	2/4/2026	174	8.68	9.24	9.435	9	940-1	6.0%	Encouraging	Low CR, terminated due to OC
Intertek	E10	2/4/2026	216	9.45	9.24	9.18		1011-1	4.5%	Surprisingly clean	Confirmed discrimination
Intertek	E10	4/10/2026	166	-	-	-	-	931	5.5%		Terminated due to derate
SwRI	M-000054-3	4/21/2026	288	8.16	8.81	9.06	1.88	940-1	5.5%	Mild sludge, severe APV	Cooler Stage 1 and 3 with additional timing ad
Lubrizol	N-000010-14	4/29/2026	216	8.85	9.28	8.17	6.84	940-1	6.4%	Mild sludge, severe APV	Cooler Stage conditions with low CR pistons
Afton	M-000054-3	4/29/2026	76	-	-	-	-	940-1	3.5%	Terminated due to OC	Cooler Stage conditions with low CR pistons +
SwRI	M-000054-3	5/8/2026	288	9.24				940-1	6.0%	Mild sludge	

* Data is from June 4th, 2026, table is available upon request.

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Mar ‘25 | Apr ‘25 | May ‘25 | June ‘25

Ford provides flashed PCM with modified fuel injection timing to match VG (420 ATDC)

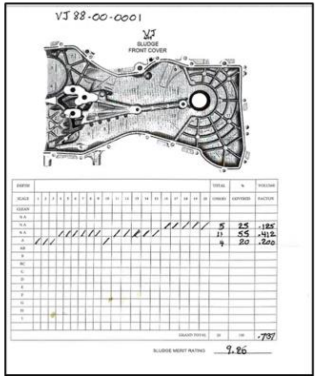
Lubrizol sets up stand with Haltech PCM

Intertek: N-batch & 940
Duration: 288h
AES = 7.9 merits @ 5% FD
Comment: Too mild

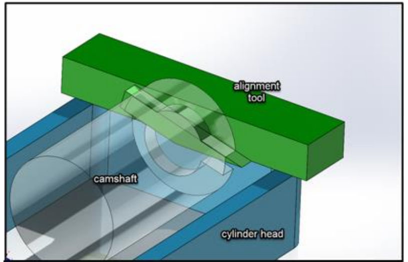
Lubrizol confirms fuel injection timing and defines linear relationship with NOx and spark timing

3	Condition	Stage 1	Stage 2	Stage 3	Control
4	Duration, min	120	75	45	
5	Engine speed, r/min	1750	3250	700	x
6	Engine power, kW	18	37	4.5	
7	Manifold abs press, kPa (abs)	65	67	70	
8	Engine oil in, °C	68	100	45	x
9	Engine coolant out, ° C	57	85	45	x
10	Engine coolant flow, L/min	40	70	28	x
11	Engine coolant pressure, kPa (gage)	70	70	70	x
12	RAC coolant in, °C	29	85	29	x
13	Rocker cover flow, L/min	12	12	12	x
14	Intake, air, °C	30	30	30	x
15	Intake air press, kPa (gage)	0.05	0.05	0.05	x
16	Lambda	1	1	0.75	
17	Blowby flow rate, avg, L/min	—		—	
18	Intake air humidity, g/kg	11.4	11.4	11.4	x
19	Exhaust back pressure, kPa abs	104	107	record	x
20	Fuel flow, kg/min	3.2	8.9	2	
21	Torque N/m	105	110	36	x
22	BMEP	5.2	5.5	2	

Ford matches BMEP between 4.6L and 2.5L



Intertek develops rating forms



Lubrizol intake cam advanced to convert from Atkinson cycle to Otto

SwRI working to confirm ring gap and blowby relationship

Seq VH M-000054-3 Fuel Batch approval matrix ongoing...

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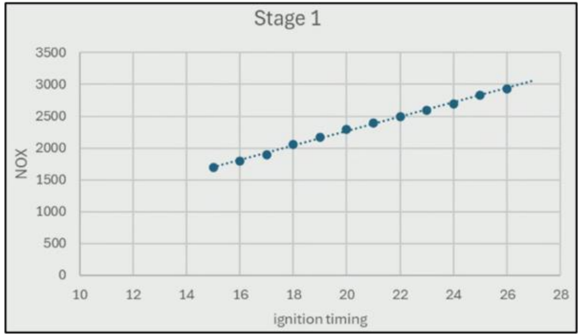
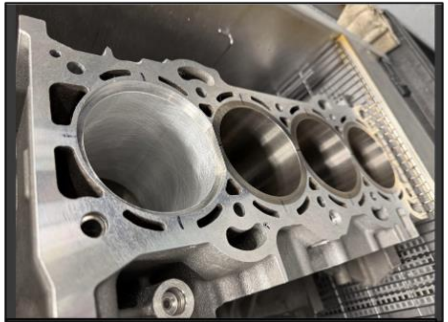
June '25 | Jul '25 | Aug '25 | Sept '25

Fuel dilution experiments with cam timing and test cycle changes: 2 to 12% range



Intertek working with alternate fuel supplier

Ford working to acquire oversize pistons via OE-supplier



Sleeved blocks considered

Afton: N-batch & 940
Duration: 216h
Modified test cycle
AES = 9.0 merits @ 12% FD
Comment: Too mild

Lubrizol stand visit to observe Haltech, sleeved block and discuss development status

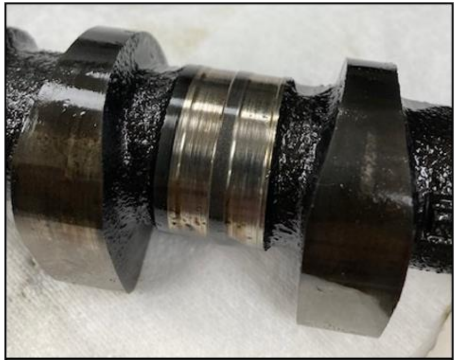
Lubrizol working with Wiseco to develop forged low CR piston

Seq VH M-000054-3 Fuel Batch approval matrix ongoing...

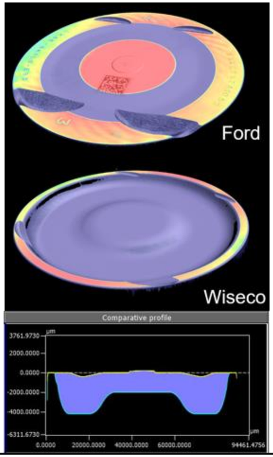
Sept '25 | Oct '25 | Nov '25 | Dec '25

Intertek: E10 & 940
Duration: 126h
AES = 6.9 merits @ 5% FD
Comment: Too severe

Labs made little progress during this time due to M-000054-3 fuel batch approval



Intertek E10 fuel cam damage



Ford approved low CR piston approach

Ford abandoned effort with OE piston supplier due to lack of response

Seq VH M-000054-3 Fuel Batch accepted October 28th, 2025

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Jan ‘26 Mar ‘26 May ‘26 July ‘26

Lubrizol: N-batch & 940-1
Duration: 174h
Low CR pistons
Terminated due to OC (2000g)

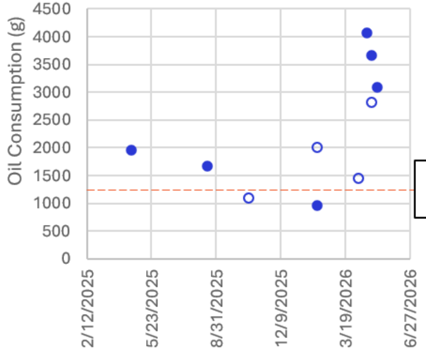
Intertek: E10 & 931
Duration: 166h
Terminated due to derate

Intertek: E10 & 1011-1
Duration: 216h
AES = 9.5 merits @ 5% FD
Comment: Very clean result

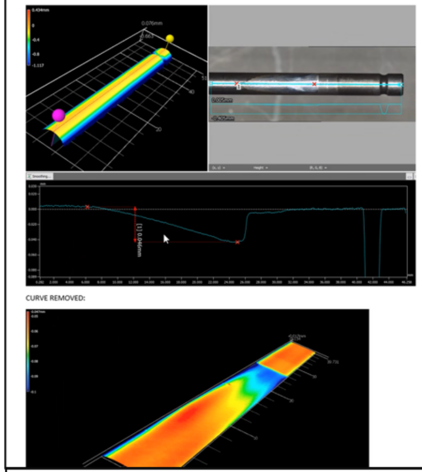
SwRI: M-batch & 940-1
Duration: 288h
Cooler temps
plugged oil squirters
high timing advance
AES = 8.1 merits @ 6% FD
Sludge too mild
Very severe piston varnish
Excessive OC at 4061g

Lubrizol: N-batch & 940-1
Duration: 216h
Low CR pistons
Cooler temps
Mild sludge, severe APV
Excessive OC at 3666g

Afton: N-batch & 940-1
Duration: 76h
Modified test cycle
Low CR pistons
Excessive OC at 2800g



Typical VH OC = 1200g



Valve stem wear identified

Blowby stacks under scrutiny
with good collaboration among
labs to trial out new setups

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Sequence VJ – Summary

- Labs correctly divided up the work in pursuit of test severity while navigating a VH fuel batch approval
- Recent results have significant oil consumption across multiple stand configurations
- Commonize best practices and remove degrees of freedom
- Hardware is a concern with no obvious solution identified

Sequence VJ Development
Test 3 Results

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Christian Exposito
Sr. Research Engineer

Reminder of what this run is:

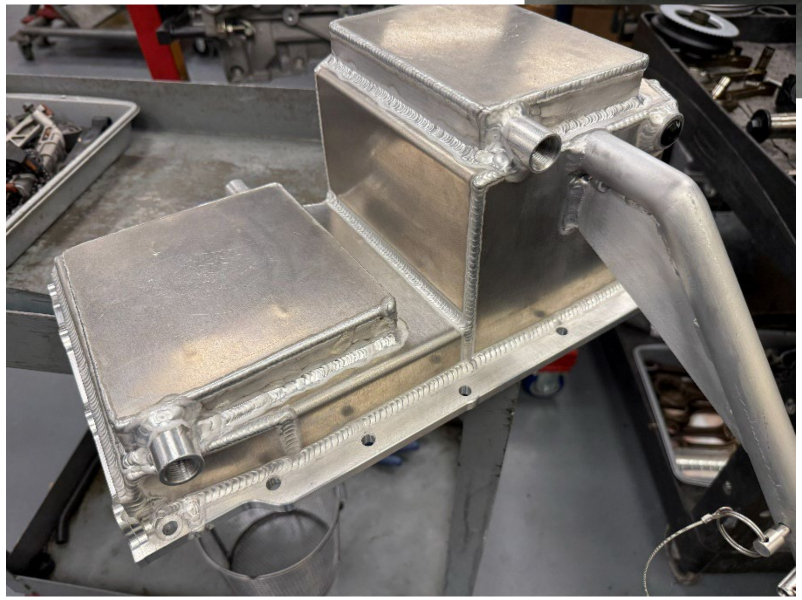
- New stock engine rebuilt (#5)
  - Stock pistons, piston squirters, and hone
  - TEI RAC
  - Water cooled oil pan prototype
  - Haltech ECU with cam timing modifications
    - Updated fuel trim for more stable engine control
  - Lambda using test stand calibrated Horiba O2 Sensor fed into Haltech
- Long ¾" Tygon tube at a 45° angle going to IIIH JTEC Separator for oil separation
  - About 6 feet long before separator without returning to intake
  - Condensate and oil returning to engine
- Stage modifications and Ignition timing
- M-000054-3 fuel
- 940-1 reference oil
- Engine was cleaned prior to reassembly

Piston #	Ring Gaps
1	106/110
2	105/111
3	105/112
4	106/111

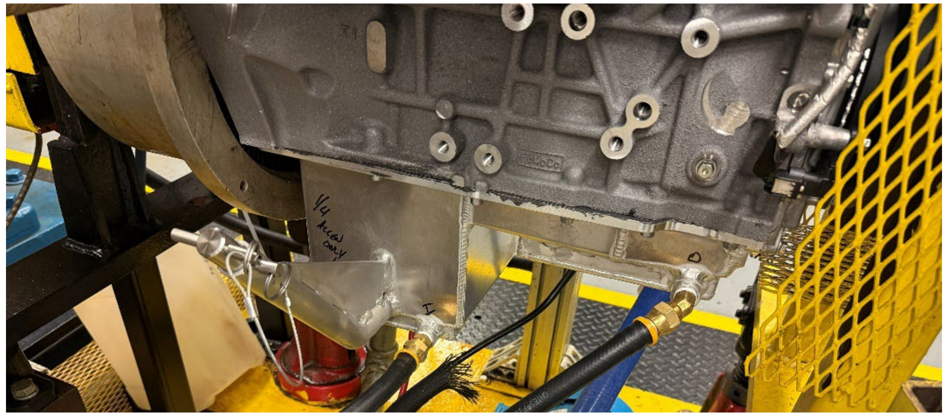
Cylinder	Ø at Window (mm)	Average bore Ø (mm)	Piston to cylinder clearance (mm)
1	88.965	89.000	0.035
2	88.958	88.997	0.039
3	88.964	88.998	0.034
4	88.965	89.000	0.035

Water Cooled Oil Pan

- Esslinger Engineering RWD Swap Oil Pan
- 2 Cold baffled blocks added on lower and upper surfaces
  - Flow in series from lower pan to upper
  - Entire oil charge fits in lower sump
- OHT dipstick fitted to pan for oil level
- Stock pan has issues with welding due to oil impregnation
- Goals:
  - Shift some of the oil cooling to a rated part
  - Offset heat from reintroducing piston squirters



Source: esslingeracing.com



Picture missing control TC

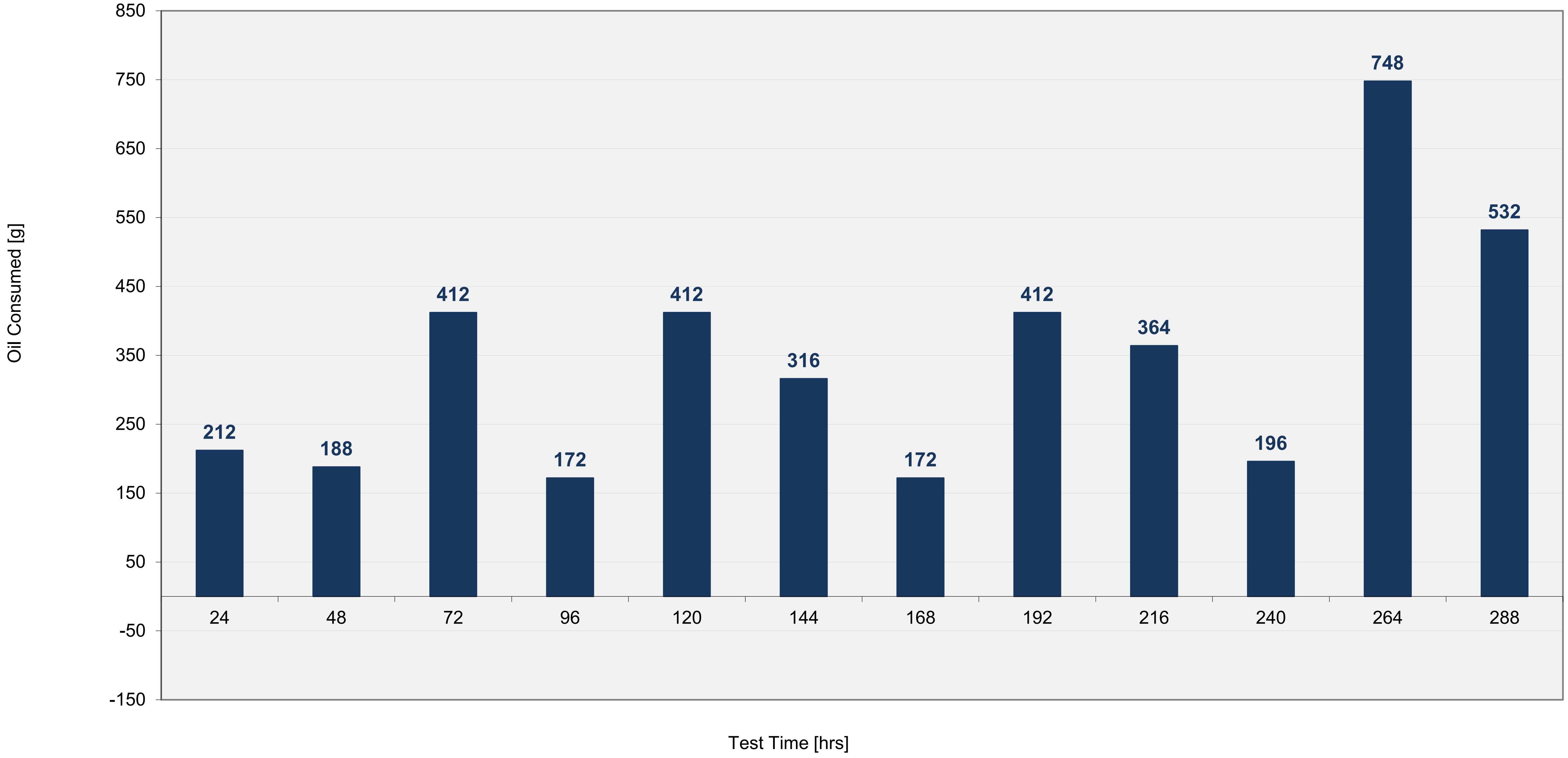
Operational Conditions

Condition	Stage 1		Stage 2		Stage 3	
	VJ Orig.	SwRI	VJ Orig.	SwRI	VJ Orig.	SwRI
Duration, min.	120	120	75	75	45	45
Engine speed, RPM	1750	1750	3250	3250	800	800
Engine Oil in, °C	68	58	100	100	45	40
Engine coolant out, °C	57	45	85	85	45	40
Engine coolant flow, L/min.	40	120	70	120	28	120
Engine coolant, kPag	70	70	70	70	70	70
RAC coolant in, °C	29	25	85	85	29	25
Rocker flow, L/min.	15	15	15	15	15	15
Intake. air, °C	30	30	30	30	30	30
Intake air press, kPag	0.05	0.05	0.05	0.05	0.05	0.05
Lambda	1	1	1	1	0.75	0.75
Intake air humidity, g/kg	11.4	11.4	11.4	11.4	11.4	11.4
Exhaust back pressure, kPaA	104	104	107	107		
Spark Timing, degrees	25	33	25	35	25	20
Torque, N/m	105	105	110	110	36	36
Oil pan water flow rate, L/min.		15		15		15
Oil pan water out, °C		40		40		40

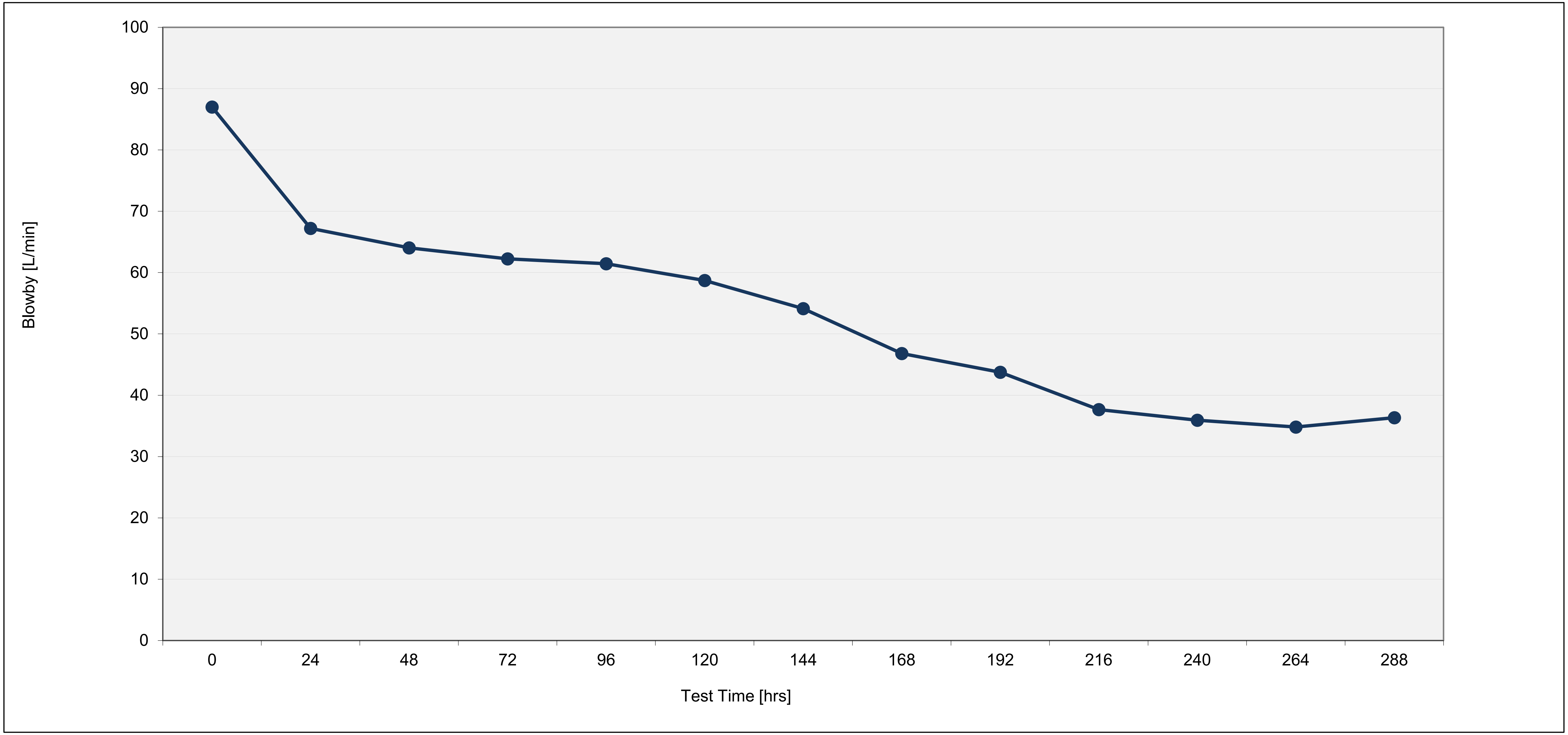
Operational Summary

- Initially planned on running different oil pan cooling temperatures in each stage.
  - First cycle showed 40°C had intended impact of removing piston squirter oil heat in stage 2 at 40°C with a similar oil out temperature to VH.
  - Considering this is to the lower end of coolant control temps, we decided to simplify controls and left setpoint at 40°C for all stages.
- Overall still seeing an oil consumption issue (4136 grams)
  - Observation of operation during stage 2 showed small oil droplets making about 4 ft up the tube, but no oil identifiable in separator drain or pcv exhaust.
  - Initially lower oil consumption was promising.
- Oberg cleaned several times
  - Water cooled oil pan pickup tube off the bottom more than OHT pan, which should reduce pickup of particulate off the bottom
  - Potentially something a baffle over the main sump may help resolve (minimal direct drain back)

High Oil Consumption – 3776 grams added



Blowby – Average 50.26 l/min.

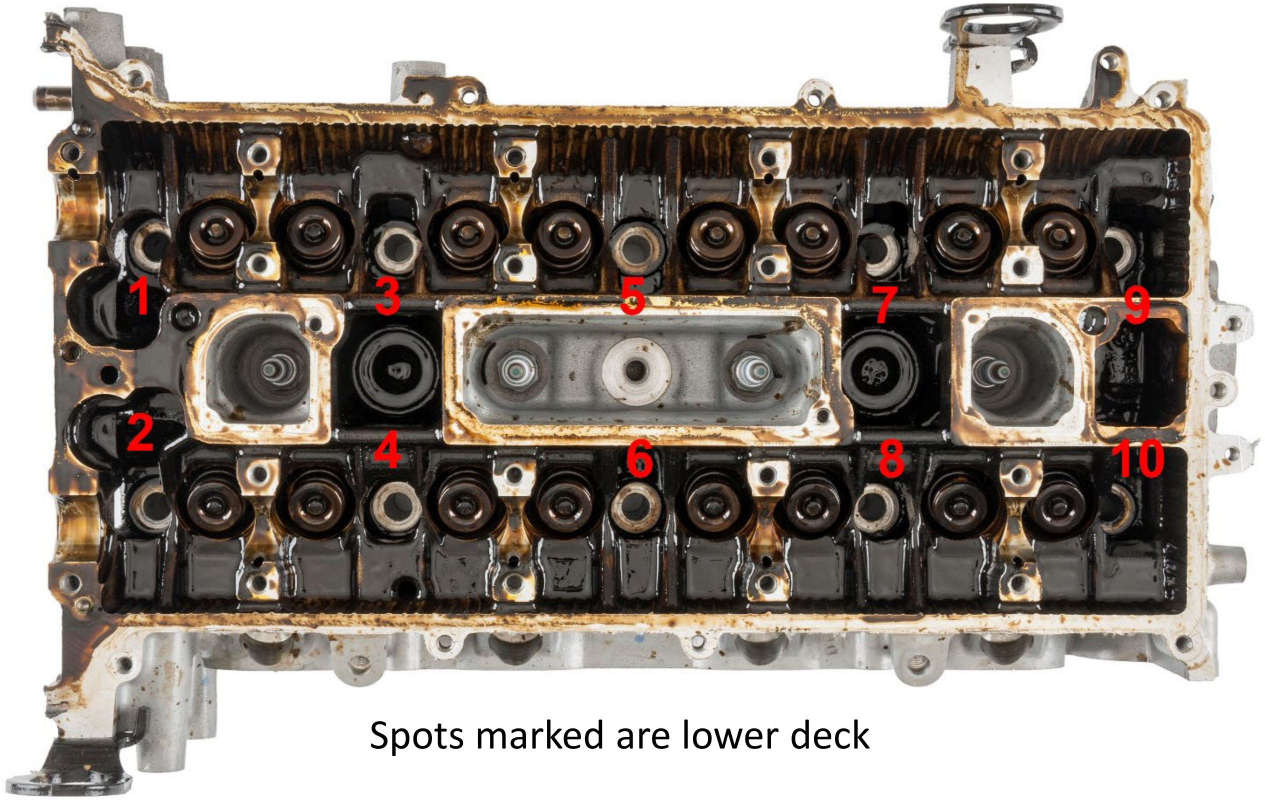


Chem Data Detail

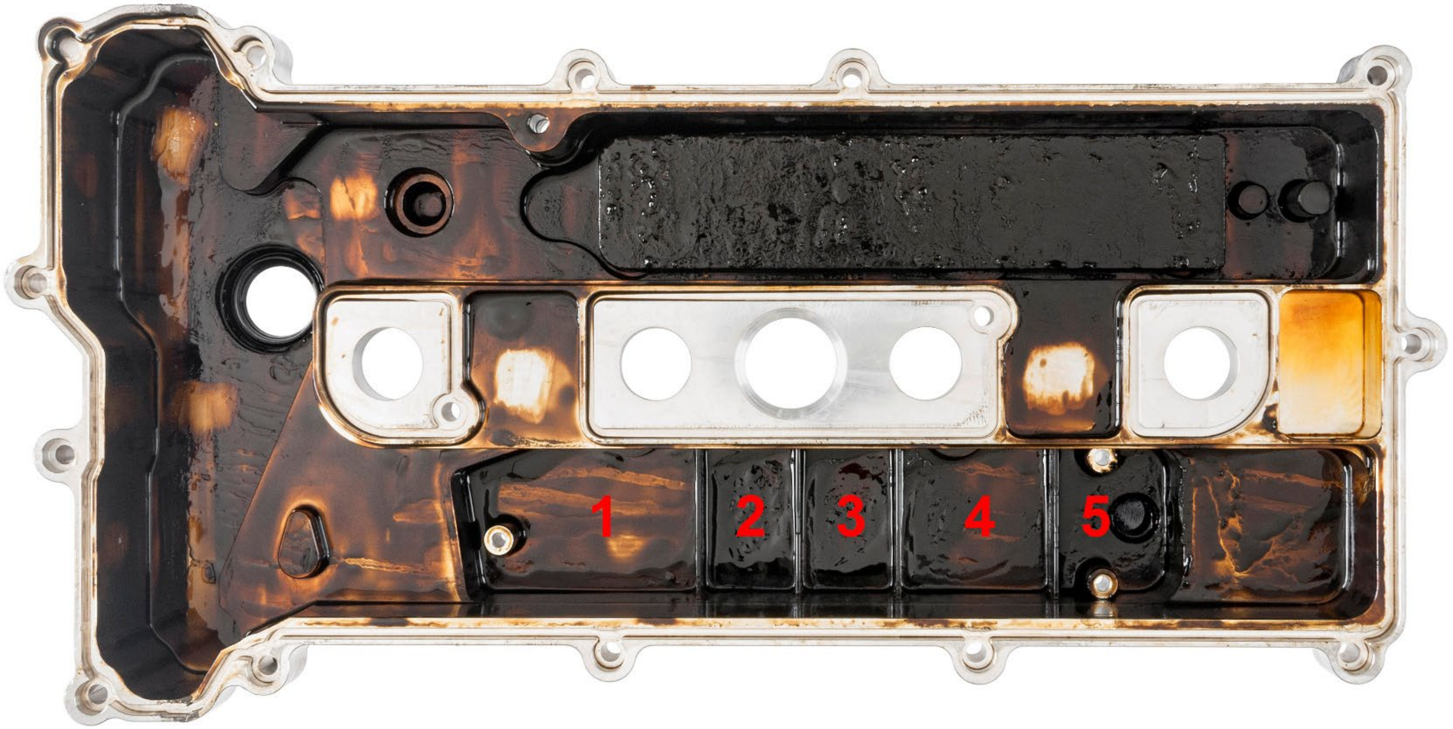
ASTM Method	Analysis Description	Units	0	24	48	72	96	120	144	168	192	216	240	264	288
D445	Kinematic Viscosity @ 100°C	cSt	10.68	7.68	7.64	7.96	8.14	8.76	9.19	12.46	27.84	41.63	48.04	56.55	32.84
	Kinematic Viscosity @ 40°C	cSt	64.34	41.96	40.50	45.10	46.19	50.44	59.73	66.34	61.64	96.42	115.08	111.26	85.97
D3525-M	Fuel Dilution	wt. %		6.0	6.9	7.1	7.2	6.8	7.8	7.2	7.9	7.2	7.3	7.4	6.9
D5185 (ICP)	Al	ppm	<1	10	13	19	21	25	25	27	29	30	31	35	32
	Sb	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Ba	ppm	<1	4	4	4	4	3	3	2	2	2	2	2	1
	B	ppm	<1	1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1
	Ca	ppm	2311	2206	2157	2084	2111	2031	1990	2019	1966	1966	1922	1823	1822
	Cr	ppm	<1	<1	<1	1	2	2	3	3	4	5	5	6	6
	Cu	ppm	<1	44	45	46	44	42	37	34	32	28	25	23	19
	Fe	ppm	<1	46	66	103	123	161	175	200	238	261	280	315	298
	Pb	ppm	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Mg	ppm	5	7	7	8	9	8	9	8	8	8	9	8	8
	Mn	ppm	<1	4	5	6	6	6	6	6	6	5	5	5	4
	Mo	ppm	39	37	34	34	33	33	32	32	31	31	31	30	31
	Ni	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	P	ppm	728	679	639	639	624	612	605	604	606	596	596	576	594
	Si	ppm	4	26	26	28	24	24	22	20	20	18	18	18	16
	Ag	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Na	ppm	<5	8	9	12	9	9	7	6	6	<5	<5	7	7
	Sn	ppm	<1	<1	<1	<1	<1	1	1	1	2	2	2	2	2
	Zn	ppm	789	740	699	713	705	696	679	672	676	666	663	631	642
	K	ppm	<5	8	8	10	9	9	7	7	6	6	5	<5	<5
	Sr	ppm	<1	<1	<1	1	1	1	1	1	1	1	1	1	<1
	V	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Ti	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Cd	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
D4739	TBN	mg KOH/g	6.77	4.08	1.87	0.82	0.60	0.42	0.40	0.34	0.17	0.18	0.20	0.03	0.20
D893B	Pentane Insolubles	% weight		0.11	1.67	2.67	3.20	4.32	4.65	5.16	5.32	5.52	6.15	6.57	5.93
FTIR	Oxidation (peak)	ABS/cm^2		40.1	284.2	490.2	604.5	931.9	981.1	1064.3	1364.4	1398.7	1475.3	1644.9	1453.8
	Nitration (peak)	ABS/cm^2		8.3	54.2	155.5	279.7	865.2	872.5	968.6	1044.4	1067.6	1096.2	1142.4	1070.7
	Oxidation (area)	ABS/cm^2		5.9	27.1	44.8	52.7	62.5	65.4	71.1	79.4	79.7	80.8	86.1	77.7
	Nitration (area)	ABS/cm^2		1.5	5.7	5.8	21.5	33.8	37.0	41.3	47.4	49.2	51.4	56.3	51.4
D6304C	Water	mg/kg	240	358	702	814	778	715	730	688	739	718	683	590	675
D5762	Nitration	µg/g	525	1011	1639	2247	2579	3100	3265	3492					

Sludge Ratings

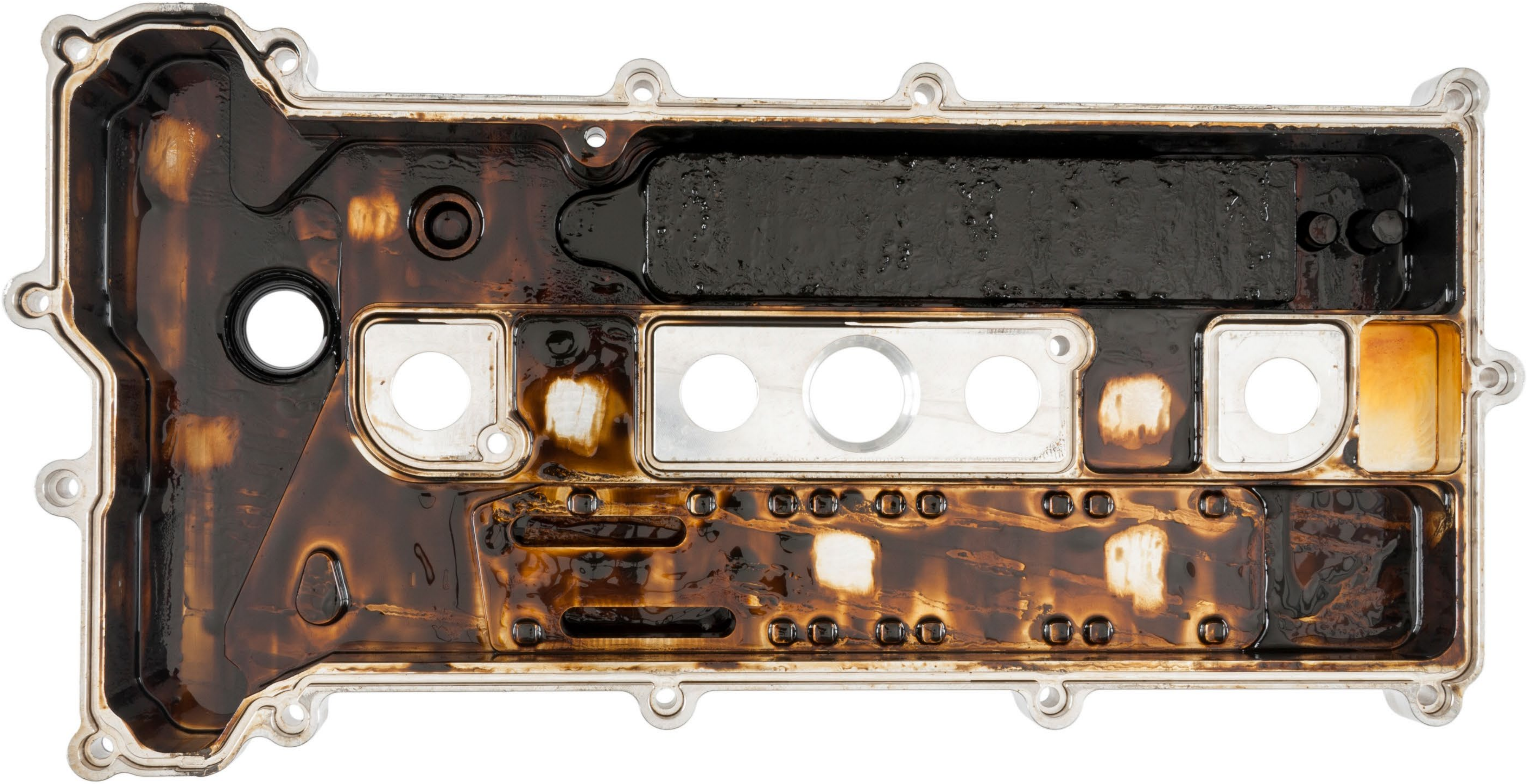
Sludge			Sludge Extra (new areas considered new parts)	
Front Cover	8.41		Rocker Cover (21)	8.66
Rocker Cover	8.64		Rocker Cover Baffles (5)	6.65
Oil Pan	5.74		RAC Baffle Plate (5)	5.55
Valve Deck Upper	7.15		Valve Deck Lower (10)	5.32
Block Front	6.84			
PCV Gallery	8.27			
ASTM Round	7.51	**AES**	ASTM Round	6.95 **AES**



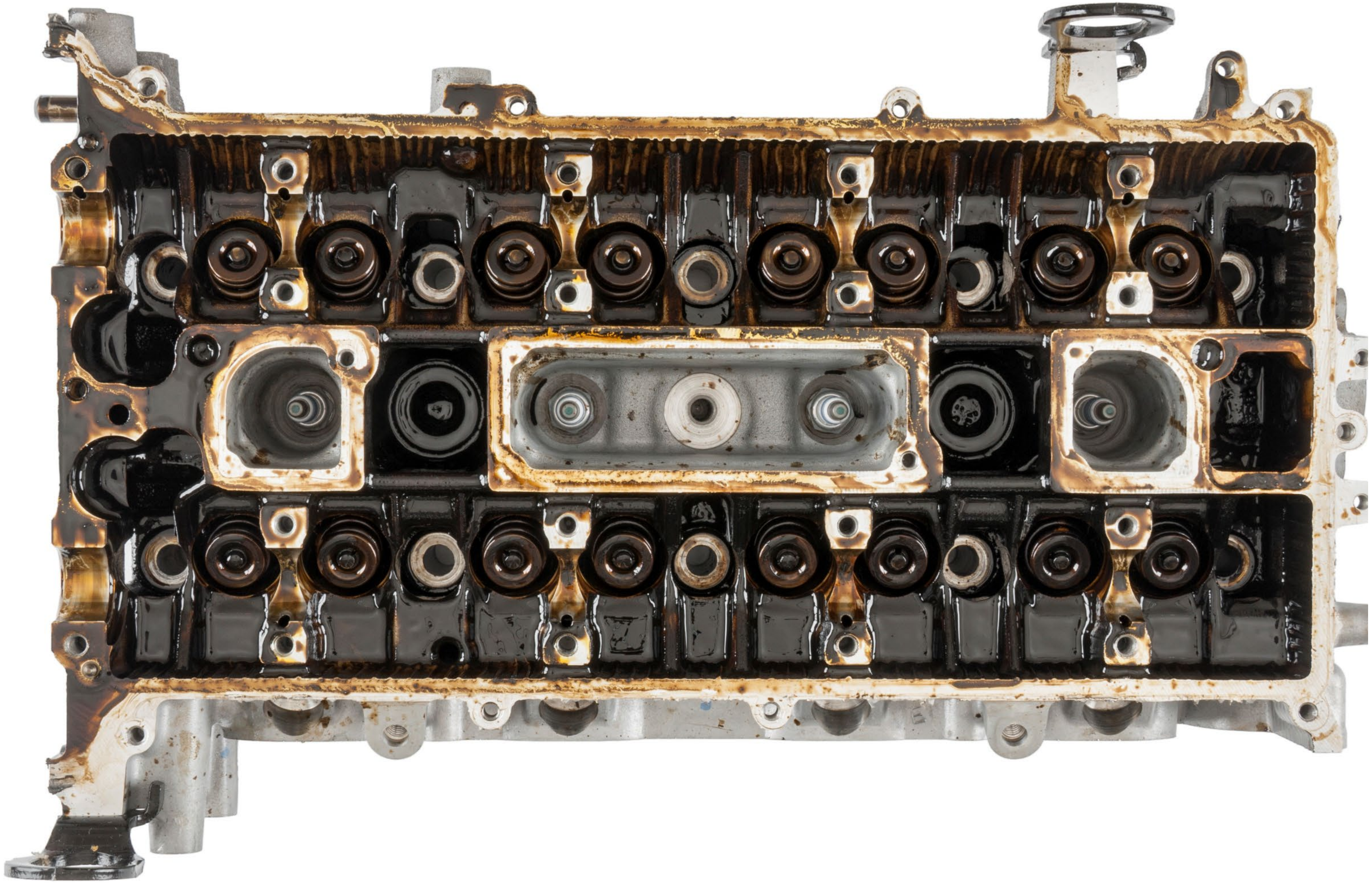
Spots marked are lower deck



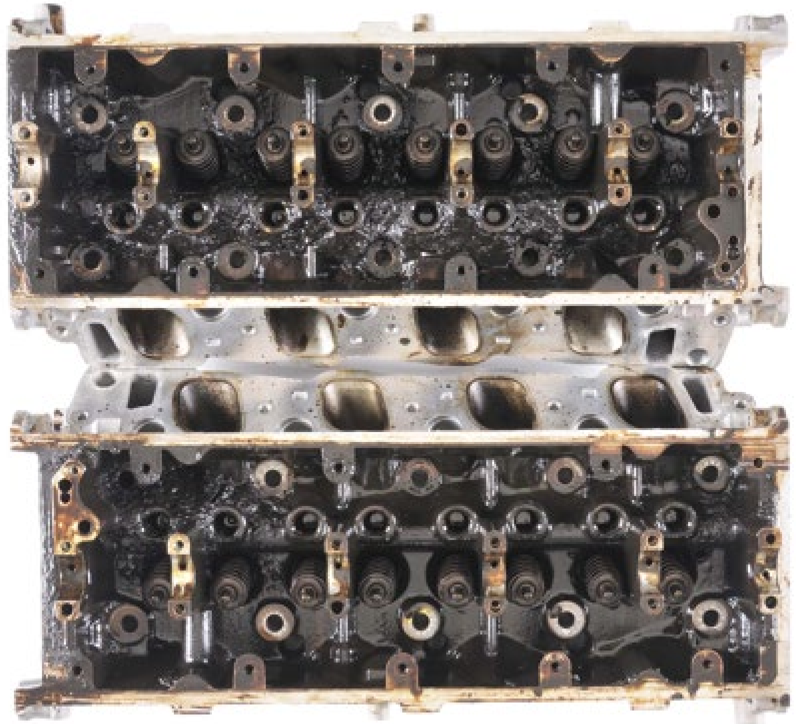
EOT Rocker Cover



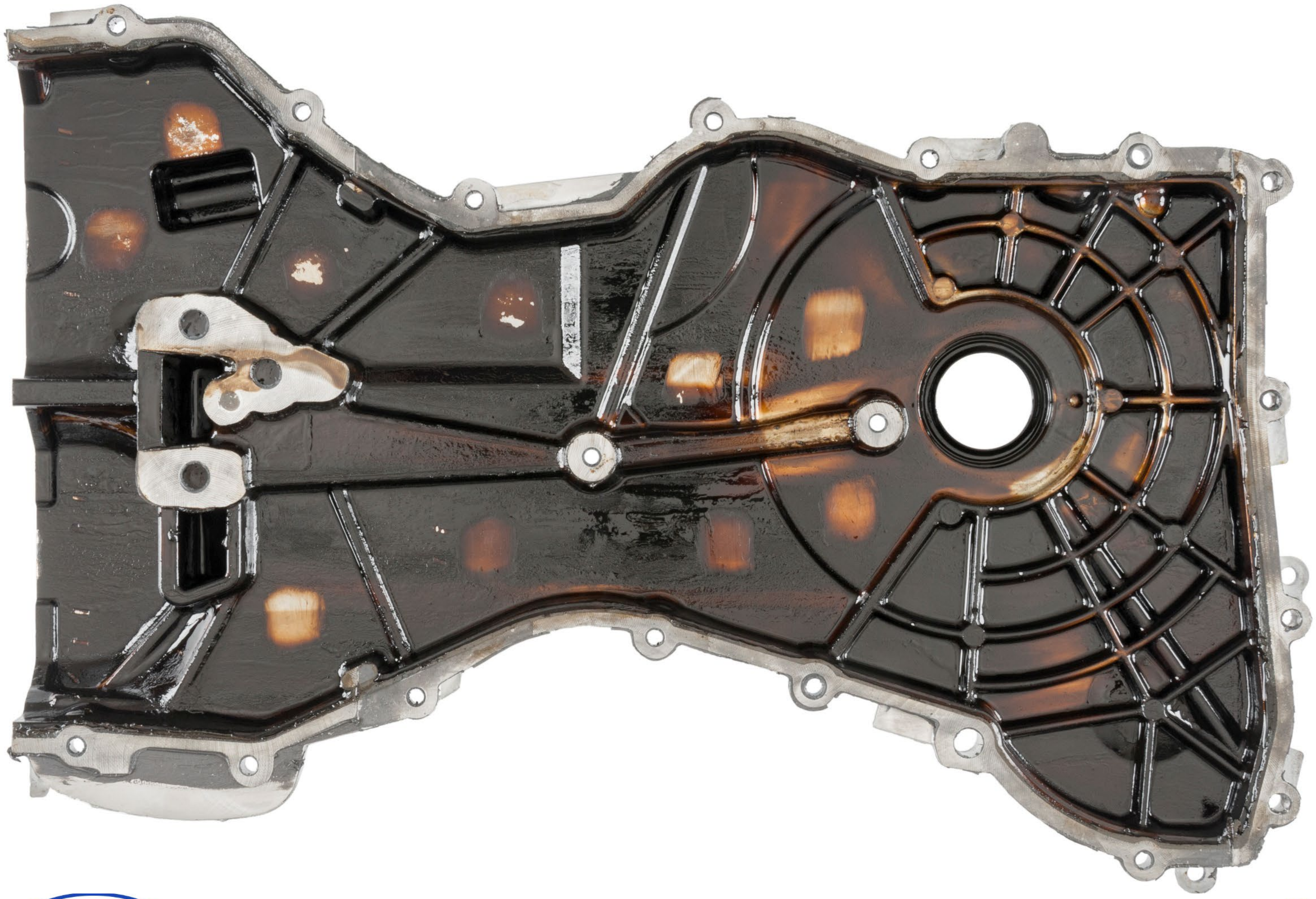
EOT Valve Deck



VH 940

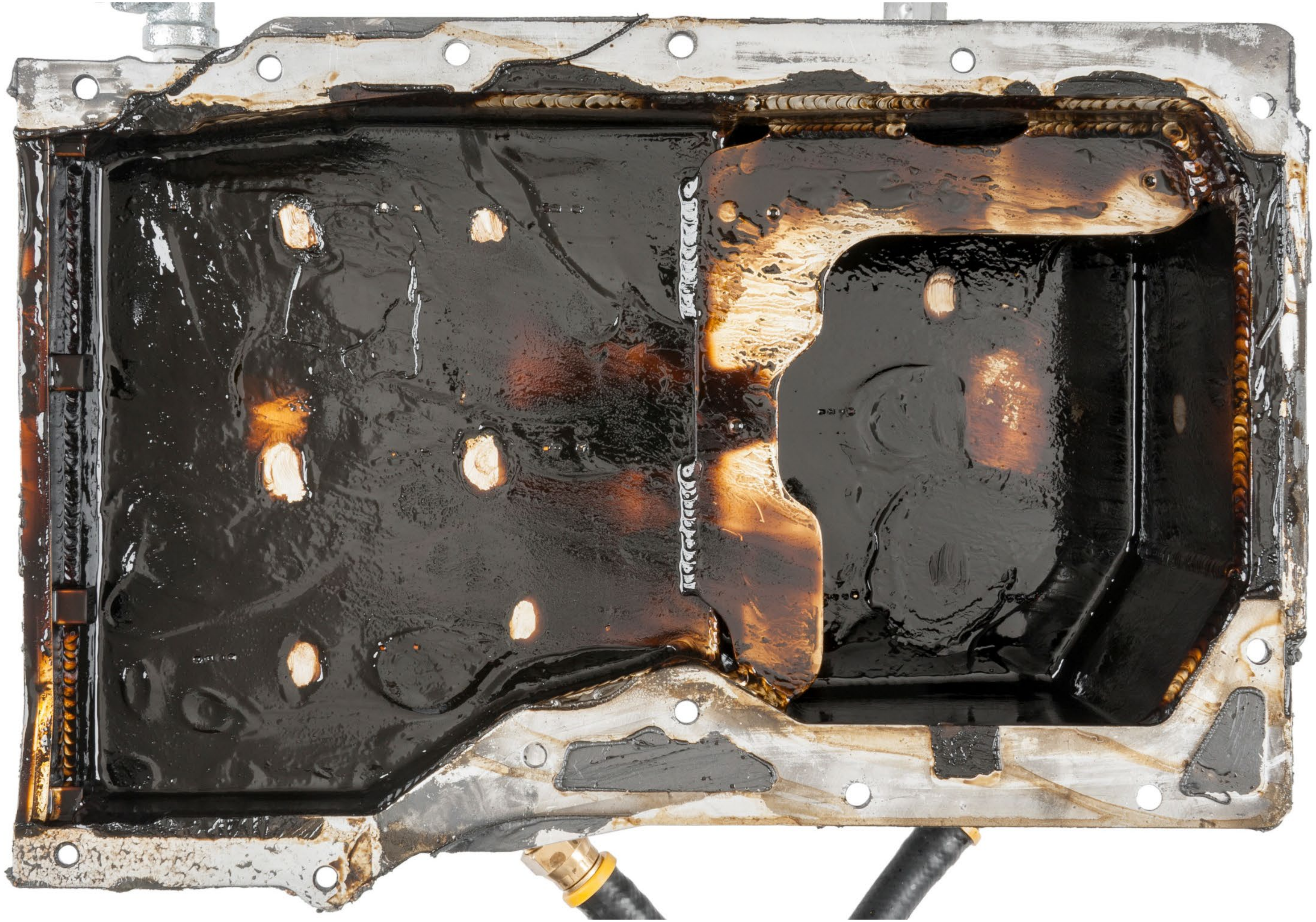


EOT Timing Chain Cover

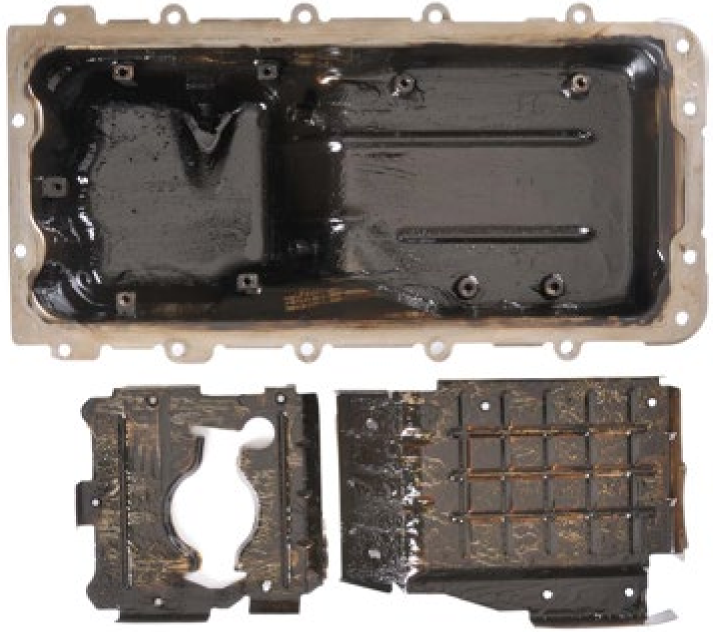



VH 940

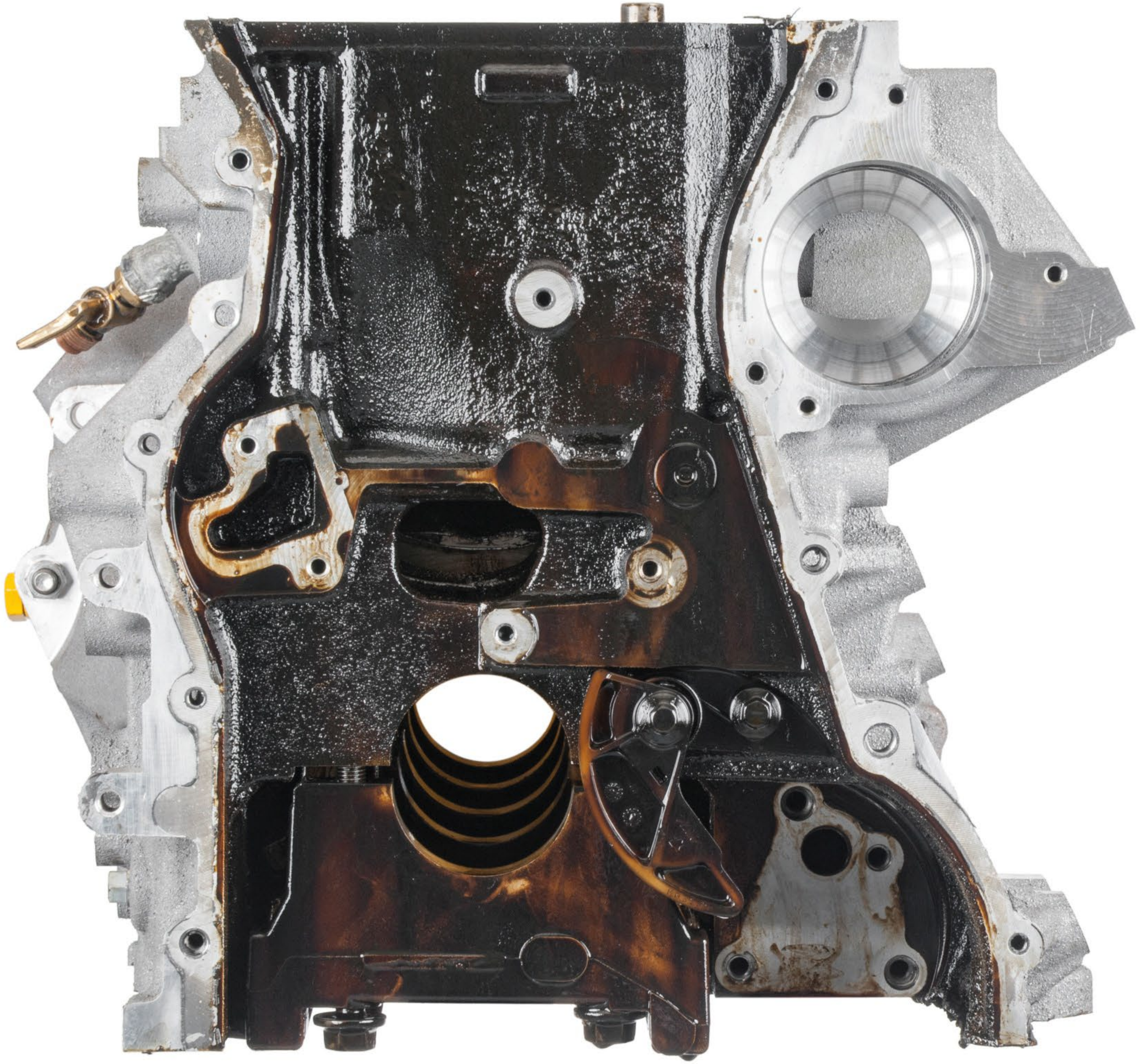
EOT Oil Pan



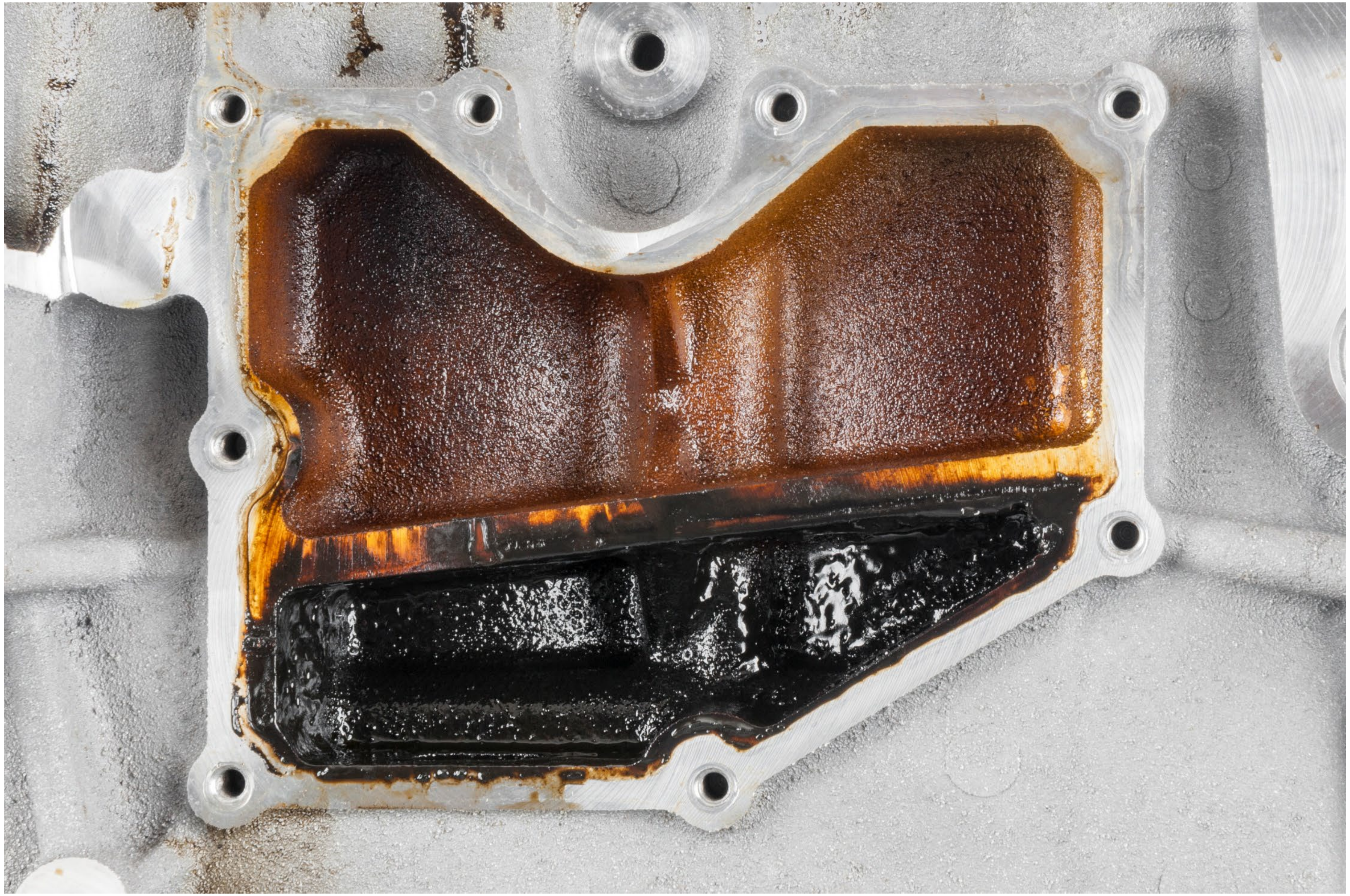
VH 940



EOT Block Front



EOT PCV Gallery



EOT Rear Cover

VH 940

EOT VVT Solenoid

Cams

Varnish and Pistons

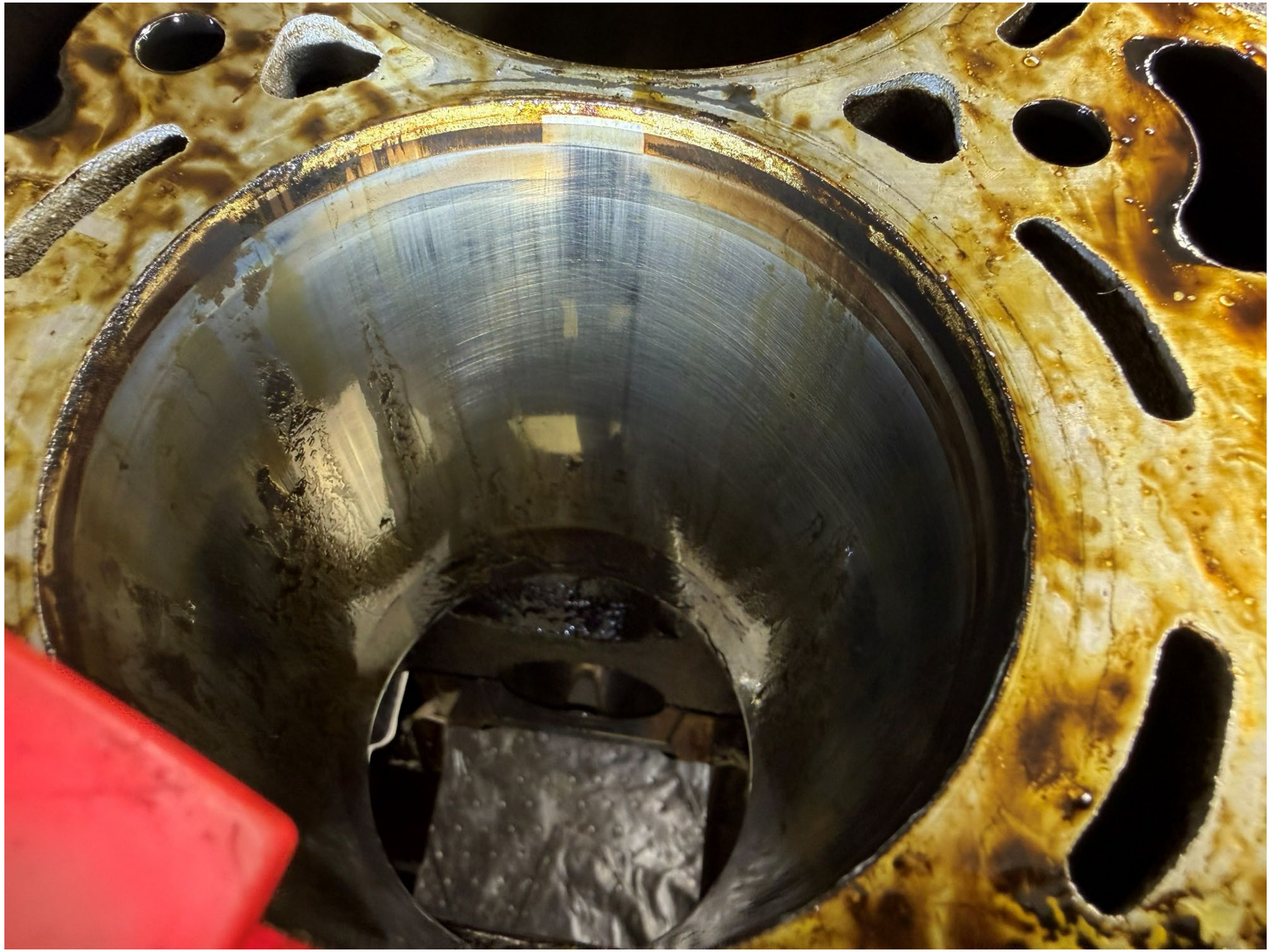
- Front Cover: 5.23
- Rocker Cover: 7.92
- Oil Pan: 7.86
- AEV: 7.00

- WPD improved from 1.88 to 3.14
- No stuck rings, but one hard deposit on piston 1
- Still no significant skirt varnish apparent
  - Continuing with IIIH rating method for now

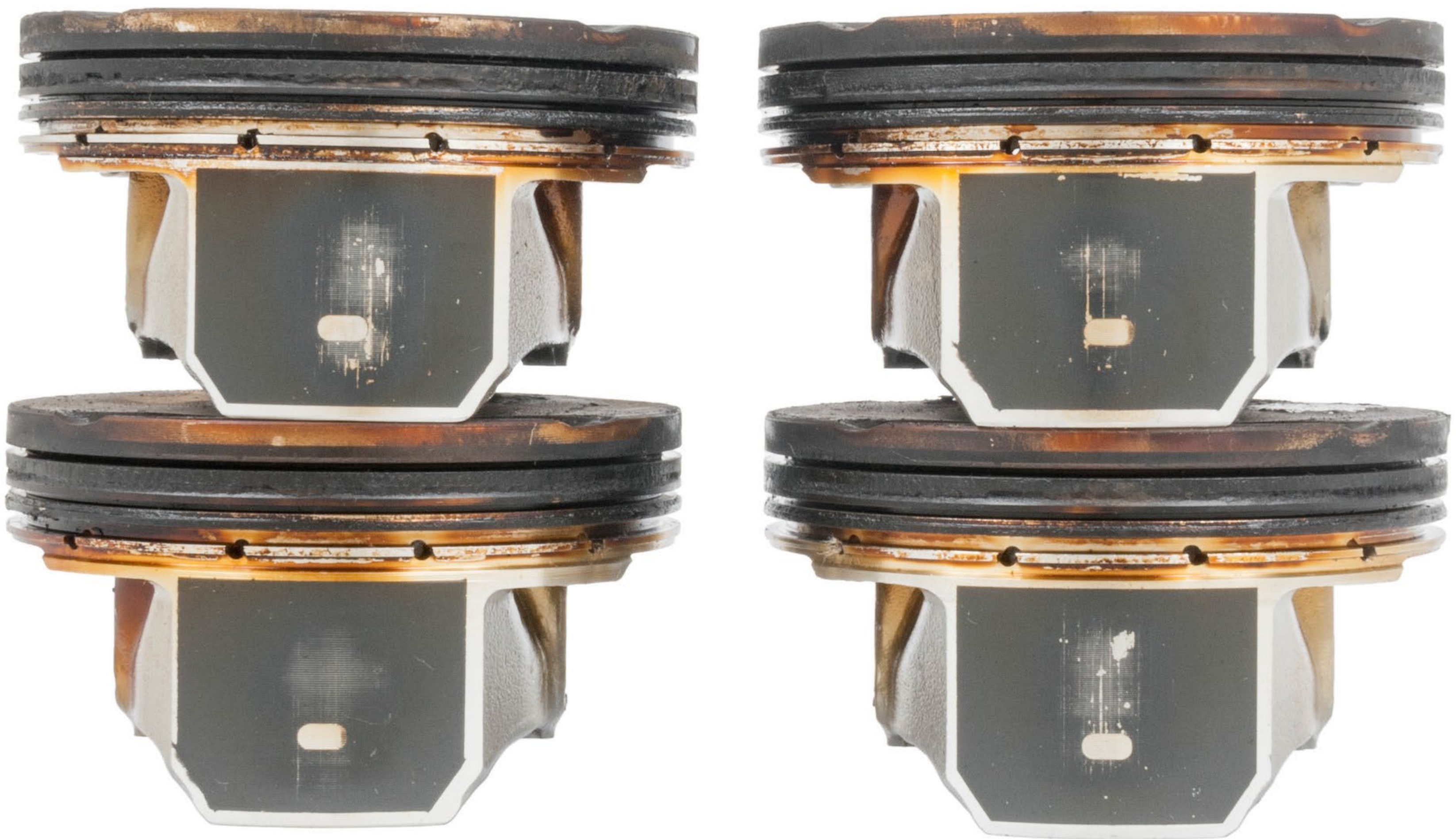
Un-Weighted Pison Deposits								
	Grooves			Lands		Undercrown	Piston Boss Varnish	
	1	2	3	2	3		Front	Rear
Piston 1	0.75	1.56	5.86	1.23	1.91	4.70	8.08	8.42
Piston 2	1.60	0.82	4.55	1.05	1.20	4.75	7.70	9.30
Piston 3	1.01	1.08	6.14	1.14	1.22	5.25	8.52	9.00
Piston 4	1.02	0.71	4.41	0.99	1.68	3.85	7.90	9.23

Weighted Piston Deposits	
	Merits
Piston 1	3.42
Piston 2	2.91
Piston 3	3.32
Piston 4	2.90
Average	3.14

Hard deposit bore polishing



EOT Pistons



EOT Pistons

VH 940

EOT Pistons

EOT Pistons

EOT Pistons

Intake Valves

Discussion of Results

- This test is very close in our opinion, if we can fix oil consumption, we expect this would be severe of target at 288 hours.
  - Potential to return to 216 hours if oil consumption resolved.
- Oil pan cooling worked as expected
  - Need to transition away from prototype to a long term, more standardized part available to everyone
  - Emphasized the need to remove heat where we can in ratable areas, also <u>need cooled exhaust</u>
  - Proposing current vendor for VH (TEI) to build water cooled exhaust and the modified oil pan.
    - SwRI can work on providing parts if they agree to work on this.
    - Would prefer input from W.G. on both parts.
- Oil consumption appears to be from the rings
  - Suspicion that larger gaps are aggravating the OEM rings that have no indicated field consumption issues
  - Would Ford support Wiseco modifying the rings and grooves on the factory oversize to be thicker/higher tension? i.e. something more similar to the VH rings

Direction forward

- Next test to include same build parameters as this test including oil pan
- Adding Ford recommended break in
  - Clarification of what RPM Ford considers Idle
    - All mapping data shows down to 1000 RPM
    - Should we also modify stage 3 to 1000 RPM?
  - Going to try to control all temperatures to stage 2 for now
  - Oil full level established at end of break in, per George's recommendation
- Reduce spark timing in Stage 1 and 2 to 30°
- Heat shield exhaust for now
- Reverse coolant flow to cool head more, need Ford input on if this is possible
- Introduce chain wear heat exchanger on PCV to help oil separate
  - Originally was planning on a cooling block on the top of the RAC baffles, again to shift it to a rate-able area
    - Ben convinced me to compromise to the chain wear setup
  - In series with RAC circuit
  - Return RAC temp to 29°C due to returning to a more adequate RAC and the expected severity this will provide