How to read the Engine Angel Assessment reports

Re: www.enginepolygraph.com

2016-08-13

Topics

- **Background**
- **Engine Angel® Assessment Report**
- **Engine Polygraph®**
- **Reviewing and Accessing Current Engine Volumetric Efficiency allows the operator/user to establish a baseline before work begins**

Background

- **The I. C. engine vs. the electronic control system**
- **Basic Principe of Engine Polygraph**
  - **Spark-ignition vs. diesel**
- **Assessment vs. Diagnosis**
  - **Dirty vs. Broken engines**

The I.C. engine, Electronic Control Module, and the Emissions Control System

- When we talk about the 'physical integrity' of the engine, we are referring to the components of the engine that move the fluids and parts to convert the fuel and air to kinetic energy of motion of devices (vehicle propulsion, electrical generation, etc.)
- Other parts of the engine control the speed and power delivered, consisting of sensors and feedback loops to various actuators altering the spark (for spark-ignitions) and flows of air, fuels, coolant, and oil.
- We focus on the 'physical' components of the engine; OBD focuses on the control systems and the ECM (engine control module) keeps the engine running, sometimes in spite of physical issues.
- The recent Emissions Control System overlaps with the other two, providing lower environmental impact when operating as designed. We are finding that these components and design changes associated with their introduction result in 'unintended consequences' of carbon accumulations affecting the engine performance. Identification of these issues and possible solutions are being developed. Since that carbon buildup is a physical component altering the shape of engine components (buildup on valves and rings, plugging up orifices, etc.), we see these changes with the FirstLook sensors and the changes in the patterns of the signatures (waveforms).

Spark-ignition vs. Diesel

- The SenX FirstLook® sensor produces a voltage whenever the air pressure at the nozzle changes (0.170 V → 1 psi). We call the voltage waveform over an engine cycle a 'signature'.
- Engine Polygraph gets these voltages from the exhaust & crankcase simultaneously and shifts the timeline so that the exhaust stoke of each cylinder is aligned with the crankcase voltage from when the same cylinder is in its power stroke.
- Then the engine polygraph divides the engine cycle (720° for 4-stroke or 360 for 2-stroke) into segments associated with the cylinders in firing order.
- The shape of each cylinder segment is mathematically extracted and the shapes for each are compared – a 'perfect' engine would have each cylinder profile identical. In addition, the differences are compared and related with specific issues that have appeared in previous engines using machine learning methods.
- None of this is dependent on whether the engine is spark-ignited or diesel.

Assessment vs. Diagnosis - 1

- **Engine Polygraph reports the results as scores for various 'areas/components' of the engine. The scores are on a scale from 1 (best) to 10 (worst) and are divided into two categories:**
  - **Areas of risk of engine failure: Upper Engine (E.G., valves, valve springs, head gasket, injectors, ignition) and Lower Engine (E.G., rings, pistons, cylinder walls)**
  - **Areas of performance impact: Volumetric Efficiency score and Valve Seating**
- **Some engines are 'broken' which result in high scores for the Upper or Lower engine but many more engines are 'dirty' with high carbon deposits with high score on the VE and VS scores.**
- **If you have large score in both sections, treat the VE and VS issues first (they are usually cheaper and faster to fix.)**

Assessment vs. Diagnosis - 2

- **An Assessment report does give some ‘triage’ information and the graphics can be used to help the diagnostics of the engine.**
  - **A major rule is that if the Upper and Lower scores are good (4 or better) and there is an OBD code tripped, proceed as though the code is correct.**
  - **If the Upper or Lower scores are worse than 4, any OBD code is likely miss-leading – fix the ‘’physical integrity’ problem first.**
- **If the VE or VS score are bad, use a procedure to clean the engine of carbon deposits before undertaking the expensive opening up the engine. That might solve the problem that was observed.**
- **By comparing the Assessment reports ‘before’ and ‘after’ a procedure or repair, the value of the activity can be clearly documented. This is the basis of Engine Polygraph®**

Engine Angel® Assessment Report

This report provides visibility of operational parameters of an engine while it is running at typical operational speeds. A report before a procedure (treatment with additive, electronic or mechanical adjustment, or a part replacement or repair) can be compared to a report following the procedure to demonstrate the impact of the procedure on the engine's performance.

The first page of the 4-page report gives an Overall engine assessment score (1= best; 9 = very bad condition) that is color coded (green is good, red is bad). The Overall score is an indication of the risk of premature engine failure.

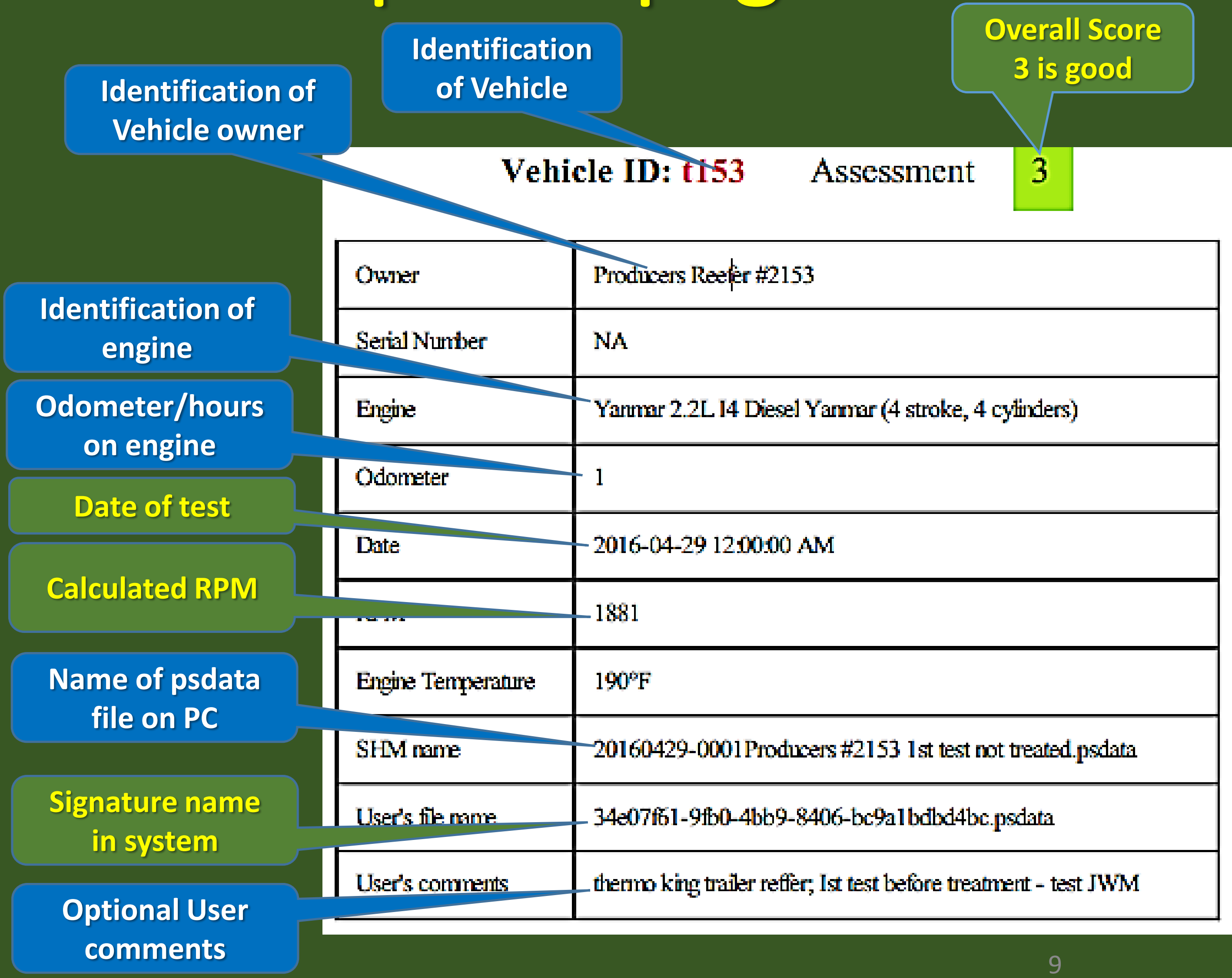
The rest of the page documents the engine and situation tested.

Each page of the report is explained on the following pages.

Engine Angel® Assessment Report – page 1

We use an engine in good condition to illustrate the various components of the report.

The first set of data comes from the user (this page); the second set (page 2) is generated by the system.



Vehicle ID: t153 Assessment 3

Owner	Producers Reefer #2153
Serial Number	NA
Engine	Yanmar 2.2L I4 Diesel Yanmar (4 stroke, 4 cylinders)
Odometer	1
Date	2016-04-29 12:00:00 AM
RPM	1881
Engine Temperature	190°F
SHM name	20160429-0001Producers #2153 1st test not treated.psdata
User's file name	34e07f61-9fb0-4bb9-8406-bc9a1bdbd4bc.psdata
User's comments	thermo king trailer reffer; Ist test before treatment - test JWM

Engine Angel® Assessment Report – page 2

Software version number

Scores indicating risk of engine failure:

Upper Engine: Issues with valves, fuel supply, gaskets, etc. mainly exhibited in the exhaust.

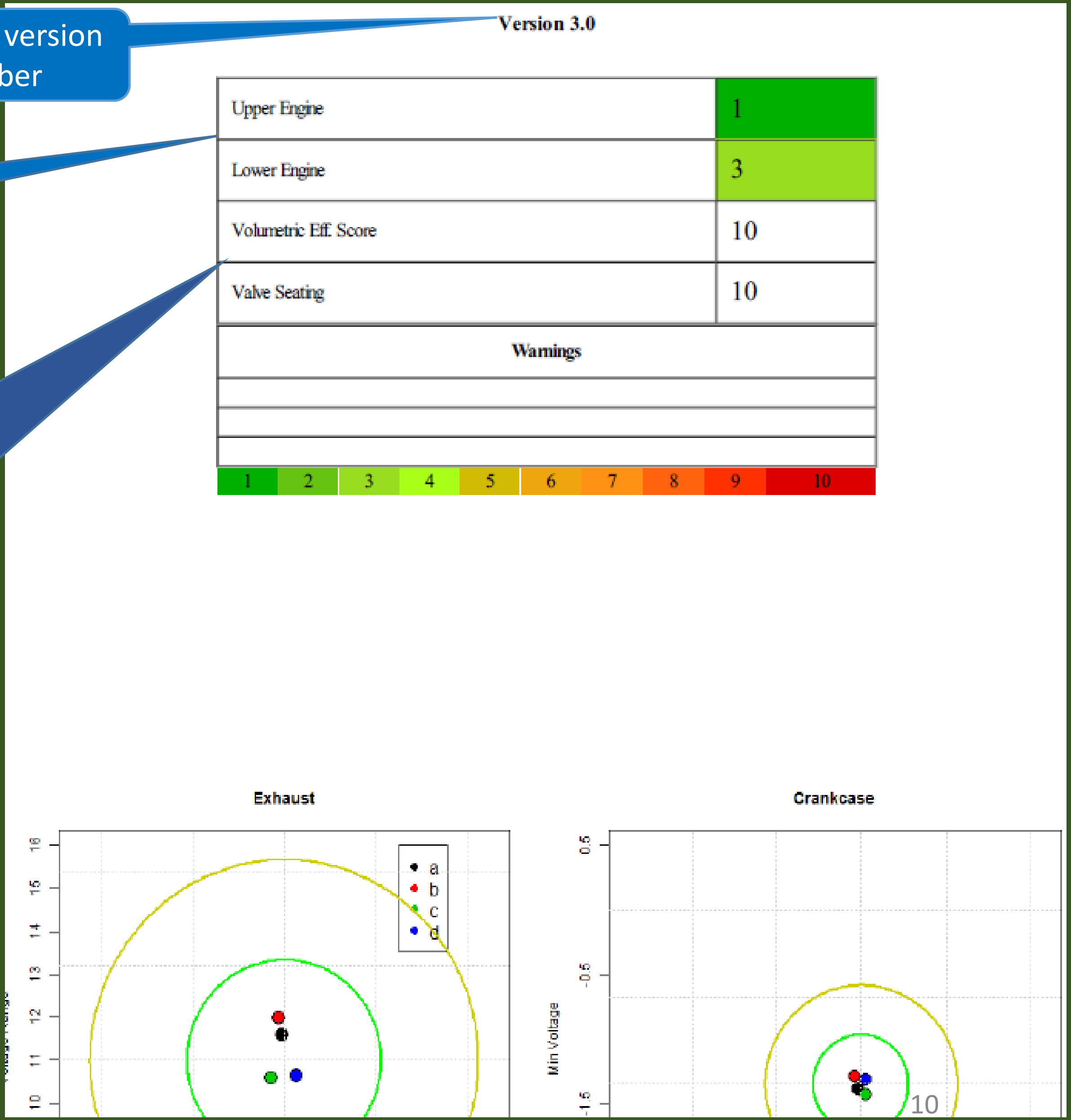
Lower engine: Issues with rings, pistons, cylinder walls, etc. mainly in the crankcase.

Scores indicating performance loss (often carbon issues):

Volumetric Efficiency score: Turbulence in the gas flow into and out of the cylinder.

Valve Seating: tightness of the valve seal when closed.

Warnings will be listed as identified during the analysis.



Version 3.0

Upper Engine	1
Lower Engine	3
Volumetric Eff. Score	10
Valve Seating	10

Warnings

1	2	3	4	5	6	7	8	9	10

Engine Angel® Assessment Report – page 2 (continued)

Engine Integrity Diagrams

Combustion Efficiency:

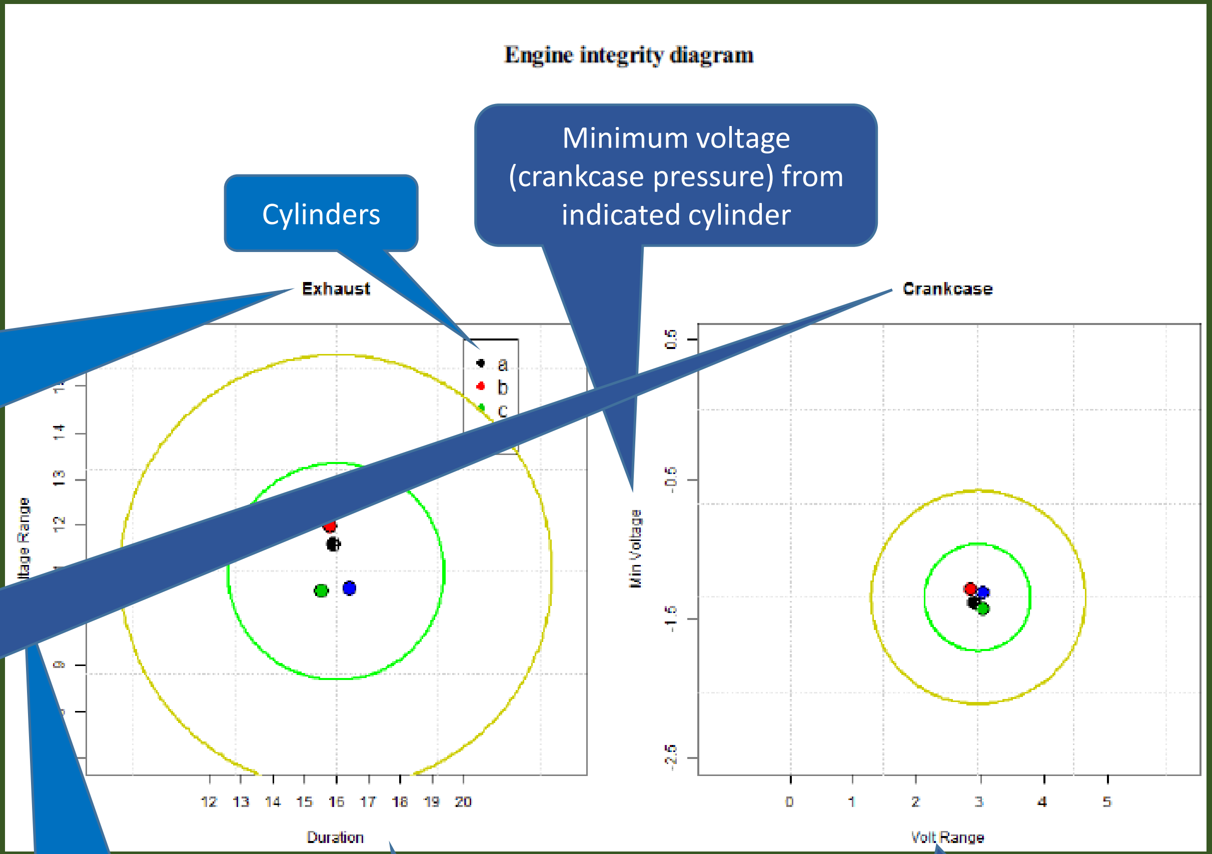
Combustion output from each cylinder will be the same if there is high combustion efficiency. – the points will be on top of each other.

Exhaust pressure and duration indicates the success of ignition & completeness of combustion **ruined by** mis-fires, poor ignition timing, blow-by or loss from poor valve seal or gasket compromise

Crankcase Target Diagram:

All cylinders should show the same behavior in a perfect engine. Variation caused by poor piston/rings/cylinder wall seal integrity – blow-by

Voltage Range (pressure change) indicates blow-by during Power stroke. Minimum Voltage indicates vacuum from intake manifold through PCV valve and any ‘reverse blow-by’ into cylinder during intake stroke. Ring seal varies between Power and Intake strokes.



Cylinders

Minimum voltage (crankcase pressure) from indicated cylinder

Max-to-min voltage (exhaust pressure) change from indicated cylinder

Duration of each cylinder’s duration (ms) for exhaust stroke.

Max-to-min voltage (exhaust pressure) change from indicated cylinder

Engine Angel® Assessment Report – page 3

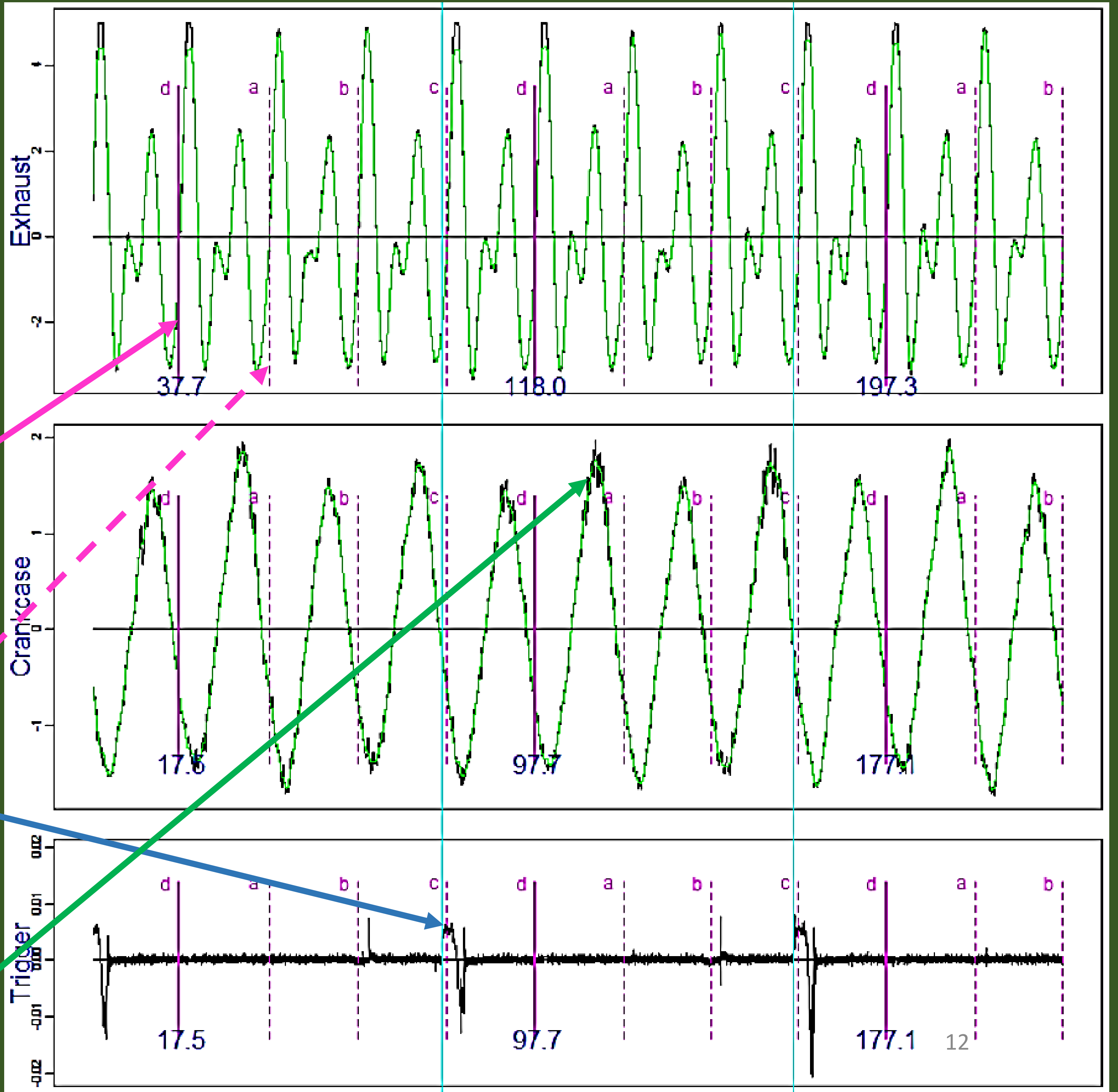
Scale can change in value as well as units (volts or millivolts). In the exhaust and crankcase, the pressures depend on speed of engine and size of exhaust pipe.

Vertical pink lines (solid) show engine cycle boundaries so the rpm is calculated from the time between those boundaries.

Vertical pink lines (dashes) show cylinder boundaries to the extent that they can be determined from the shape of the curves.

The last 'curve' at the bottom is the (optional) voltage from the trigger (spark-plug). The blue line that spans all three marks the beginning of the power stroke (spark)

On each waveform the black line is the raw voltage, the green is the 'pressure pulse' and the differences are 'vibrations'.



Engine Angel® Assessment Report – page 3 (continued)

Exhaust signature – Current Volumetric Assessment @ RPM

The smoothness of the Exhaust signature on the previous page is a major part of the Volumetric Efficiency. Roughness is from:

- Carbon deposits causing turbulence & blockage
- Weak or broken valve springs
- Gasket failures
- Blow-by

Crankcase signature

Crankcase pressure is significantly driven by intake manifold through the PCV Valve

The roughness of the Crankcase signature is a major indicator of lubrication issues

- Rough/corroded cam lobes
- Bearings
- Inadequate lubrication of the ring-cylinder wall

More background on Vibrational Spectra

- We do show two measures of the 'vibrations' in the exhaust curve where we interpret the higher frequencies to valves closing quite tight, but carbon particles or pitting of the valve allows high pressure in the power stroke to 'whistle' out. The lower frequencies in the exhaust, we interpret as the turbulence of airflow due to valve overlap, poor lash adjustment, or significant carbon obstruction in the manifold. These factors impede the volumetric efficiency.
- In the crankcase, we calculate three measures of vibrations but don't yet have specific measures on the reports (next version). The highest frequencies show us black regions on the crankcase curve (waveform) and relate to things like metal on metal rubbing (the oil film has been polished off the liners possibly), the lower frequencies show as oscillations in black and are from audible frequencies that we call 'rumble' and associated with variations smaller than a mm, and can be due to cam lobe pitting/corrosion or even bearings that are out of round.
- Many of the vibration measures vary by cylinder; if one does not (in the crankcase) vary by cylinder, it might be an issue with the oil itself.

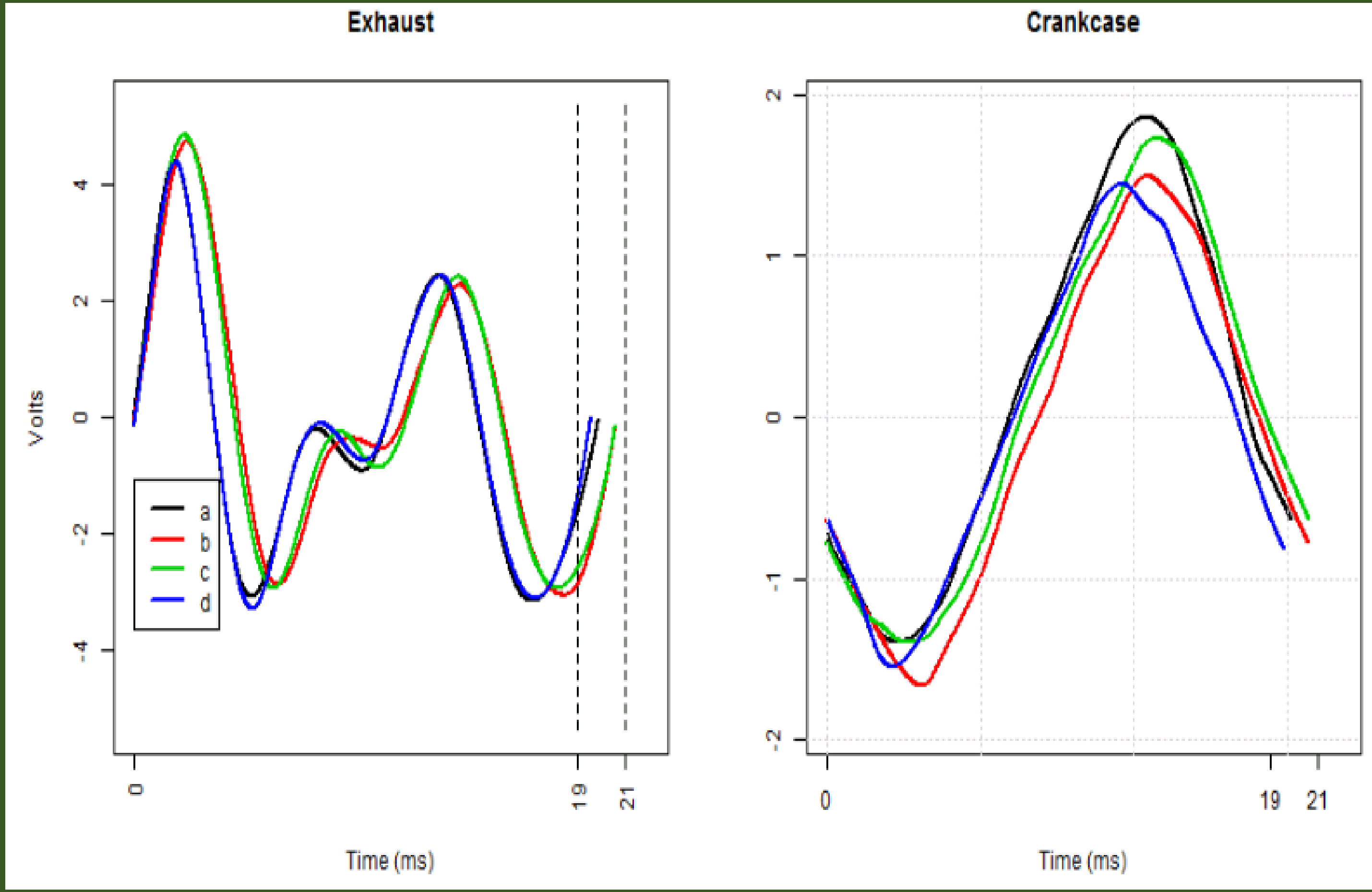
Engine Angel® Assessment Report – page 4

The Cylinder Profiles

The cylinder profiles show each cylinder profile as the voltage (pressure) in the exhaust and crankcase:

- The Exhaust profile shows balance between the cylinders
- The Crankcase profile shows the cylinder-to-cylinder seal and lubrication comparison

These curves are have the vibrational component removed.



Cylinder Offset table for many I6 Engines

The Cylinder Offset table shows what is (should be) going on in each cylinder at any instant (rotation angle of the crankcase). It is dependent on the firing sequence of the engine.

It is shown here to point out that peaks are primarily associated with one cylinder but does have other inputs from the other cylinders at least part of the time.

Pulses are largely generated in the early part of each stroke, but for example, poor valve seating and blow-by from other cylinders can confound the signature.

Firing Order:		1	5	3	6	2	4						
Crankshaft rotation		0 to 180°			180 to 360			360 to 540			540 to 720		
		60	120	180	240	300	360	420	480	540	600	660	720
Fire Seq. 1	Cyl #1	Power Stroke			Exhaust Stroke			Intake Stroke			Compression Stroke		
Fire Seq. 2	Cyl #5	Comp Stroke		Power Stroke			Exhaust Stroke			Intake Stroke			
Fire Seq. 3	Cyl #3		Compression Stroke			Power Stroke			Exhaust Stroke			Intake Stroke	
Fire Seq. 4	Cyl #6	Intake Stroke			Compression Stroke			Power Stroke			Exhaust Stroke		
Fire Seq. 5	Cyl #2	Exhaust Stroke		Intake Stroke			Compression Stroke			Power Stroke			
Fire Seq. 6	Cyl #4		Exhaust Stroke			Intake Stroke			Compression Stroke			Power Stroke	

Engine Polygraph: Before and After

- **Comparing the signatures of two different engine models vs. comparing signatures from the same engine at two different times. A change in the score values indicates the change observed in the various categories. Often the uniformity of the graphics improves greatly if the procedure were effective.**
- **If the Voltage (pressure) increases in the exhaust, that would mean more complete combustion and/or less power escaping around the pistons or out ‘leaky’ valves during the corresponding power stroke. But it is important to read the scale and units before reaching conclusions. A future version will be able to produce a Before/After report.**

The Report – Two Examples

Signature Processor/Dougs/0bdfabb3-1d7b-42ae-aed6-da6462856ac3 strock 2-11-16 before

Vehicle ID : 2006 Assessment **6**

Owner	Doug Strock
Serial Number	NA
Engine	Chrysler Chrysler EGH 3.8L V6 (4 stroke, 6 cylinders)
Odometer	252547
Date	2015-11-13 12:00:00 AM
RPM	1481
Engine Temperature	195 F
Engine Polygraph name	20151112-0001_Untreated_Chrysler_1500-1.psdata
User's file name	09792009-d510-4228-b94d-19e013363bfb.psdata
User's comments	Untreated Signature Number 2

Engine Polygraph Assessment

Version 3.0

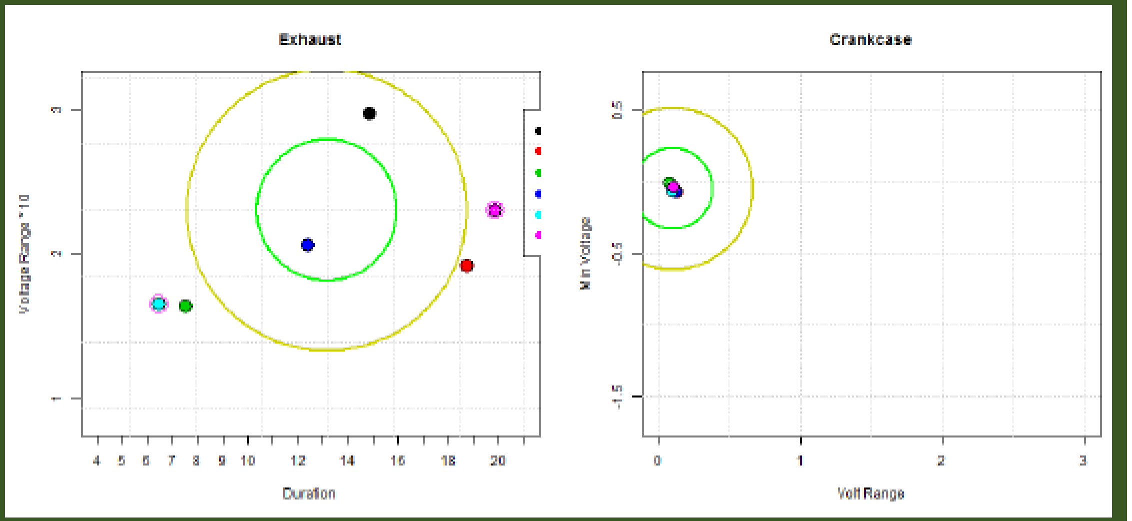
Upper Engine	6
Lower Engine	3
Volumetric Eff. Score	10
Valve Seating	10
Warnings	
Low exhaust pressure. Check leakage	

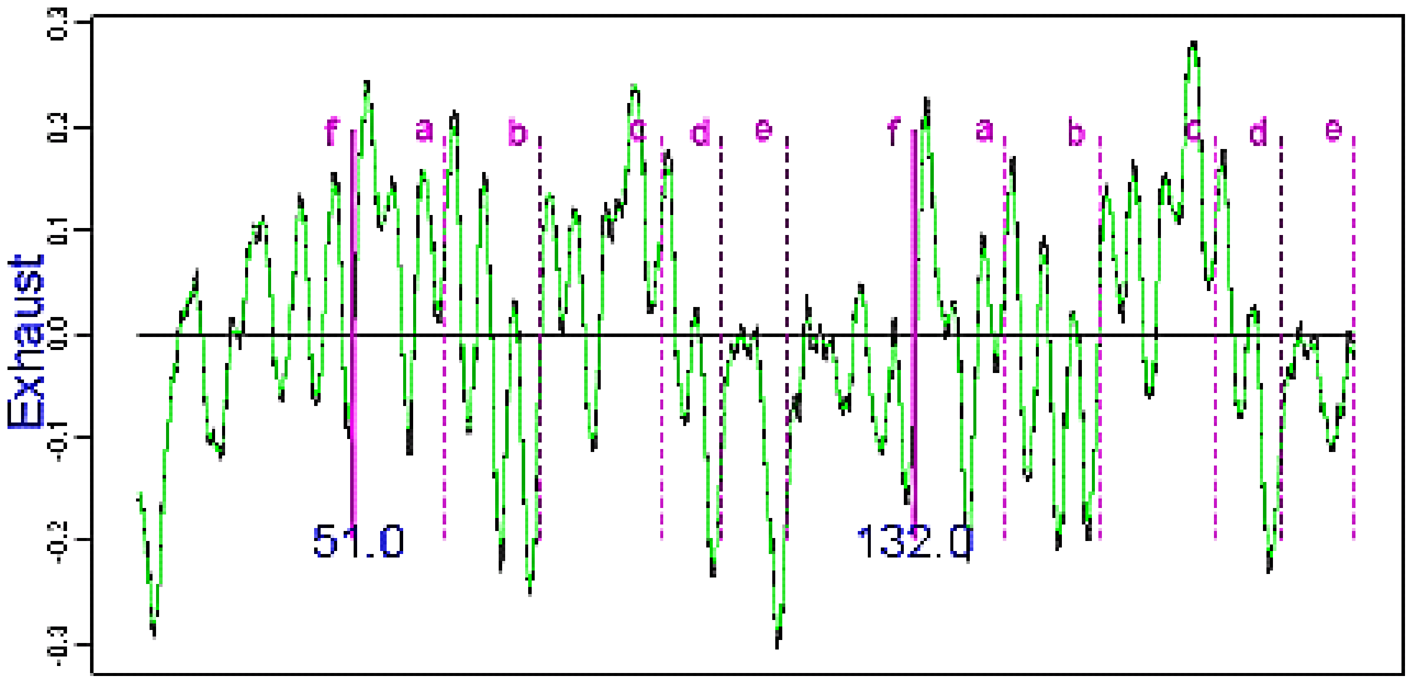
1	2	3	4	5	6	7	8	9	10

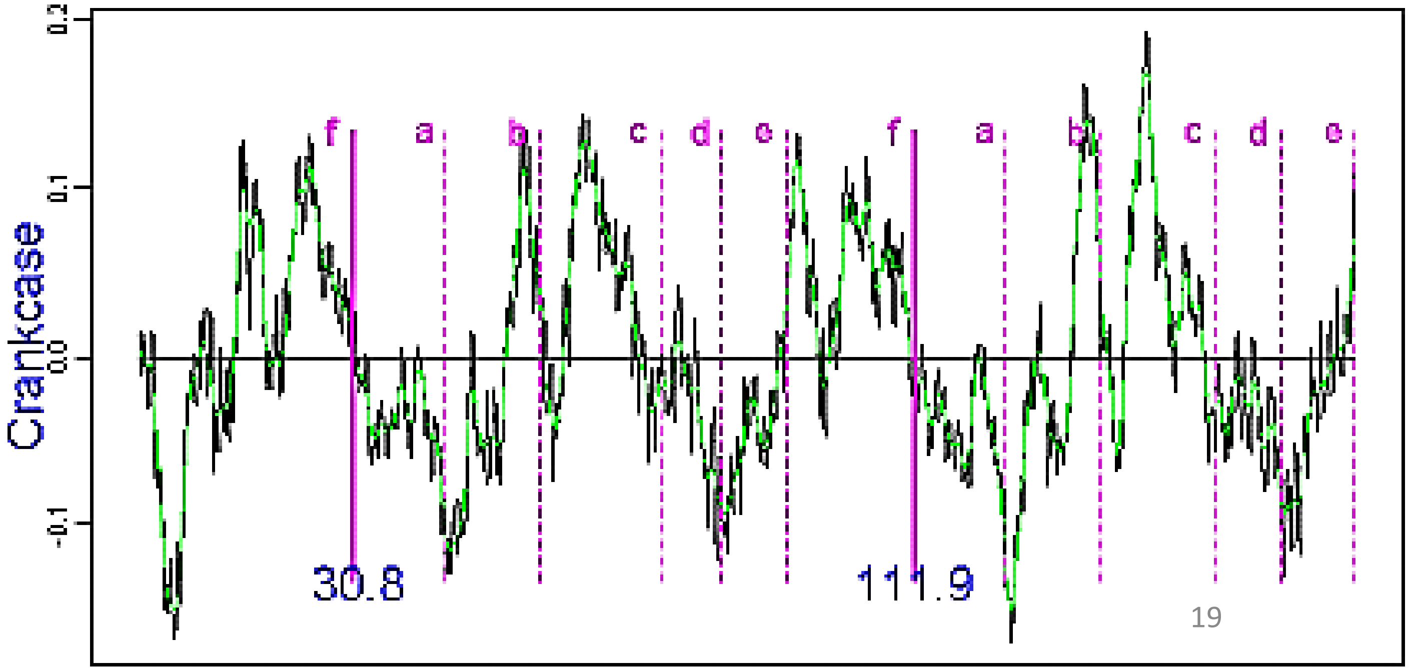
Chrysler 3.8L V6 Transverse mount 'Before'

This engine was running quite well, but the scores indicate growing problems and the signatures show a miss-fire and some blow-by. With bad VE and VS scores, it shows a 'dirty engine'.

Engine Integrity Diagram



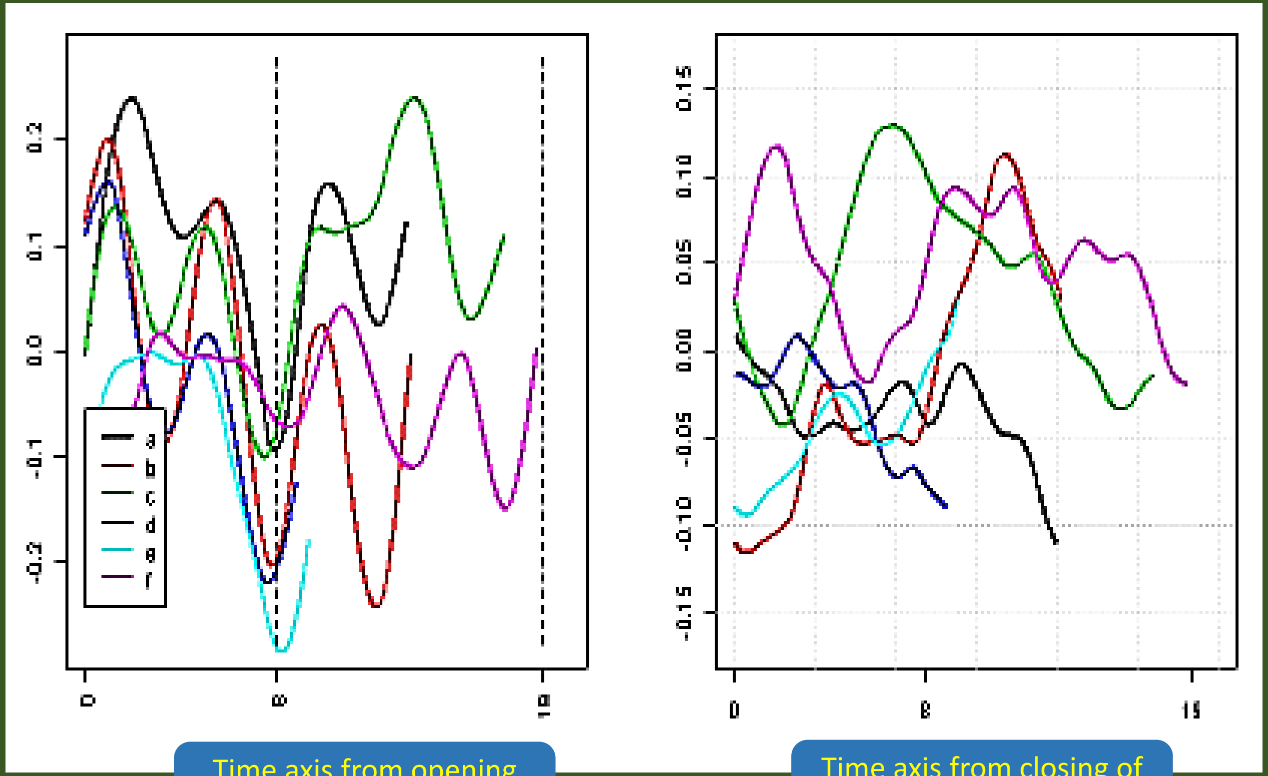




Pressure Profiles for Exhaust & Crankcase

These cylinder profiles are difficult to read.
There are three distinct exhaust patterns:
c & f are the slowest exhaust cylinders
a & b are mid-range (14 ms)
d & e are the fastest at about 10 ms.

Crankcase profiles can show blow-by by the maximum and minimum values; in addition, 'ripples' suggest poor lubrication on cam lobes or possibly bearings.



Time axis from opening of exhaust valve

Time axis from closing of intake valve

Chrysler 3.8L V6 ‘After #1’

Signature Processor/Dougs/9231910f-0b19-4b32-b92b-3efab2e54d38

Vehicle ID:
Chrysler

Assessment 3

Owner	Doug Strock
Serial Number	NA
Engine	Chrysler Chrysler EGH 3.8L V6 (4 stroke, 6 cylinders)
Odometer	268192
Date	2016-06-23 12:00:00 AM
RPM	1616
Engine Temperature	180°F
SHM name	20151112-0001_Treated_Chrysler_1500-5.psdata
User's file name	9231910f-0b19-4b32-b92b-3efab2e54d38.psdata
User's comments	After 28,000 miles with Oxytane

Doug Strock, #Chrysler, 2016-06-23 08:26:05 PM, Odometer: 268192

http://www.SenXSM.com

SenX Signature Assessment

Version 3.0

Upper Engine	3
Lower Engine	3
Volumetric Eff. Score	2
Valve Seating	1

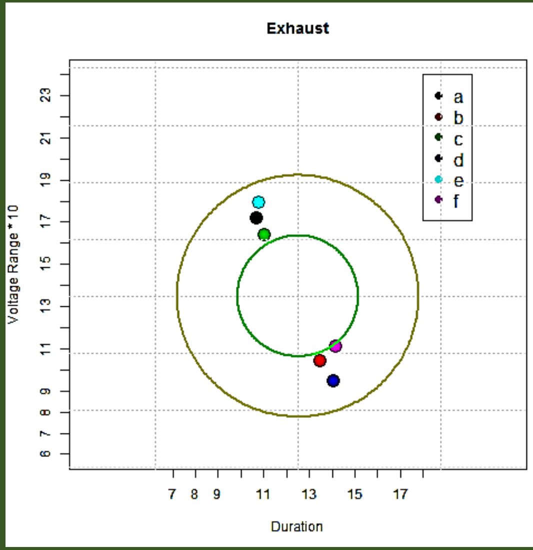
Warnings
High differences between cycles
Low exhaust pressure. Check leakage

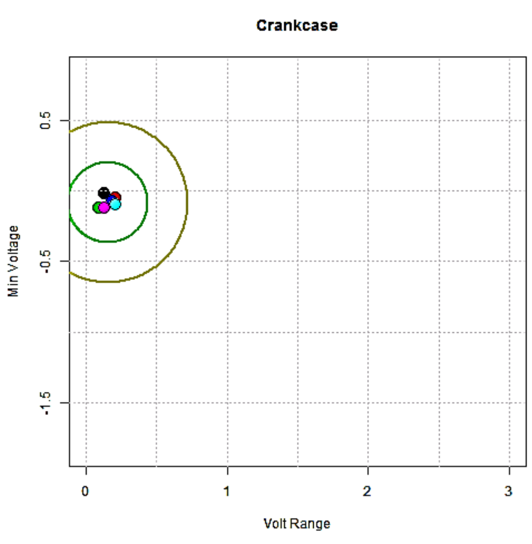
1	2	3	4	5	6	7	8	9	10

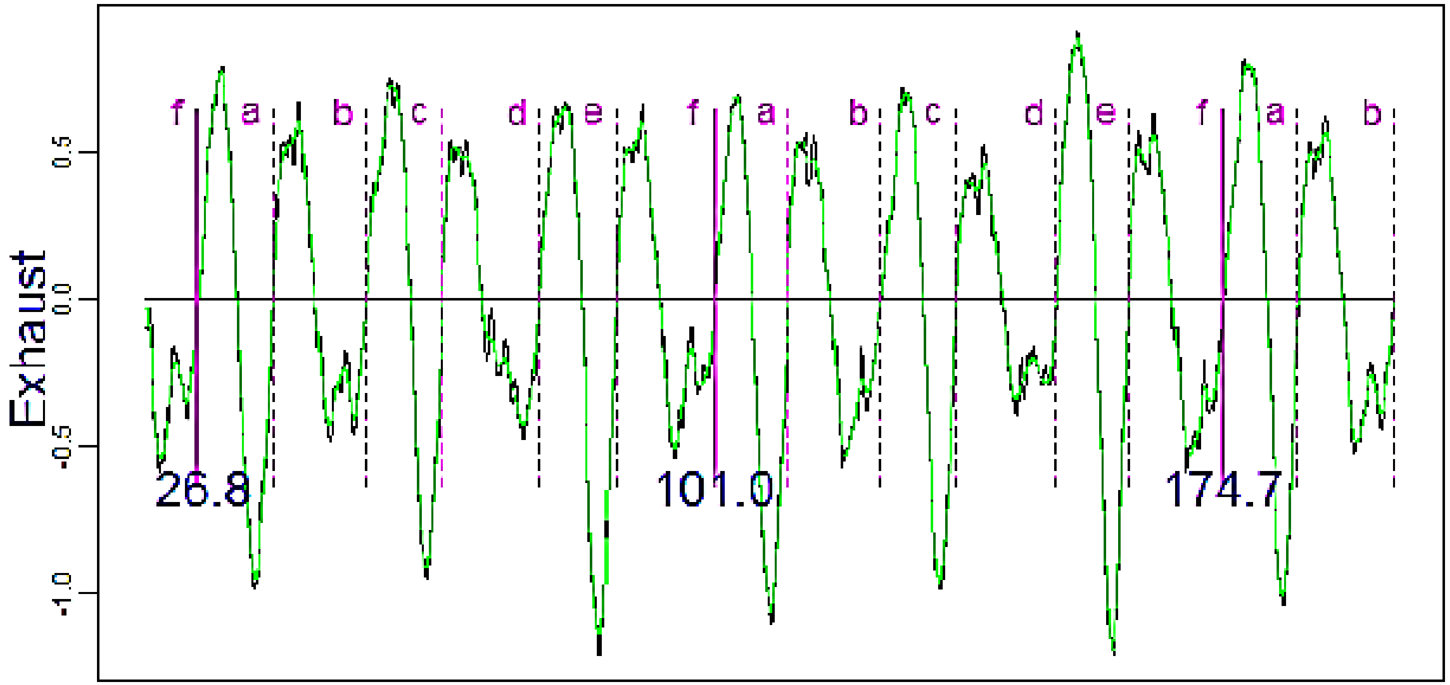
Chrysler 3.8L V6 ‘After #1’

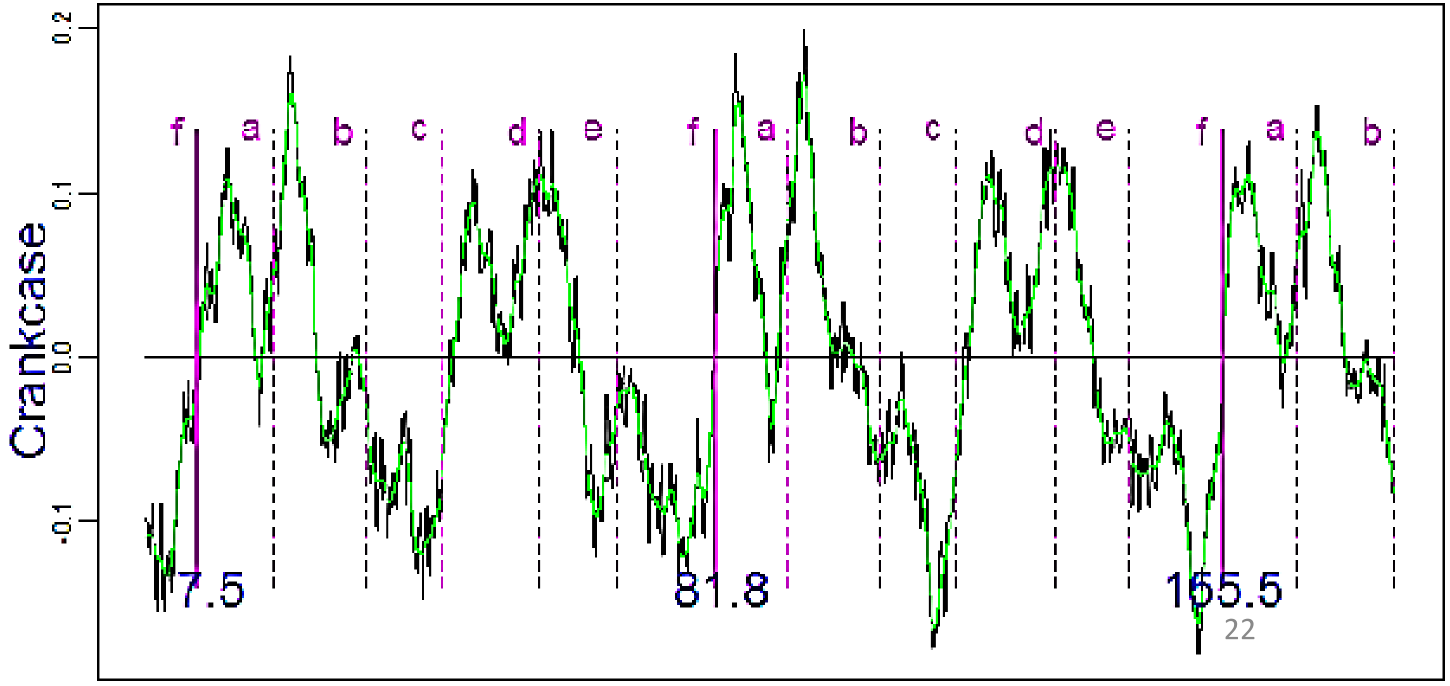
Scores are greatly improved, Exhaust is much more uniform into 2 sets of 3 cylinders. The transverse arrangement causes an offset in the exhausts from the manifolds mixing as a pulse from the forward set hits the vacuum from the second row of cylinders. Output pressure from the exhaust is significantly increased.

Fuel economy improved.





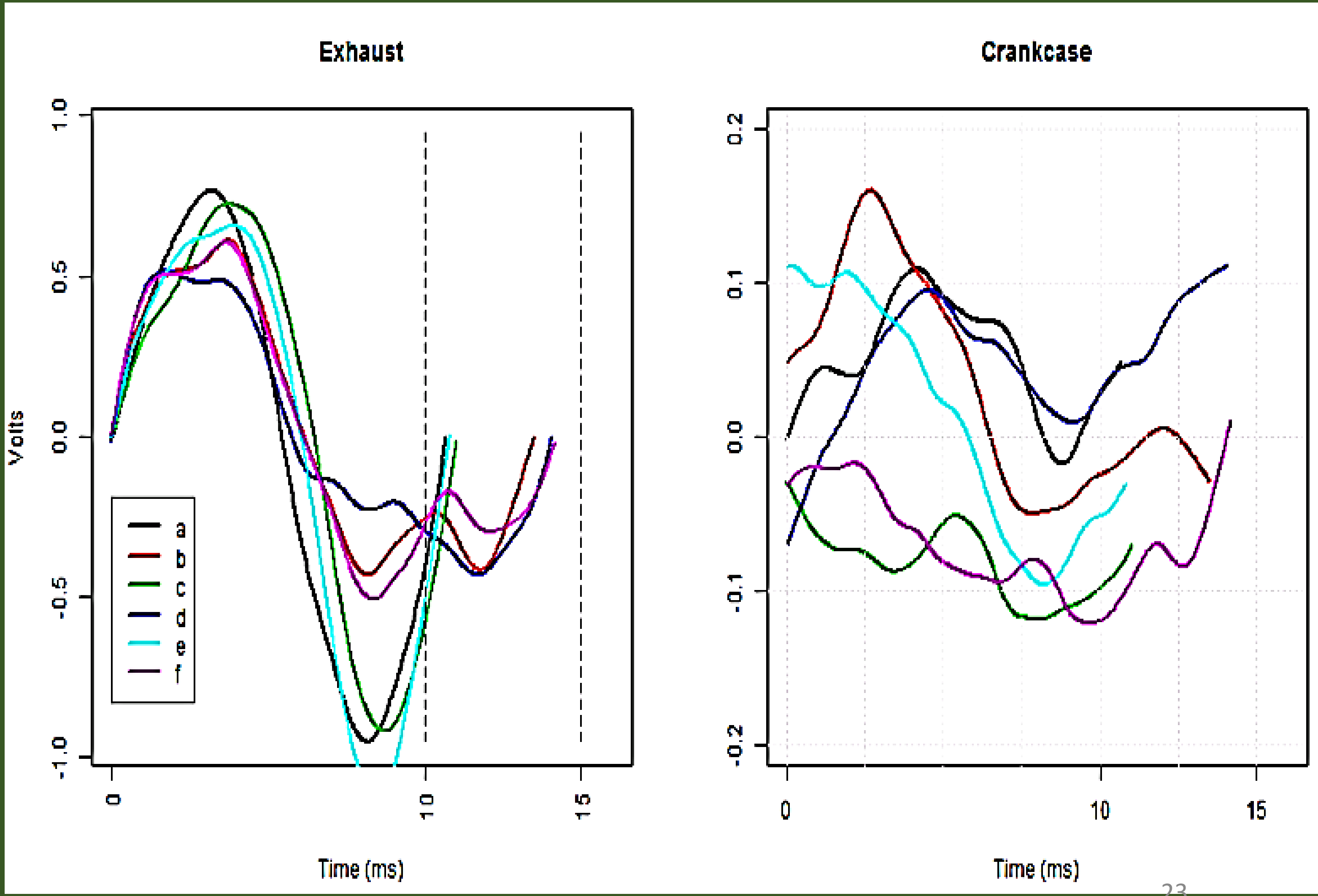




Chrysler 3.8L V6 'After #1'

**No miss-fires, much more uniform exhaust
cylinders. Low variation in crankcase voltages.**

Big improvement.



Chrysler 3.8L V6 'After #2' (RVS)

Signature **Processor/Dougs/85e54d54-a673-477f-a599-c4414134ae9e**

Vehicle ID:
Chrysler Town and Country

Assessment 3

Owner	Doug
Serial Number	NA
Engine	Chrysler Chrysler EGH 3.8L V6 (4 stroke, 6 cylinders)
Odometer	269157
Date	2016-07-05 12:00:00 AM
RPM	1524
Engine Temperature	185°F
SHM name	20151112-0001_Treated_Oxy-RVS1-Chrysler_1500-7.psdata
User's file name	85e54d54-a673-477f-a599-c4414134ae9e.psdata
User's comments	Retest with RVS added and using Oxytane - before first oil change 2

Version 3.0

Upper Engine	2
Lower Engine	3
Volumetric Eff. Score	1
Valve Seating	1

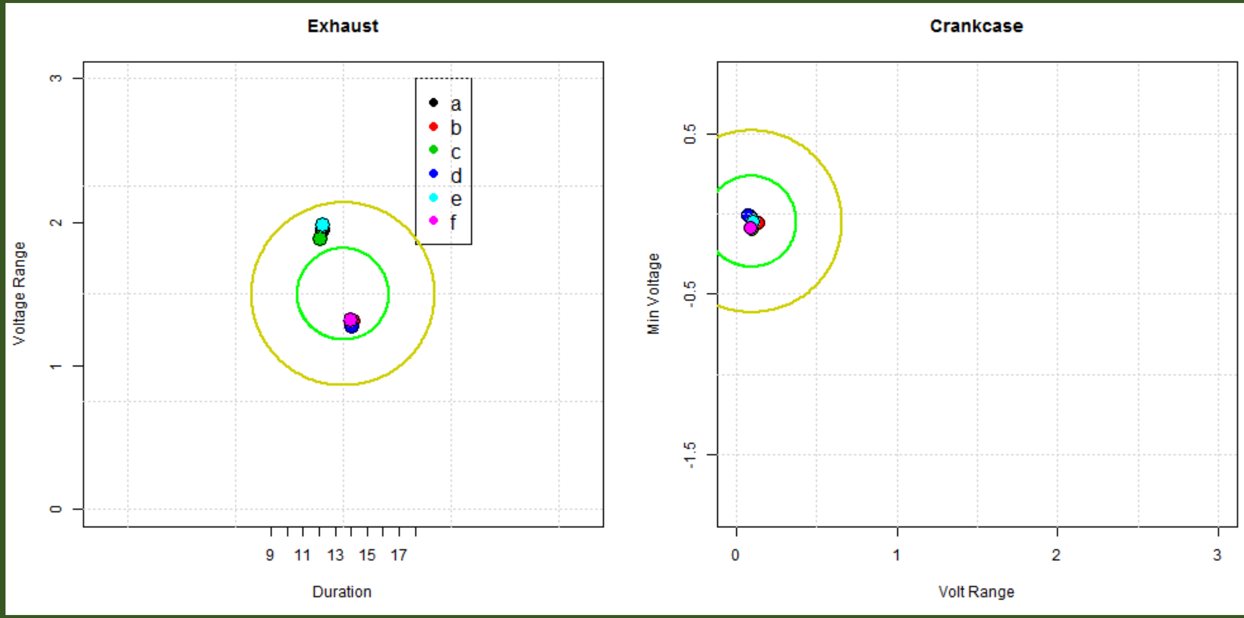
Warnings

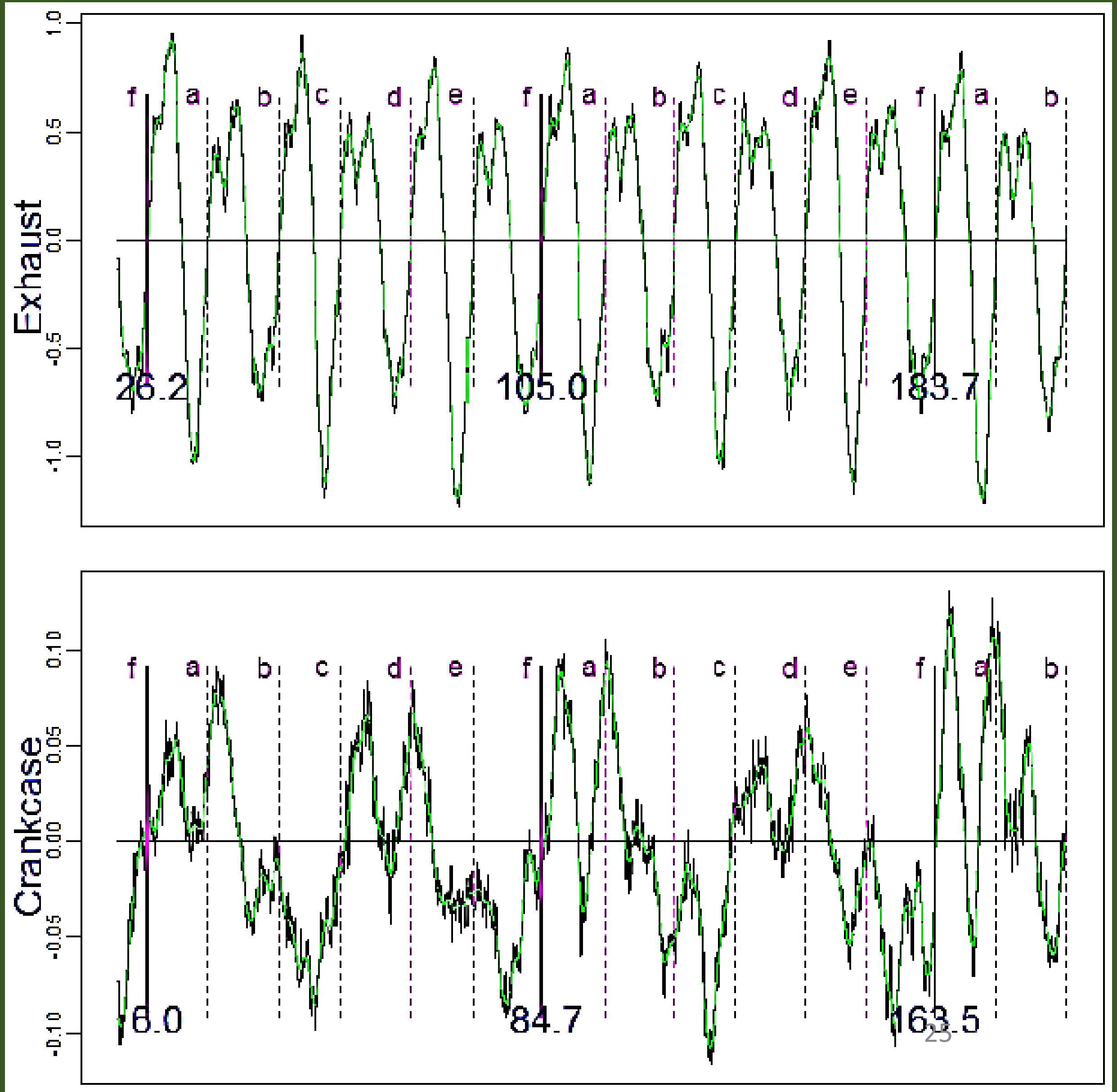
Low exhaust pressure. Check leakage

1 2 3 4 5 6 7 8 9 10

Chrysler 3.8L V6 'After #2' (RVS)

Scores improved, exhaust voltage increased. Cylinders more uniform in exhaust, showing much less turbulence from the blending of the two manifolds, suggesting that there was carbon buildup exterior to the valve outlet and valve, itself.

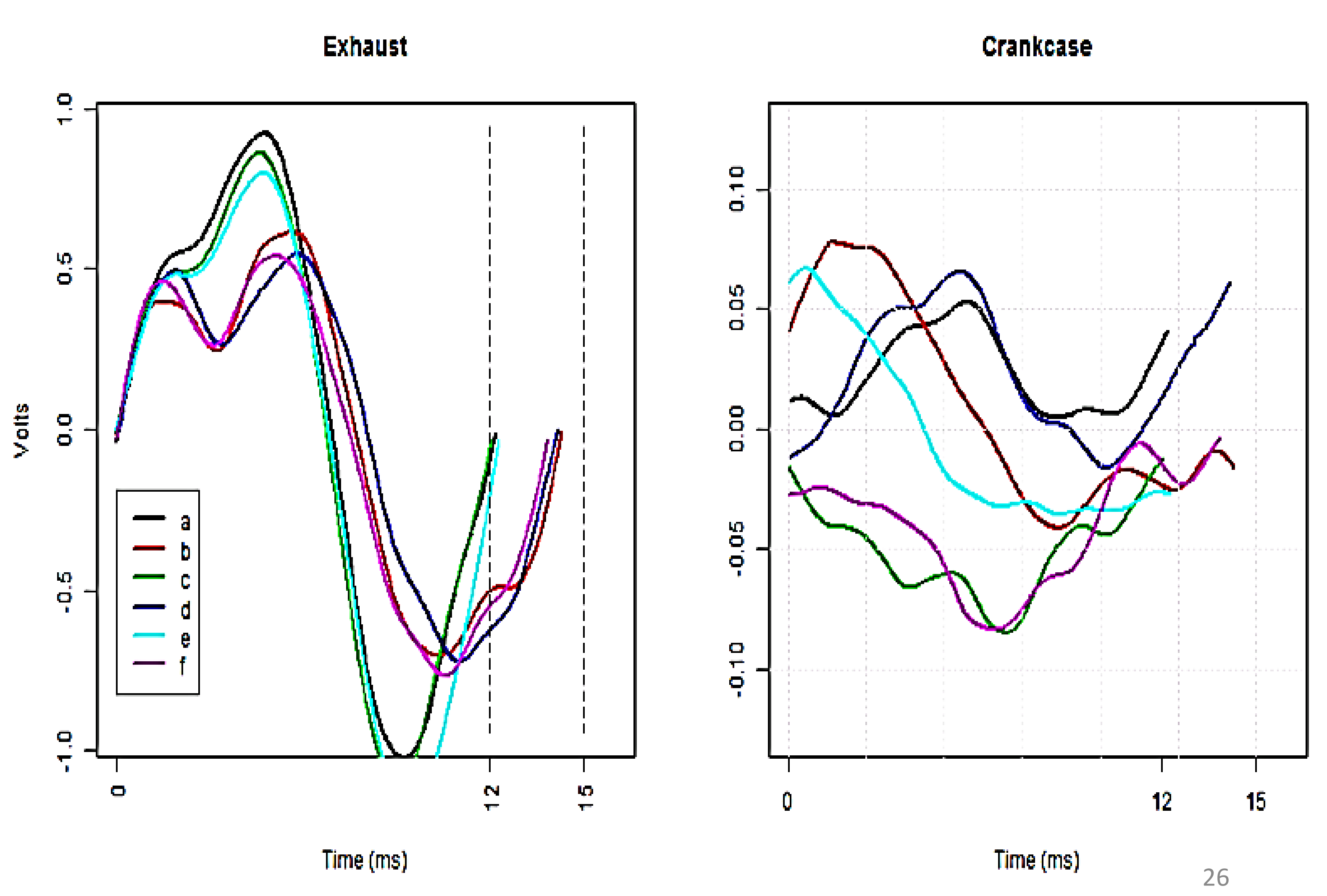




Chrysler 3.8L V6 'After #2' (RVS)

Cylinder Profiles are more uniform, forming the two sets from the V6 architecture with transverse mount.

The crankcase shows three sets of two. They are not remarkable.



Before and After from second engine

This engine had relatively low miles on it. But due to stricter emission regulations:

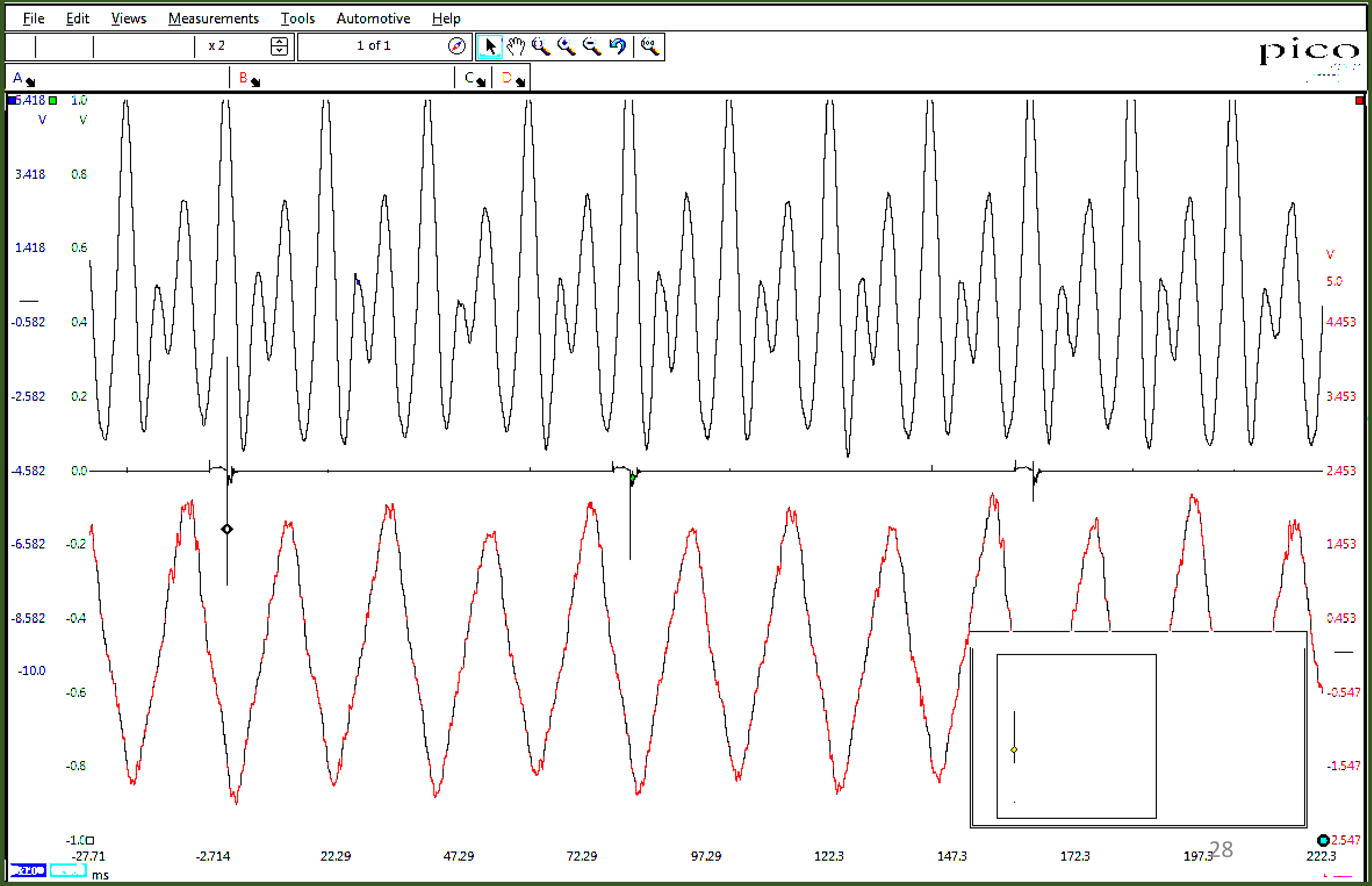
It looks like the manufacturer may have had to use more emission control to meet the regulations. The un-intended consequence of this is more engine deposits sooner. The after report shows significant improvement from new more advanced automotive engine cleaning chemistry.

Engine Polygraph/Engine Angel advanced data acquisition and resolution bare this out.

The reader/technician can now provide far more accurate and repeatable before and after reports to the customer

Kia 2012 Sportage – 'Before'

2.4L Kia GDI Theta II on 2016-02-24



Marketing & Funding/Carbon Buildup tests/JLB tests

Kia: 2016-07-11 'After'

Vehicle ID:
Sportage 2012

Assessment 3

Owner	John Brock
Serial Number	NA
Engine	Kia 2.4L L Theta Kia I4 (4 stroke, 4 cylinders)
Odometer	39534
Date	2016-07-11 12:00:00 AM
RPM	1495
Engine Temperature	195°F
SHM name	Kia_Sportage_2012_20160711-0001#3update.psdata
User's file name	de88a0e3-cc4c-4581-867c-6b1ae552bfcb.psdata
User's comments	AFter RVS and oxytane 3 rd

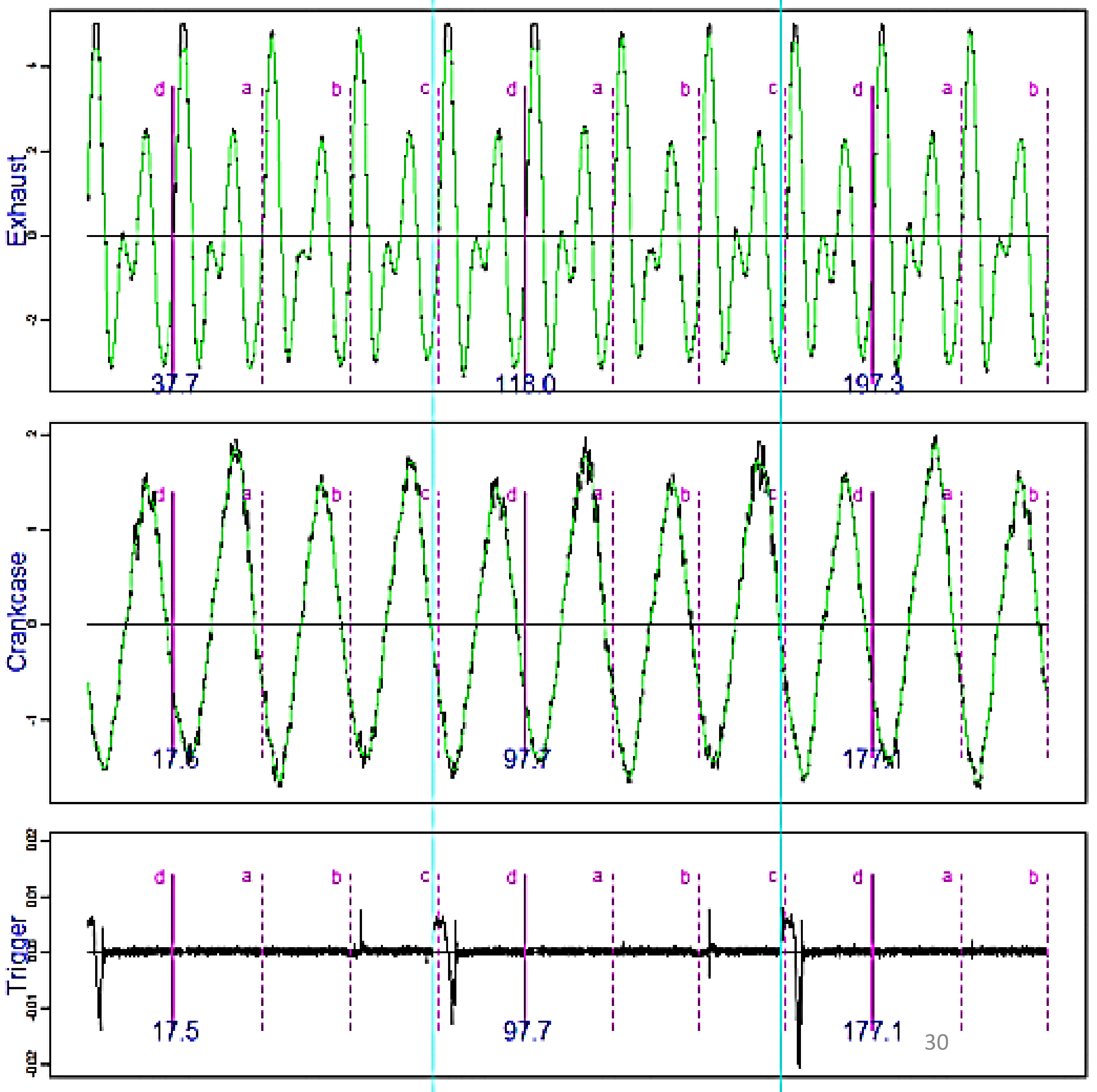
Version 3.0

Upper Engine	1
Lower Engine	3
Volumetric Eff. Score	1
Valve Seating	1

Warnings

1	2	3	4	5	6	7	8	9	10

Kia 2012 Sportage 'After'



Engine Polygraph by Predictive Fleet Technologies

- **US Patent Application US 2016/0025027 A1**
- **Web-based Analytics and Reporting**
  - **Report provides insight to physical condition of engine**
    - **Dirty or broken**
    - **Upper engine and Lower engine**
  - **Signatures stored for comparison to do ‘Before’ and ‘After’**
  - **Signatures captured periodically for predictive failure analysis**

- **Interface with Engine Angel for Fleet Management**

Some Physics of the Engine

- **Volumetric Efficiency**
- **Combustion completeness**
- **Conversion of combustion (chemical energy) to ‘useful’ work**

Major Components

- Fuel quality and delivery
  - Contents of fuel – reactants, catalysts, ‘cleaners’, contaminants, entrapped air, static electricity
- Gas Flow from Air intake to Exhaust to environment (Volumetric Efficiency)
  - Air from the environment through air filter
  - Exhaust gas to the environment through catalytic convertor, DPF, muffler
  - EGR connecting exhaust gas to intake
  - Compromised gaskets
  - Blow-by from power and compressions strokes to crankcase
  - PVC valve routing crankcase gas to intake
  - Timing of valve action
  - Tightness of valve sealing
  - (Un)obstructed air flow into and out of cylinders

[1] See following page

- Combustion
  - Dispersion of fuel
  - Completeness of burning
  - Increase of moles of gas
  - Increase of kinetic energy of gas
- Energy extraction (exergy & anergy[1])
  - Timing of the combustion (GDI)
  - Mechanical work
  - Heat
    - Exhaust
    - Coolant – heat exchange
    - Oil temp
    - Friction

Energy = Exergy + Anergy

Exergy is the energy that is available to be used.

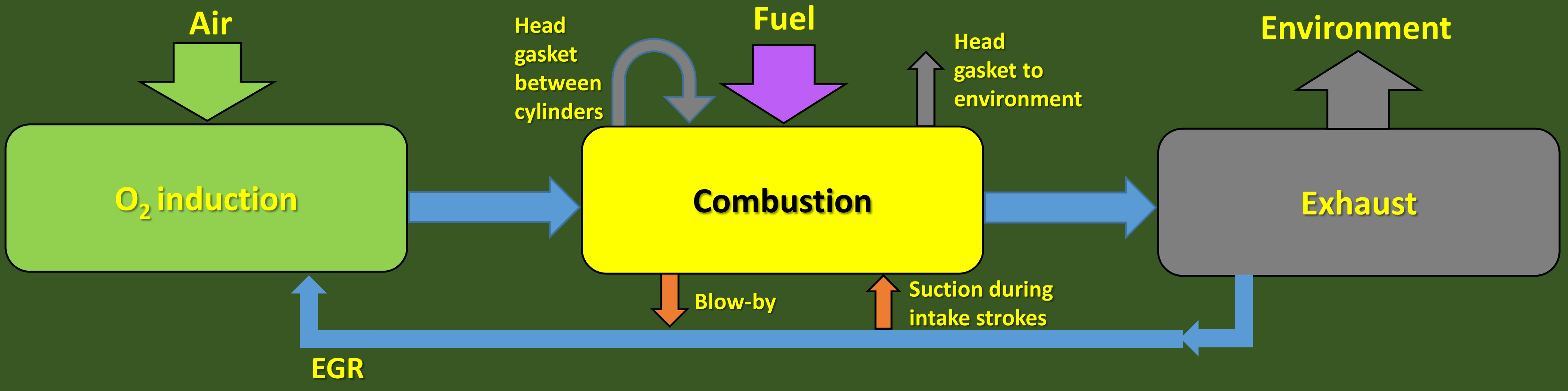
- Torque delivered to the road is the primary interesting energy for vehicles.
- Air conditioning from the compressor belt is also interesting on hot days.
- And the alternator charging the battery, power steering and brakes pumps are interesting.

Anergy is dis-organized energy that cannot be harvested.

- Heat from friction in the differential, the axles, tires all subtract from interesting energy.
- Heat in the exhaust, after the EGR, is anergy.
- Heat of the coolant, engine block, pistons, catalytic convertor, etc. are anergy.

Lubrication is a huge factor to minimize anergy.

Flow of Gases



Measure
- Volumetric Efficiency

Enhancers
- Turbochargers

Inhibitors (barriers)
- Air filter
- Turbulence
- Valve timing
- Valve seating

Measure
- Exhaust composition
- Blow-by into crankcase

Enhancers
- Timing
- Catalysts

Inhibitors
- Fuel dispersion
- Contaminants
- Entrapped air
- Static electricity

Measure
- Exhaust pressure (gas flow)

Enhancers
- Tuned manifold

Inhibitors (back pressure)
- Filters (back pressure)
- Muffler, Cat. converters
- Turbulence
- Valve timing
- Valve seating

Engine Polygraph

Danger of catastrophic failure

- **Overall Engine Score**
- **Upper Engine**
- **Lower Engine**
- ***Cam lobe wear***
- ***Crankcase Bearings***

Need for cleaning or adjustments

- **Volumetric Efficiency Score**
- **Valve Seating**
- ***Blow-by***
- ***Crankcase pressure***
- ***Engine oil Volatility-Lubricity***