

A decorative horizontal band featuring a close-up of a woven basket on the left and a piece of brown leather with a metal fastener on the right.

# Caterpillar HTK0973 SOA Engine Review

**Newmont USA, Ltd**  
**Asset Management**  
**Fluids Management**  
July, 2017

## HTK0973 Engine History

- **CAT 3516 Engine – S/N 8WM01450 CID #E0049R**
- **Newmont Phoenix Surface Mines Budgets CAT 793D - 3516 Engines at 17,500 Hours for Life Expectancy**
- **Original fitment 6/28/2007**
- **Removed 3/21/2009 with 11,519 hours**
- **Fitted 4/19/09 with 11,519 hours with repairs to zero hours**
- **Removed 8/10/2011 with total 28,287 hours**
- **Fitted 10/7/2011 with Zero hours**
- **Removed 7/17/2014 with 44,842 hours**
- **Fitted 8/20/2014 with zero hours and SOA Pistons**
- **Removed 2/20/2017 with 61,623 hours**
- **Total hours on Block 61,623 Hours**

# HTK0973 Engine Action from Oil Samples



## Action From Oil Analysis

Asset	Review Date	Fault Effect	Recommended Action
1101-20-40-00-HTK0973	1/9/2017	Filter Restriction	Inspect Engine Air Filters Change as Needed
1101-20-40-00-HTK0973	8/23/2016	High Temperature	VIMS (793 VIMS high Exhaust Temp.pdf)
1101-20-40-00-HTK0973	7/14/20	High Temperature	VIMS (793 VIMS high Exhaust Temp.pdf)
1101-20-40-00-HTK0973	5/2/2016	Coolant Entry	Resample Oil to Confirm Corrective Actions
1101-20-40-00-HTK0973	4/26/2016	Dirt Contamination	Inspect for Dirt Entry
1101-20-40-00-HTK0973	4/26/2016	Dirt Contamination	Change Oil
1101-20-40-00-HTK0973	4/26/2016	High Particle Count	Change Filters
1101-20-40-00-HTK0973	4/15/2016	Dirt Contamination	Inspect for Dirt Entry
1101-20-40-00-HTK0973	4/15/2016	Dirt Contamination	Change Oil
1101-20-40-00-HTK0973	2/29/2016	High Temperature	VIMS (793 VIMS high Exhaust Temp.pdf)
1101-20-40-00-HTK0973	11/11/2015	High Particle Count	Change Filters
1101-20-40-00-HTK0973	8/3/2015	High Wear Metals	Change Oil
1101-20-40-00-HTK0973	6/10/2015	No Fault Identified	VIMS (MID 49 CID 096 FMI 04.pdf)
1101-20-40-00-HTK0973	4/27/2015	Oil Pressure	VIMS (MID 27 CID 177 FMI 04.pdf)
1101-20-40-00-HTK0973	4/8/2015	Oil Pressure	VIMS (MID 27 CID 177 FMI 04.pdf)
1101-20-40-00-HTK0973	3/25/2015	Filter Restriction	Inspect Engine Air Filters Change as Needed
1101-20-40-00-HTK0973	11/17/2014	Fluid Transfer	Inspect Oil Level Possible Oil Transfer

8/1/2017

# HTK0973 Engine Work Orders

## Repair Work Order History

Reference Date	Order	Description	Functional Loc.
08/19/2014	40008962	HT973 Planned Engine Replacement	1101-20-40-00-HTK0973-ENSY
08/20/2014	20399275	L0w Power and General Checks	1101-20-40-00-HTK0973-ENSY
09/04/2014	10625745	HT973 250 Hour Valve Adjustment	1101-20-40-00-HTK0973-ENSY
01/13/2015	20464398	Reseal Engine Turning Cover	1101-20-40-00-HTK0973-ENSY
02/09/2015	20478554	Reseal Starter and Engine Turning Cover	1101-20-40-00-HTK0973-ENSY
02/09/2015	20478555	T/S Engine Pre Lube	1101-20-40-00-HTK0973-ENSY
03/06/2015	20491473	Reseal 339-9988 Oil Tube	1101-20-40-00-HTK0973-ENSY-LUSY
03/20/2015	10759509	HT973 4,000 Hour Valve Adjustment	1101-20-40-00-HTK0973-ENSY
03/30/2015	20504653	Reseal Starter and Cover Above	1101-20-40-00-HTK0973-ENSY
03/30/2015	20507981	Change Air Filters	1101-20-40-00-HTK0973-ENSY
05/17/2015	20528805	Left Rear Engine Block Cover Leaking	1101-20-40-00-HTK0973-ENSY
06/09/2015	20541301	Reseal # 7 & # 8 Crank Case C0vers On Left	1101-20-40-00-HTK0973-ENSY
06/09/2015	20541303	Reseal 4P-9853 Block	1101-20-40-00-HTK0973-ENSY
06/23/2015	20552998	Replace Left Rear turbo	1101-20-40-00-HTK0973-ENSY
09/17/2015	20595747	Replace Engine Prelube Motor Bracket	1101-20-40-00-HTK0973-ENSY-LUSY
10/30/2015	20624918	Ambient Air Temp Sensor Needed	1101-20-40-00-HTK0973-ENSY
11/03/2015	20626204	Replace Air Filters	1101-20-40-00-HTK0973-ENSY
11/10/2015	20627506	Perform Blowby Test	1101-20-40-00-HTK0973-ENSY
11/12/2015	10933812	8,000 Hour Valve Adjustment	1101-20-40-00-HTK0973-ENSY
12/02/2015	20637239	Reseal Top Cover On Flywheel Housing	1101-20-40-00-HTK0973-ENSY
12/04/2015	20631549	Perform Bearing Roll In	1101-20-40-00-HTK0973-ENSY-ETBE
12/19/2015	20646960	Engine Oil Leak, Right Side Of Engine	1101-20-40-00-HTK0973-ENSY-LUSY
12/23/2015	20649152	Reseal Top Cover On Flywheel Housing	1101-20-40-00-HTK0973-ENSY
03/10/2016	20697024	Engine Exhaust Clamp Broken	1101-20-40-00-HTK0973-ENSY
03/11/2016	20687061	Air Filter Derate	1101-20-40-00-HTK0973-ENSY-AISY
03/12/2016	20694136	VIMS 793 High Exhaust Temp	1101-20-40-00-HTK0973-ENSY
03/25/2016	20700458	Reseal Right Exhaust Manifold	1101-20-40-00-HTK0973-ENSY-EXSY

# HTK0973 Engine Work Orders

## Work Order History Cont.

Reference Date	Order	Description	Functional Loc.
04/01/2016	20712726	Replace Right Rear Turbo Gasket	1101-20-40-00-HTK0973-ENSY-EXSY
04/30/2016	20754736	Coolant Leak From Head #9	1101-20-40-00-HTK0973-ENSY-ETBE
05/02/2016	20759904	Resample Engine Oil	1101-20-40-00-HTK0973-ENSY
05/05/2016	20660426	Oil Pump Has A Broken Bolt	1101-20-40-00-HTK0973-ENSY
05/16/2016	20767868	Replace Right Front Turbo Gasket	1101-20-40-00-HTK0973-ENSY-EXSY
05/17/2016	20767869	Replace Right Rear Turbo Gasket	1101-20-40-00-HTK0973-ENSY-EXSY
05/24/2016	11092614	12,000 Hour Valve Adjustment	1101-20-40-00-HTK0973-ENSY
05/28/2016	20767112	Reseal Alternator Drive Pulley	1101-20-40-00-HTK0973-ENSY
06/17/2016	20780531	Lower Muffler Missing Exhaust Tip	1101-20-40-00-HTK0973-ENSY-EXSY
06/17/2016	20780537	Top Muffler Hold Down Bracket is Broke	1101-20-40-00-HTK0973-ENSY-EXSY
07/26/2016	20809271	Turbos Mounting Bolts Loose	1101-20-40-00-HTK0973-ENSY-EXSY
08/05/2016	20803007	VIMS 793 High Exhaust Temp	1101-20-40-00-HTK0973-ENSY
08/05/2016	20809278	Reseal Cover On Flywheel Housing	1101-20-40-00-HTK0973-ENSY
08/05/2016	20809270	3 Turbos Have Loose and Missing Bolts	1101-20-40-00-HTK0973-ENSY-EXSY
08/08/2016	20816638	#13 Head Needs To Be re-Sealed	1101-20-40-00-HTK0973-ENSY
08/28/2016	20826650	VIMS 793 High Exhaust Temp	1101-20-40-00-HTK0973-ENSY
08/28/2016	20823201	Replace Heat Shields On Exhaust Bellows	1101-20-40-00-HTK0973-ENSY-EXSY
08/28/2016	20823208	Replace Dust Ejectors On Air Cleaners	1101-20-40-00-HTK0973-ENSY-IKSY
09/19/2016	20836991	Reseal #5 & #11 Valve Covers	1101-20-40-00-HTK0973-ENSY
10/23/2016	20854435	# 9 & #11 Head Gaskets Leaking Antifreeze	1101-20-40-00-HTK0973-ENSY
10/28/2016	20866266	Air Filters Are Plugged – Low Power	1101-20-40-00-HTK0973-ENSY-IKSY
10/30/2016	20854437	Reseal Front Left Engine Breathers	1101-20-40-00-HTK0973-ENSY
12/19/2016	20898304	LH Rear Turbo Needs Replaced	1101-20-40-00-HTK0973-ENSY-IKSY
01/11/2017	20910856	Air Filters Plugged - Need Replaced	1101-20-40-00-HTK0973-ENSY-IKSY
01/16/2017	20910655	Inspect Engine Air Filters Change As Needed	1101-20-40-00-HTK0973-ENSY
02/08/2017	20928329	Right Inlet Sensor Needs Replaced.	1101-20-40-00-HTK0973-ENSY-IKSY

# HTK0973 Engine Dingo Events

## Dingo Event History

Date	Event Type	Notes
10/22/2016	WO Repair, Service, or Inspection	WO 20854435 10/23/20 - #9 AND #11 HEAD GASKETS LEAKING - assigned to reseal cylinder head #9 and #11, washed the machine and pulled it into the shop, drained coolant. Removed head #9 and #11, all parts are on a cart next to the machine. Needs to be cleaned before going back in with the heads. Took pictures of the heads and pistons and emailed them. 10/23/2016 cleaned the top of the engine off and started going back together with the heads after removing the turbo for better access upon reassembly. The heads were installed with gaskets and spacers and the head bolts were torqued to 25 ft. /lbs. and then the exhaust and water tubes were installed. The head bolts were then torqued to 150 ft. /lbs. with additional half turn. The rocker boxes were installed. Need to install rocker arms, push rods, injectors, and turbo. Did not change O-rings on the injectors. Valve cover O-rings have been changed. 10/23/2016 finished putting the heads together, first installed the injectors and then the push tubes and valve bridges then install the rocker arms and the torqued bolts to spec. then turned engine over and checked and adjusted the valves and injectors as needed. then installed the turbo and exhaust pieces that were removed. then filled with coolant started truck up and ran till operating temp shut truck down and changed the engine oil and filters refilled with oil and released to production also took a sample.
8/8/2016	WO Repair, Service, or Inspection	WO 20816638 #13 HEAD NEEDS RESEALED, t/s-checked duration--good, click test--good, pulled injector good, blew down and found the head bolts loose and air coming around Pulled head, spacer plate bad. All head bolts but one are dug out. There is a parts list in components but workorder is not released yet. 08/07/2016 drilled out and extracted broken head bolt. Then prepped the head, rocker box and valve cover for reinstallation. cleaned the mounting surface for head to block for installation. 08/08/2016 did not have time to put text, will do tomorrow. cleaned head and related surfaces. installed head-torqued to spec, adjusted injector and intake/ exhaust valves, installed valve covers, put coolant, steer oil in and ran for half hour. 1) oil and filters need to be changed, 2) Turn ladder to fit hood, 3) install heat shields, 4) check and top off all fluids. 08/08/2016 drained old oil and then refilled also changed out old oil filters then the installed exhaust blankets and reinstalled hood and ladder back
5/5/2016	WO Repair, Service, or Inspection	WO 20660426, OIL PUMP HAS BROKEN BOLTS. ATTACH PICTURES, BEARING WAS SHOT. 05/05/2016 Removed fuel lines, fuel pump, couplings on oil pump, oil pump, adapter plate and drive gear, was no bolts holding the adapter plate was 2 broken bolts and the rest missing the bearing from the adapter plate put mark on the on the engine oil pump drive took same pic, leaned the shaft the best I could with the buffer wheel and die grinder, removed broken bolts. Cleaned parts and resealed, installed oil pump drive gear adapter plate with all 5 new bolts, oil pump, fuel pump, hook up lines on oil pump couplings on engine oil pump, change oil filters filled engine oil, check all the oils start truck check for leaks and released to production job completed

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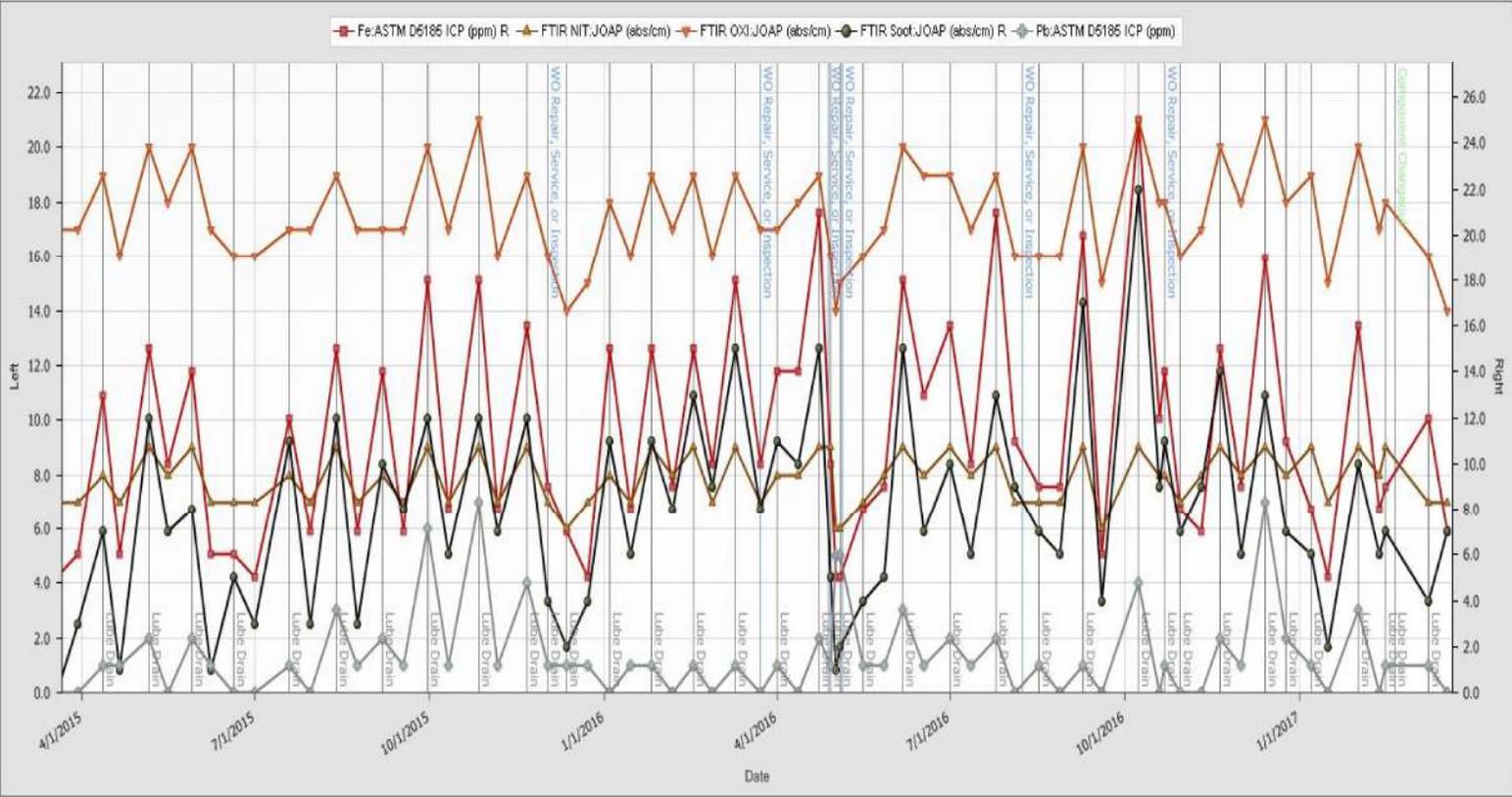
# HTK0973 Engine Dingo Events

## Dingo Event History Cont.

4/28/2016	WO Repair, Service, or Inspection	<p><b>WO 20754736, #9 HEAD, BROKEN BOLTS, COOLANT LEAK. 04/28/2016</b> Got call of coolant leak. Went to truck and found coolant was leaking from where the head meets the block on #9 cylinder. Has one head bolt broken off, and another one that you can move the washer around on. 04/29/2016 Found it had three broken bolts and a bad head gasket. Piston was TDC so couldn't look at liner package. Still need to turn engine with tool and look at it. Also need to grab an oil sample and cut a filter open. Filter is on bench. Head is sitting on bench in shop along with gasket for presentation. 04/29/2016 Cut open filter and checked for material. Gave filter section to planners. Took an engine oil sample. Engine oil needs to be drained still. Was able to get one of the broken bolts out with a pair of pliers. Had to drill and extract the other two bolts. Got the broken bolts removed and cleaned cylinder head deck. Barred engine over and looked at liner pack. Also took pictures of cylinder walls and top of piston with the camera and gave camera to planner. Cleaned the head up well. Also cleaned the cylinder head mounting surface. Installed new spacer plate and gaskets associated. Installed all seals and cylinder head onto block with new intake o-rings. Torqued head bolts to spec. Still need intake and exhaust bolts installed and go back together with injector and valve bridges and rockers. New oil filters and the rest of parts are in a box on deck of truck near steering tank. <b>04/30/2016</b> went to truck to install and adjust injector and valves, found that the plug cap for the in-head exhaust probe was stuck in the exhaust port. had to rotate the exhaust manifold to free cap plug. reinstalled the exhaust manifold and installed gasket to head. also attached the intake to after-cooler, rocker box, injector (is torqued) fuel pipes, and pipe brackets/supports. valves/injector rocker lashes need to be adjusted to spec still. needs oil and coolant. left extension cord for coolant pump, and valve adjuster kit and turning tool at truck. 04/30/2016 Adjusted valves and injector to spec. Put valve cover on and breather. Eric came up and we filled coolant and engine oil. Replaced the oil filters. Checked and made sure everything was done and tight and all fluid levels were correct. Started truck up to check for leaks. Everything checked out fine. Everything looked and sounded normal. Released to Production about midnight and they have been running truck. Put all tools that were checked out back in tool room.</p>
3/23/2016	WO Repair, Service, or Inspection	<p><b>WO 20700458 Exhaust bolts &amp; turbos 03/11/2016 RESEAL RIGHT EXHAUST MANIFOLD. THE RIGHT EXHAUST MANIFOLD IS LEAKING. NEED TO REMOVE AND RESEAL. 03/11/2016 RESEAL RIGHT EXHAUST MANIFOLD. THE RIGHT EXHAUST MANIFOLD IS LEAKING. NEED TO REMOVE AND RESEAL. 03/23/2016</b> Was rescheduled in for today. Washed truck and pulled into shop. First pulled intake boots first. Then pulled the turbos. In the process of pulling turbo found that the front right turbo was bad. The turbo was loose and moved around. When were pulling exhaust bolts, found a broken bolt on #1 head. Pulled all the bolts and then pulled all the sections together and put them on the bench. Numbered them for the next crew when they reseal the sections. Tried to extract the broken bolt with no success. Put heat to broken bolt and still no success. Was told to put back together with three exhaust bolts on the #1 head. So still need to reseal sections and put exhaust back together. New turbo was in warehouse and sitting next to truck. Exhaust tubes were ordered and should be here in the warehouse. <b>03/24/2016</b> disassembled the manifold, and cleaned all surfaces, before resealing it. then installed in machine. There is one missing bolt in #1 cylinder due to bad hole in the head. <b>03/25/2016</b> INSTALLED NEW FRONT TURBO AND OLD REAR TURBO. INSTALLED TURBO DRAIN LINES. INSTALLED NEW EXHAUST. STILL NEED TO FILL COOLANT AND DOUBLE CHECK ALL OILS. THERE IS A NEW PIN THAT NEEDS TO BE INSTALLED <b>WORK ORDER NUMBER 20700105.</b></p>
12/2/2015	WO Repair, Service, or Inspection	ROLLED IN NEW ROD AND MAIN BEARINGS, WO <b>20631549</b> , WM34166
3/19/2015	WO Repair, Service, or Inspection	PERFORMED 4K VALVE ADJUST, WO <b>10759509</b> , 3/19/15
9/3/2014	WO Repair, Service, or Inspection	PERFORMED INITIAL VALVE ADJUST, WO <b>10625745</b> , WM30919
8/18/2014	Non OEM Equipment Installed	SPEED OF AIR PISTONS IN THIS ENGINE

# HTK0973 Engine OA Trends

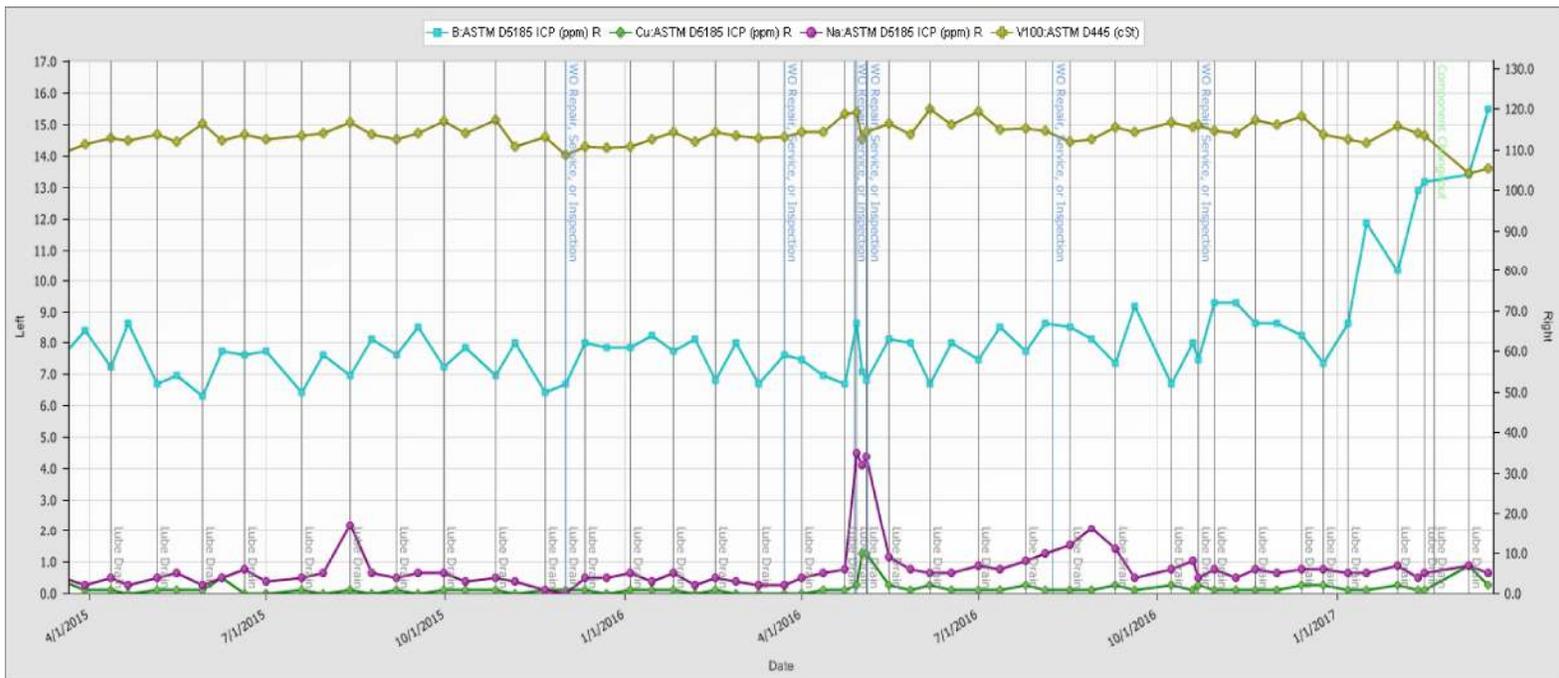
## Oxidation, Nitration & Lead Trends



8/1/2017

# HTK0973 Engine OA Trends

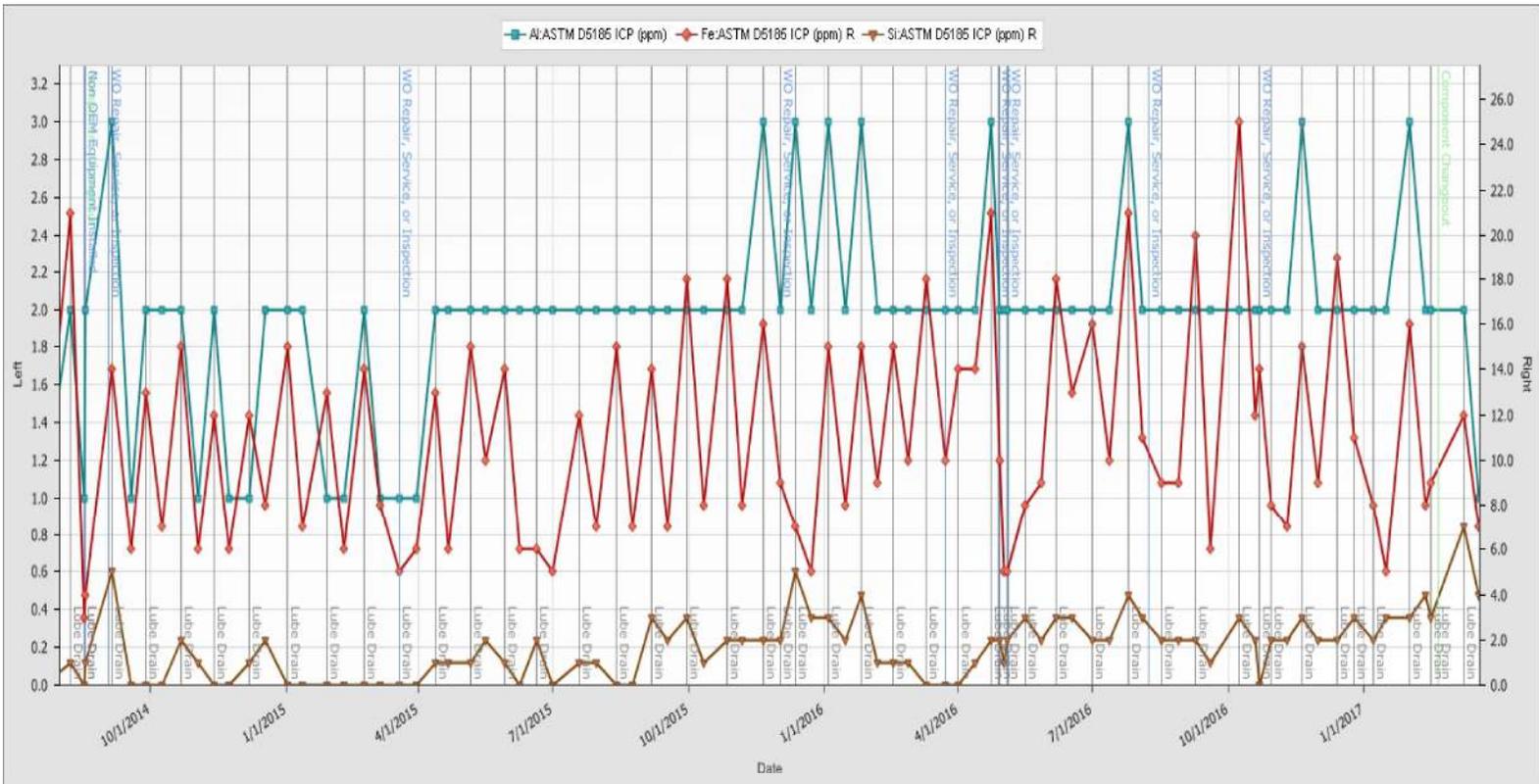
## Coolant Trend View: Coolant Entry



Note from author: The increase in Boron on the last four samples before engine removal was due to a change in base engine oil additive chemistry from the supplier, not from a coolant leak. The last two samples on the slide above is due to engine oil chemistry received from the engine rebuilder following install of the replacement engine for the SOA engine..

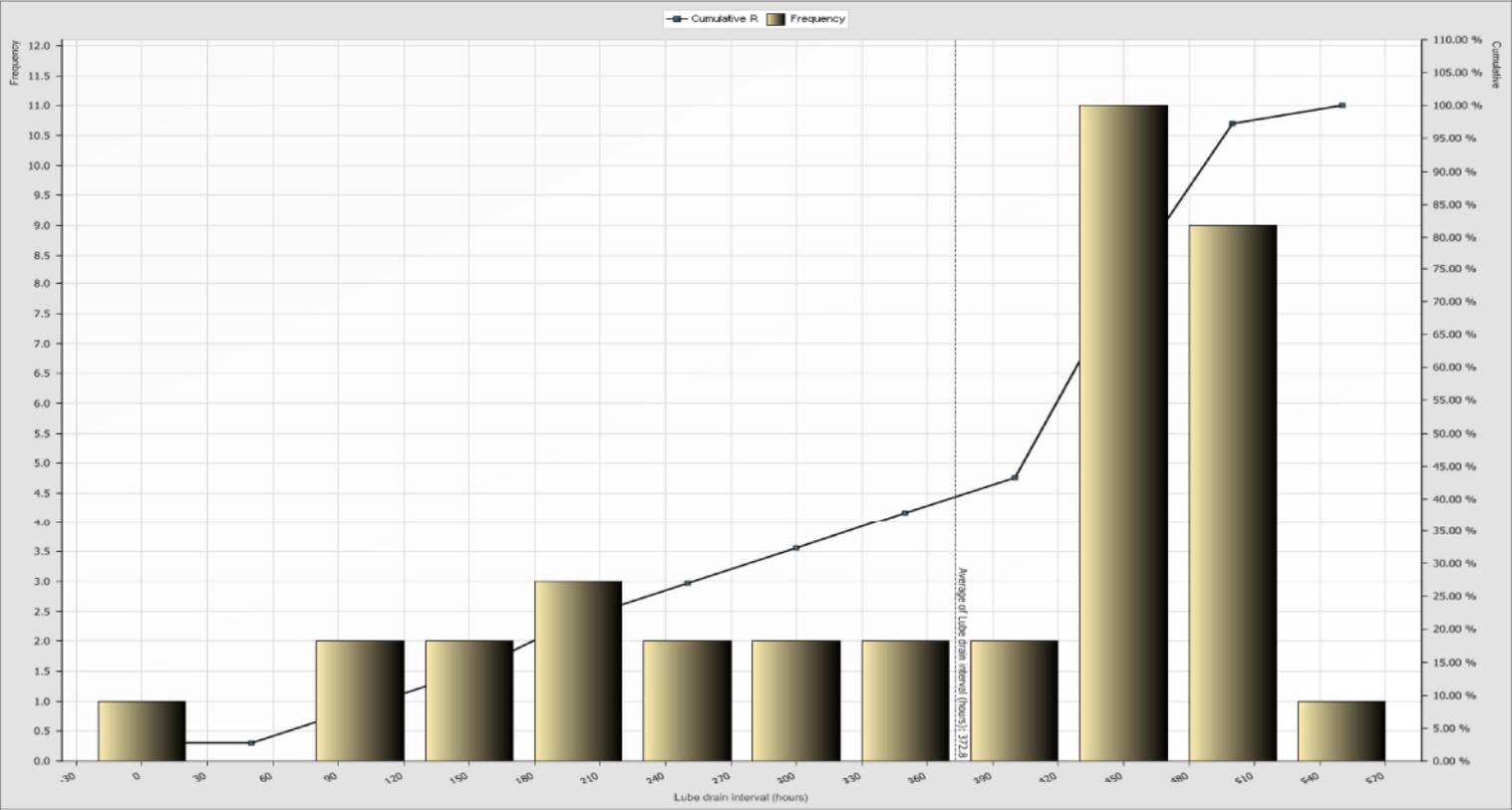
# HTK0973 Engine OA Trends

## Dirt Entry Trends: Silicon – Aluminum



# HTK0973 Engine OA Trends

## Histogram Oil Drains



# HTK0973 Engine Events

## Oil Analysis Related Events

### **Dingo CBCC Recommendation:**

This is the first CBCC assessment for this engine. Now @ 97.6% of the budgeted 17,500hrs. Over the last 6 samples trends have been relatively stable and in normal ranges, other than one sample to show higher than typical Lead, however the next 4 samples Lead was back within normal range and consistent with sample history and trends.  
I see no issues with extending this engine out.

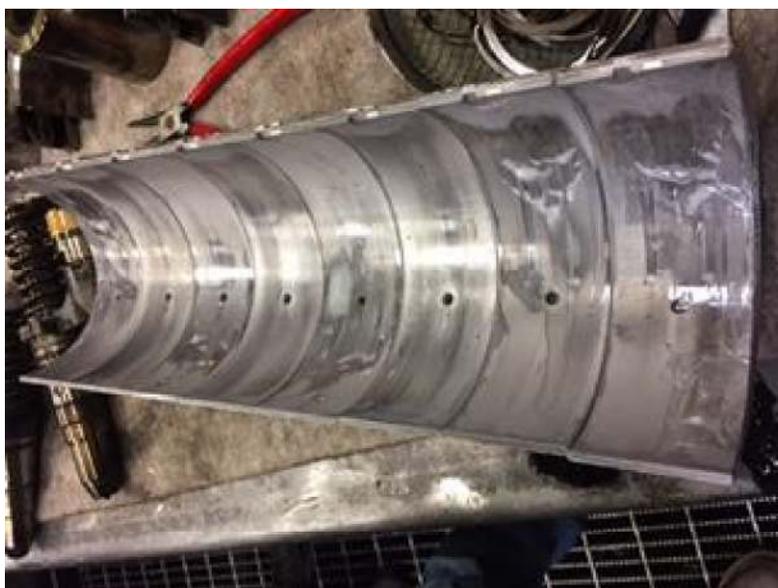
### **Site Comment:**

Due to mechanical condition of the engine itself, we have it scheduled for change out next month.

**Note:** P66 Guardol ECT (Ti) 15w40 engine oil formula change effective approx. Jan 15, 2017 can be seen by increase in Boron after this date in the Coolant trend view.

# HTK0973 Engine Component Changes

## Photos at Engine Disassembly (bearings)



# HTK0973 Engine Component Changes

## Photos at Engine Disassembly (Pistons)



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# HTK0973 Engine Component Changes

## Photos at Engine Disassembly (heads)



# HTK0973 Engine Component Changes

## Photos at Engine Disassembly (Valves)



# HTK0973 Engine Component Changes

## Photos at Engine Disassembly (Cylinders)



# HTK0973 Engine Component Changes

## Photos at Engine Disassembly (Rods)



# HTK0973 Engine Component Changes

## ECM Data

Cat Electronic Technician 2015B v1.0

Product Status Report

3/22/2017 1:13 PM

3516B 793 (8WM01450)

Parameter	Value
Equipment ID	HT973
Engine Serial Number	8WM01450
ECM Serial Number	2343B091JP
Personality Module Part Number	4855133-00
Personality Module Release Date	MAY15
Personality Module Description	OHT-793D

Logged Event Codes [Diagnostic Clock = 17548 hours] - 3516B 793 (8WM01450)

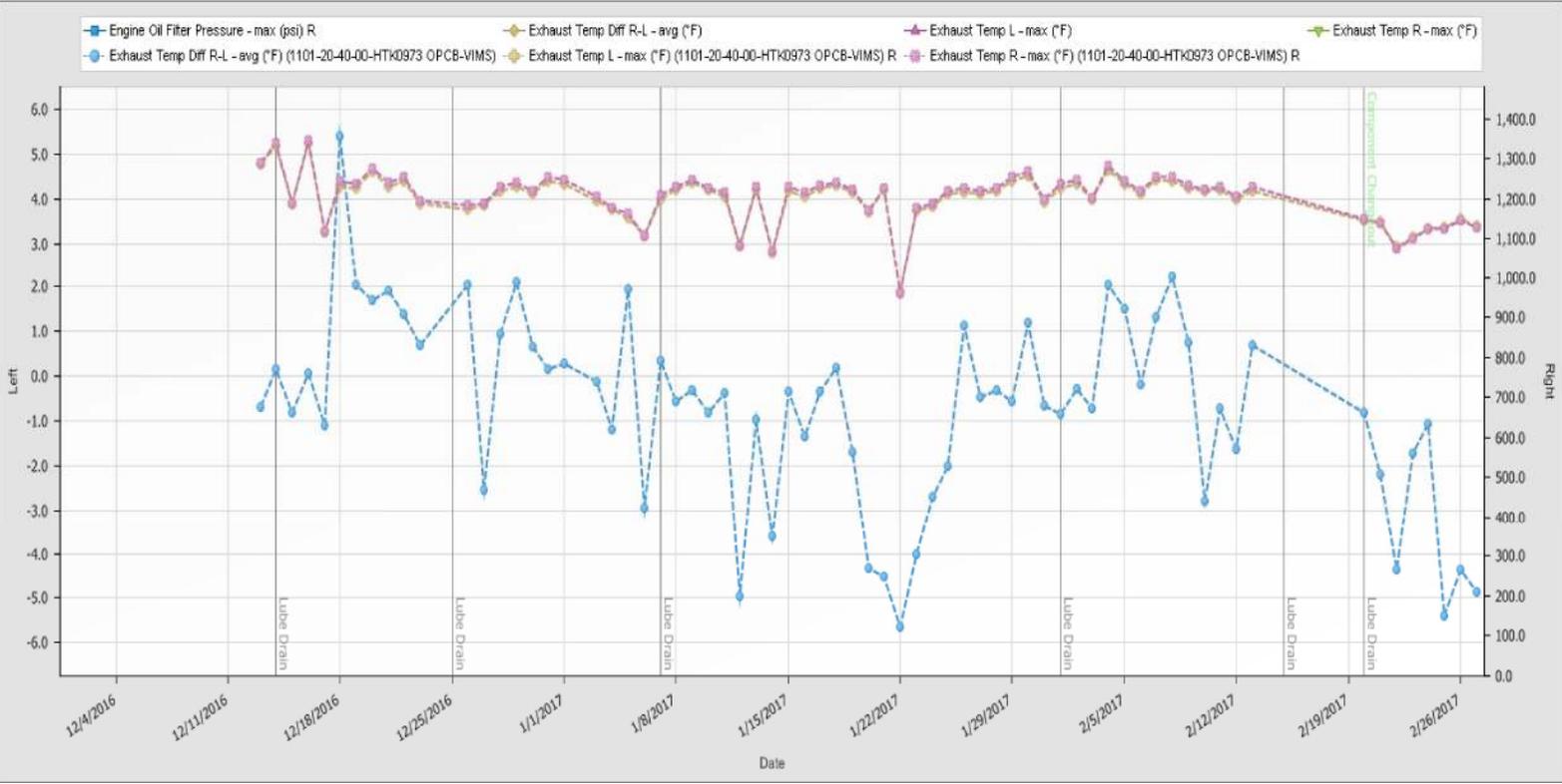
Code	Description	Occ.	First	Last
E017 (1)	High Engine Coolant Temperature Warning	4	17505	17506
E038 (1)	Low Engine Coolant Temperature Warning	10	17310	17528
E098 (1)	Engine Pre-lube Override	7	17511	17525
E272 (1)	Inlet Air Restriction Warning	19	17375	17494

Current Totals - 3516B 793 (8WM01450)

Description	Value	Unit
Total Time	17548	hours
Total Fuel	363242	gal

# HTK0973 Engine Trends

## Exhaust Temperatures



8/1/2017

# HTK0973 Engine Summary

## Summary

Per written joint agreements between Newmont, SOA and CECO CRC, Engine was built to standard specifications with the exception of the SOA pistons. This included re-use of many cylinder head bolts, and to standard injector & ECM profiles for this engine generation. Subsequently at future engine rebuilds, all head bolts will be replaced with new.

With exceptions of:

- multiple broken re-used head bolts and subsequent head gasket leakage;
- and, cautionary replacement of all crankshaft rod & main bearings with updated bearing materials;

The engine ran without any other significant maintenance/repair issues to end of life.

Had it not been for the risk of equipment downtime and possible further damage, caused by additional head bolt breakage, it is reasonable the engine would have stayed in service for a longer, but unknown, period of time.

At disassembly, several other broken head bolts were found, however, the condition of the cylinder packs, pistons, rings & liners indicated significant useful life remained. Of note was the low amount of carbon buildup and the nature of the carbon was softer than previously seen, particularly in the piston ring lands, in the head valve chambers and on the valves. Oil analysis was deemed normal for an engine in an acceptable operating condition. Crankcase deposits were notably very low and in the case of normal buildup of “sludge\varnish” in the crankshaft counterweight retainer bolt holes, there was in this engine, an unusually small amount of buildup.

Exhaust emissions testing noted significant reduction\improvement versus the comparative engine.

Tracked fuel consumption while inconclusive, due to data competency, did trend towards improvement over other same generation\operation engines.

Given that only approx. 40% (piston crown modification and thermal coating) of the available SOA technology was applied, the considered opinion is that operational improvement applicable to the SOA technology was achieved.