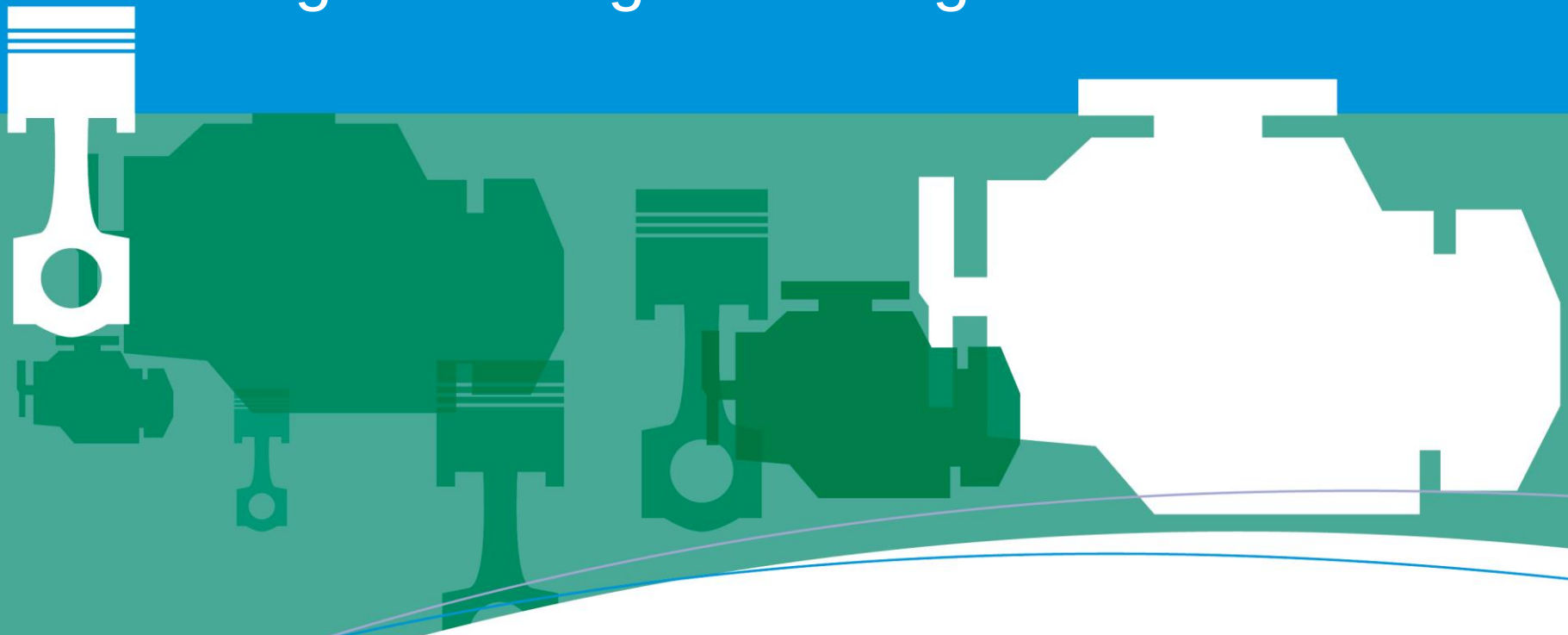
Performance you can rely on.

Engine testing and rating



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Agenda

- Why do we run engine tests?
- How are engine tests developed and run?
- How are engines rated?
- Some examples

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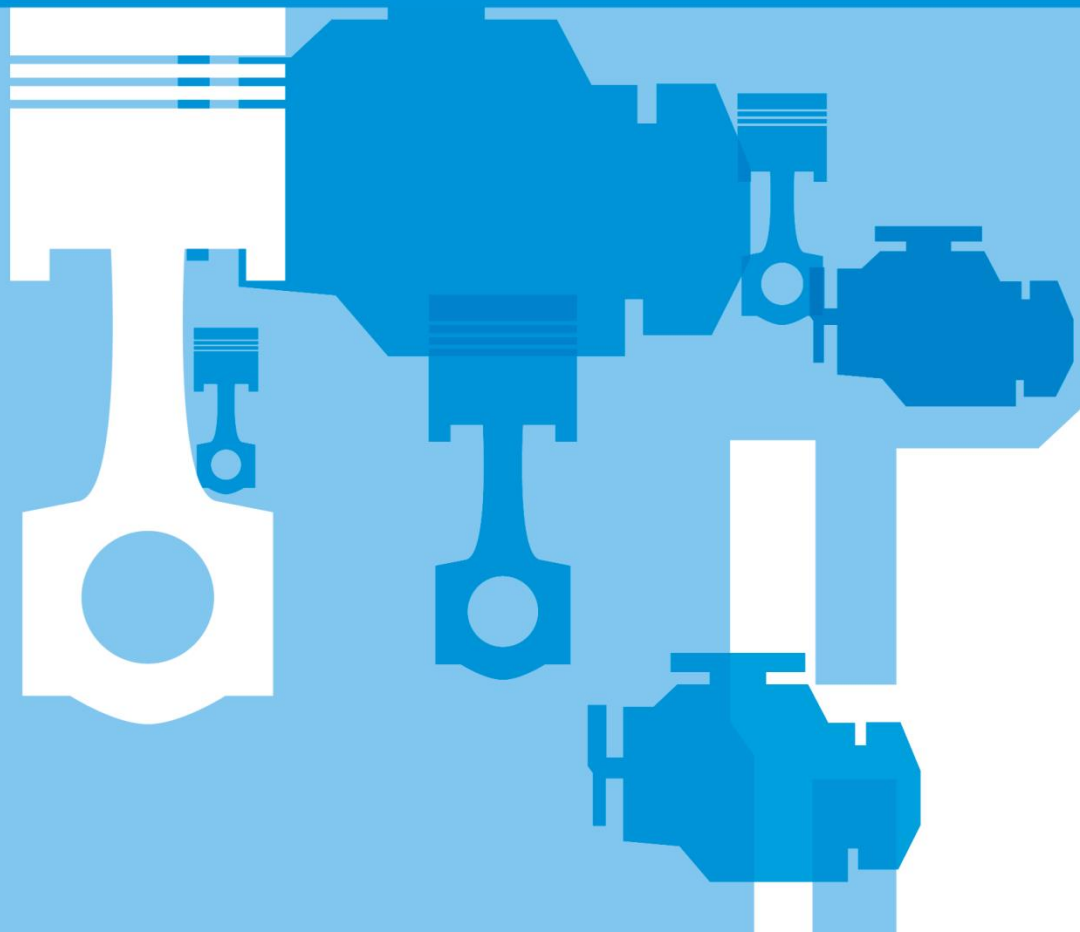
Why run engine tests?



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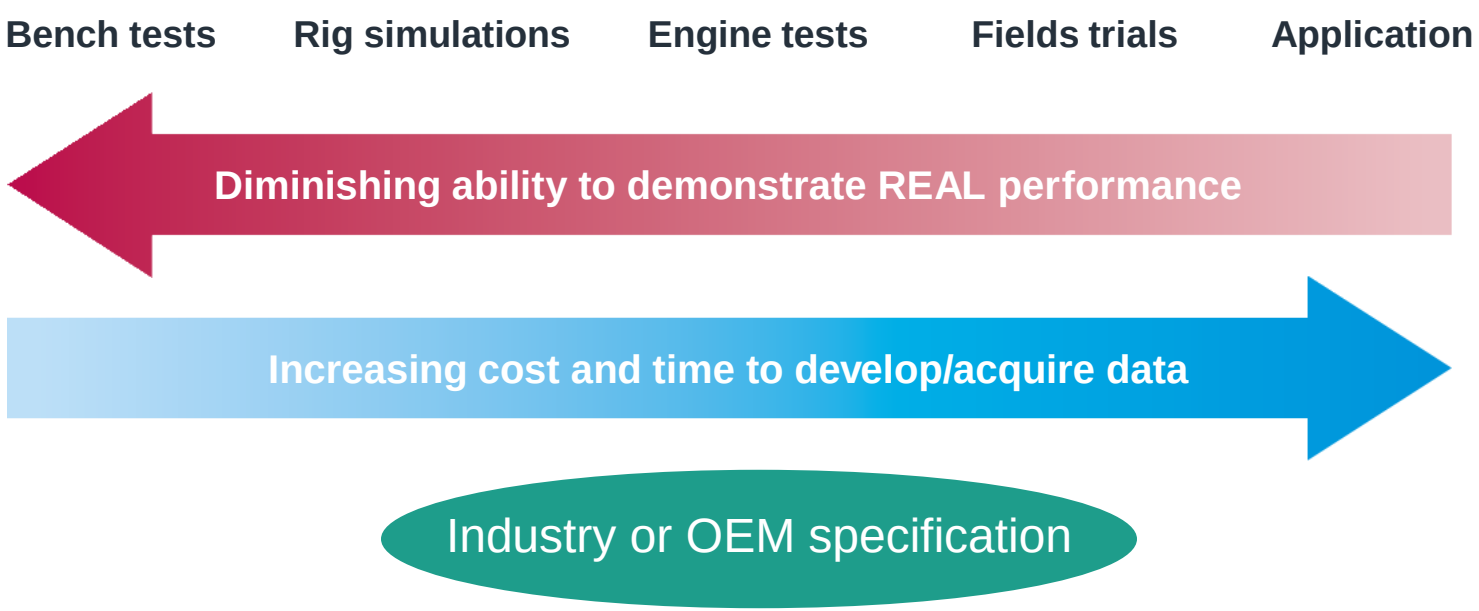
Why run engine tests?

- To ensure an oil reaches a particular performance level
- To ensure the oil will perform well in the field and prevent field failures
  - Engine tests are typically designed to run at more severe conditions to ensure robustness in the field
- A more realistic/practical alternative to field testing



Why run engine tests?

- To verify engine durability while developing new additives and formulations in response to industry drivers:
  - Primarily environmental legislation
    - Fuel economy
    - Low sulphated ash, phosphorus and sulphur (SAPS) for compatibility with exhaust after treatment
      - ACEA E6
    - Exhaust gas recirculation leading to high soot loadings
      - API CJ-4
- In response to a problem experienced in the field
- Introduction of new engine technology

Industry or OEM specification

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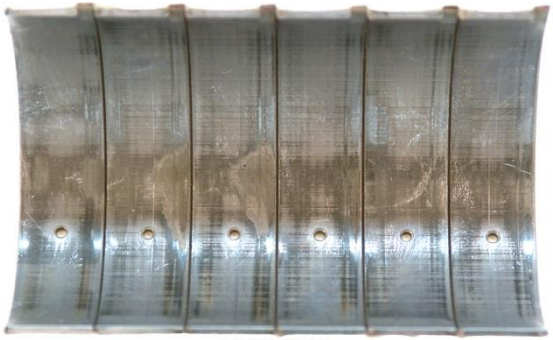
What is tested?

- Wear
  - Camshafts and tappets
  - Journal bearings
  - Piston rings and cylinder liners

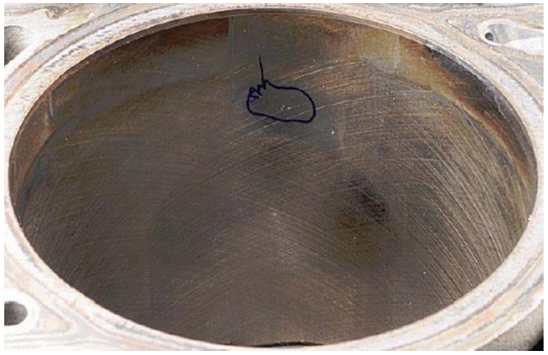
Camshafts and tappets

Journal Bearings



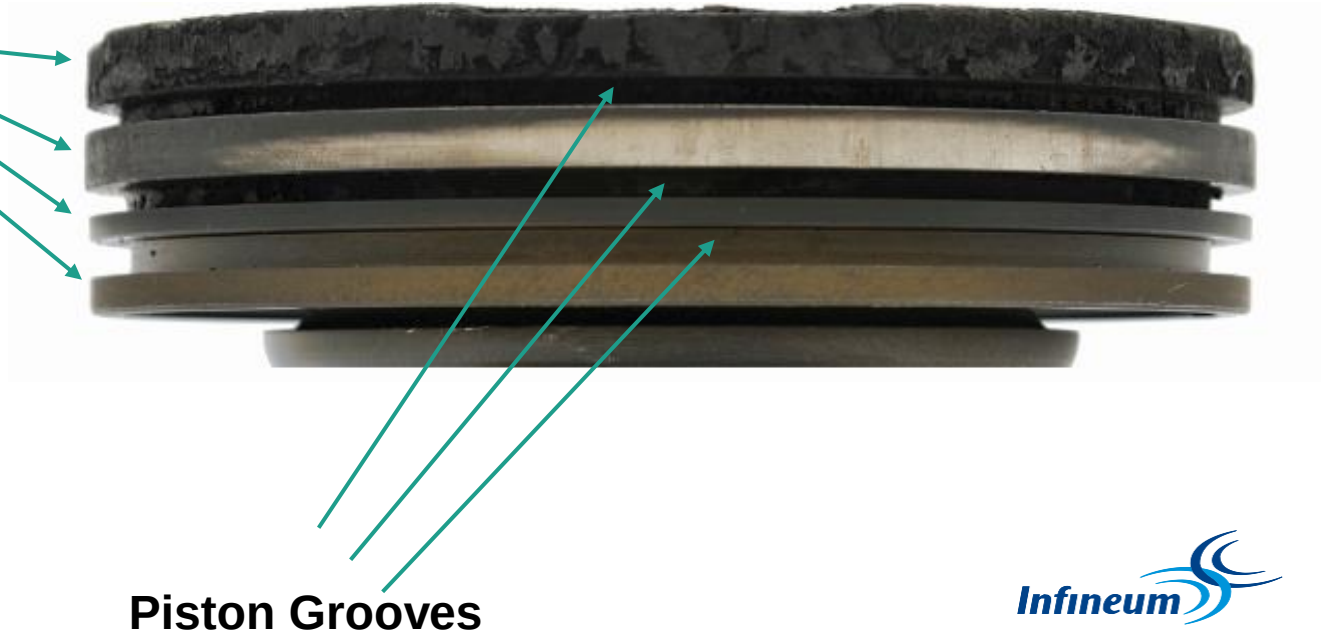
UNIT 2726
IM0502676-A
110,844 TEST MILES
CON. ROD
LOWER 1-6

Bore polish



What is tested?

- Cleanliness
  - Piston deposits
  - Turbocharger deposits
  - Sludge deposits

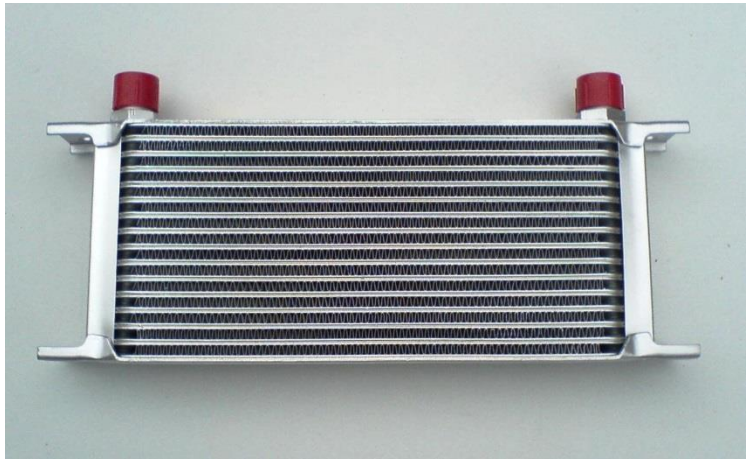


What is tested?

- Corrosion control
  - Bearings
  - Piston rings
  - Oil coolers

Bearings

Oil coolers



What is tested?

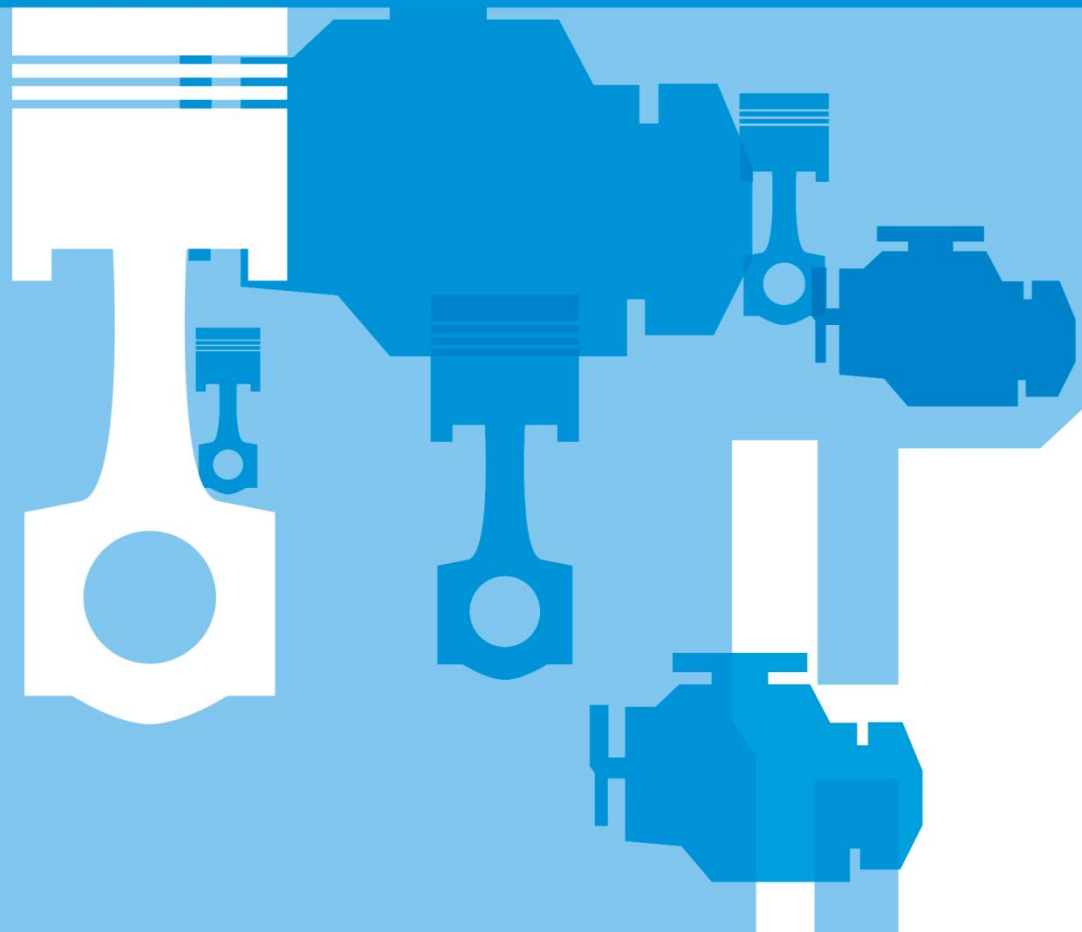
- Oil chemistry and viscometrics
  - KV100 viscosity
    - Control of oil thickening
    - Control viscosity loss due to shearing or fuel dilution
  - TBN
    - To control acids
  - Metal analysis
    - Lead, iron, tin, aluminium, chromium
      - Indicates wear and corrosion
    - Calcium, magnesium, zinc, phosphorous, boron
      - To check additive chemistry
  - Soot
    - To check control of soot induced oil thickening

What is tested?

- Fuel economy
  - Detect effects of lubricants on the fuel economy
  - Typical FE improvements can range from 0.2 % to 3.0%

Performance you can rely on.

Developing an Engine Test



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Developing an Engine Test

- Two requirements for an engine test
  - Test method
    - Definition of test engine
    - Definition of test procedure
    - Definition of critical engine components
    - Definition of fuel
  - Test limits
    - Test limits will come from an industry and/or OEM oil specification
- Two targets for developing an Engine Test
  - Discrimination
  - Consistency

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Developing an Engine Test – Test Method

- Industry body such as ACEA or an individual OEM decides that a particular aspect of oil performance needs to be tested
- Engine test method is developed
  - by the industry
    - CEC, ASTM
  - by the OEM
- Test development is done by collaboration of OEM, oil marketers, additive companies and test labs
- Same engine test can be used for both industry and OEM specifications

Developing an Engine Test – Test Method

- Test Engine
  - Known to severely test a particular aspect of oil performance
  - New engine model/technology (older model test engines may be carried over into new specifications)
  - Has shown a problem in the field due to oil performance

Developing an Engine Test – Test Method

- Test conditions
  - Chosen to stress the engine and oil
  - Examples

Running condition change	Parameter affected
High power and high torque for long periods	Oil oxidation, ability to provide long drain interval
Stop/start	Wear
High EGR	Oil degradation, nitration, soot formation
Overfuelling, timing changes	Soot formation
Special fuel	Sludge formation, acid attack etc. depending on fuel type
Large ring and liner clearances to increase blow by	Oil degradation, piston deposits

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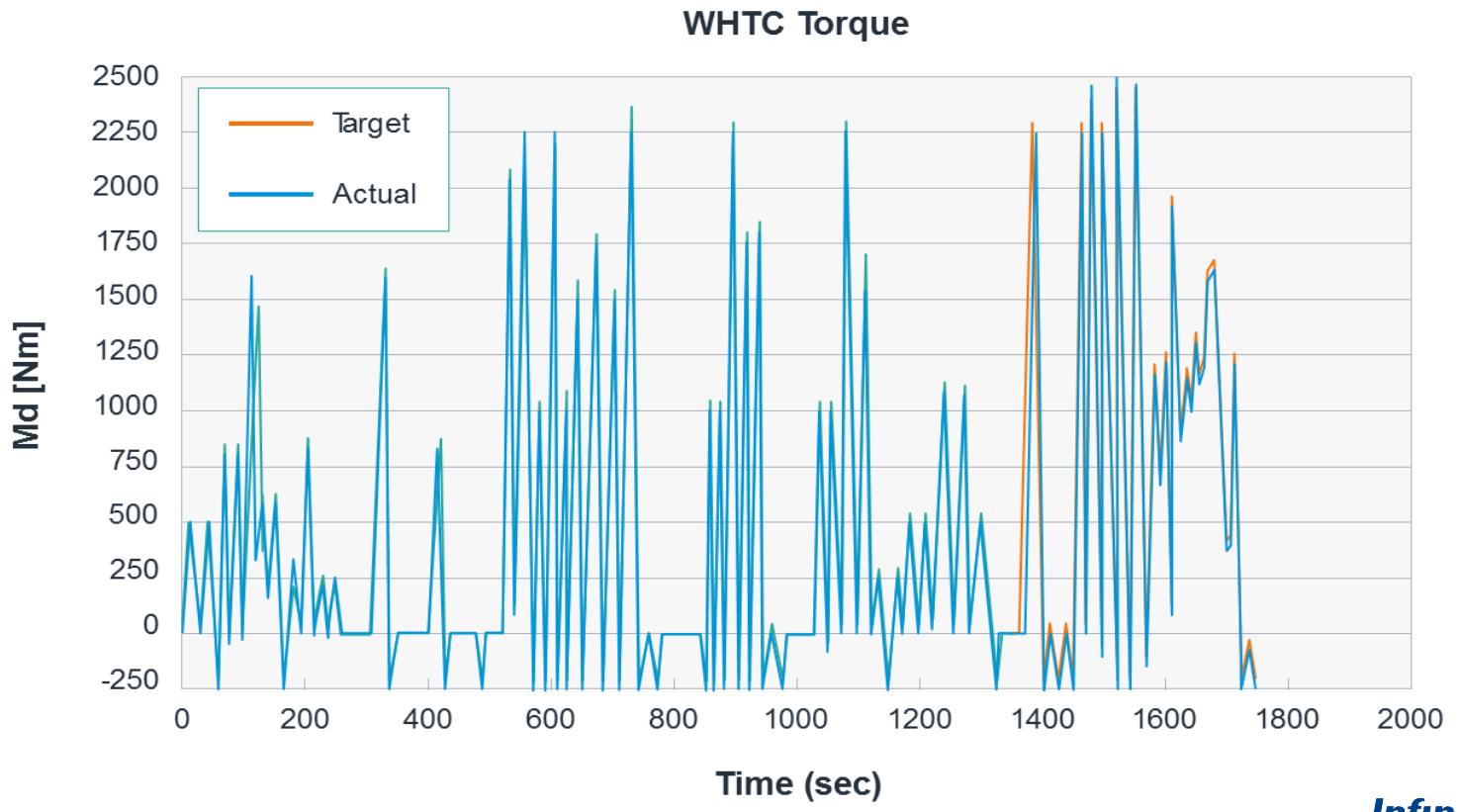
Developing an Engine Test – Test Method

- Running conditions for Fuel Economy
  - Chosen to mimic real world duty
  - World Harmonised Transient Cycle



Developing an Engine Test – Test Method

- Tests are run in special engine test facilities
  - Independent test labs
    - E.g. ISP, APL, Intertek, Southwest Research Institute
  - Oil marketers
  - Additive companies

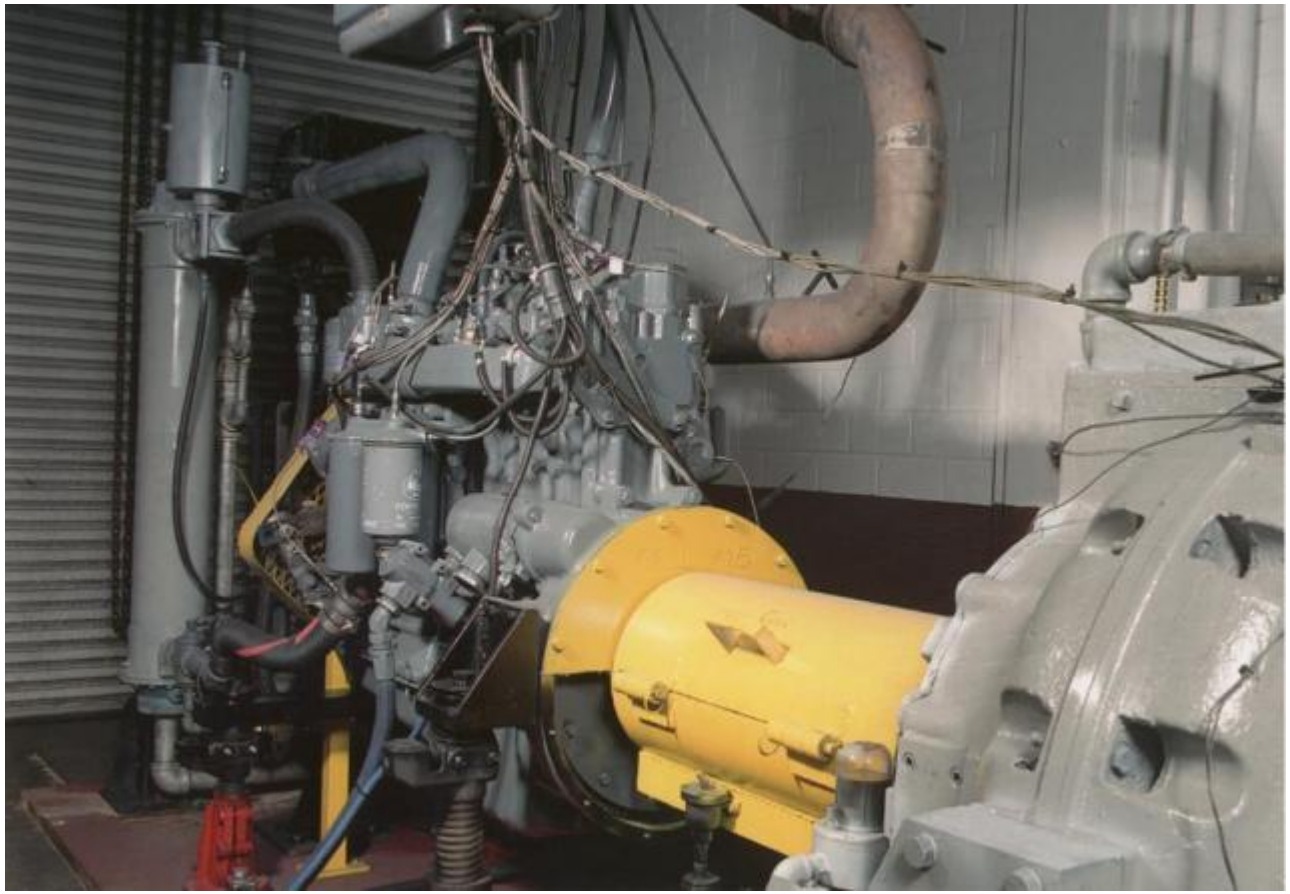
Developing an Engine Test – Test Method

- Engines usually connected to dynamometers so they can be loaded
- Controlled reference fuels used
- Various inputs can be controlled if necessary
  - E.g. OM501LA Fuel Economy test requires intake air temperature and humidity and fuel temperature to be controlled

Developing an Engine Test – Test Method

OM646LA

Developing an Engine Test – Test Method



Mack T-8

Developing an Engine Test – Test Method

- Tests are monitored to check they are operating correctly
  - CEC Test Monitoring Group (TMG)
  - ASTM surveillance panel
  - Individual OEM
- Tests monitored by running reference oils regularly
  - Results must be within defined control limits
  - If outside the limits the test stand must be brought back to standard before further testing (CEC approach)
  - Alternative ASTM approach when test trend is away from target result is to apply correction factors

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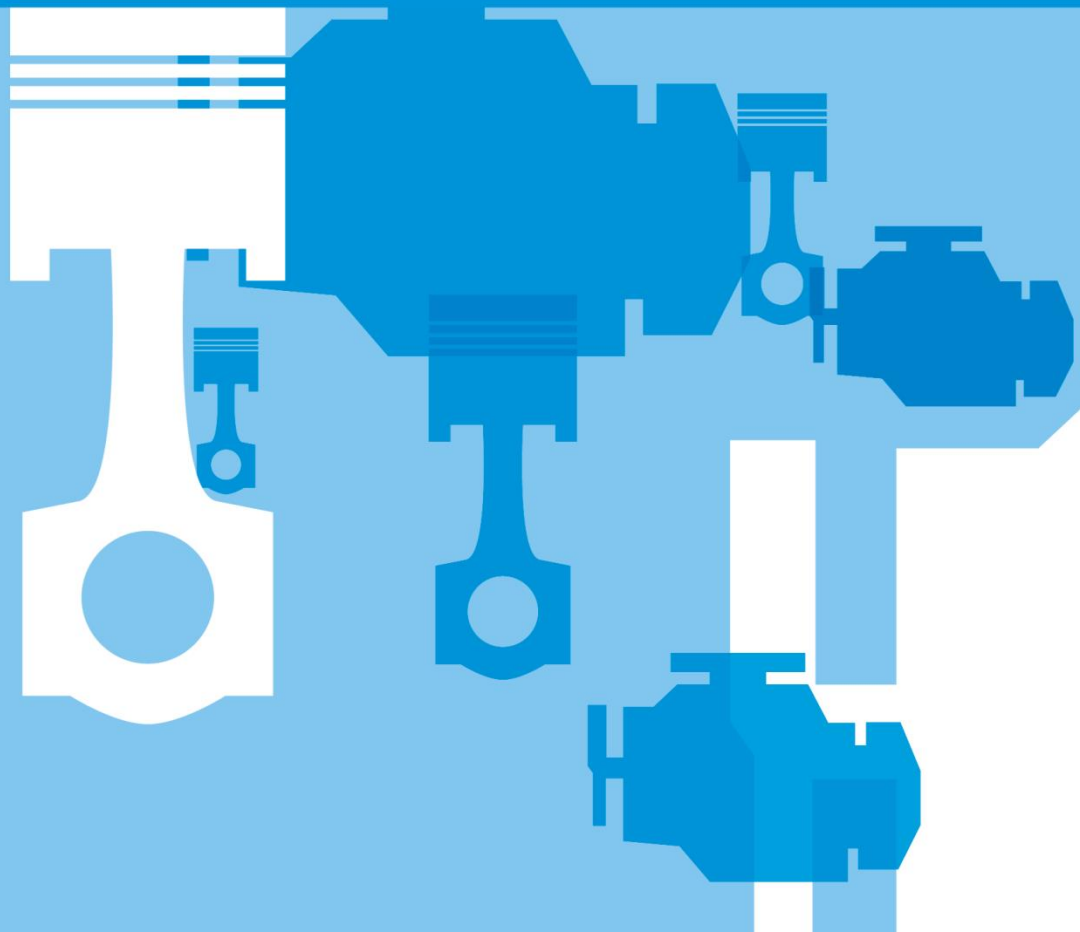
Developing an Engine Test – Test Method

- Determined by the organisation responsible for a particular specification
  - same engine test is often used with different limits for more than one oil specification
    - VW TDi ACEA A3/B3 and A3/B4
    - Daimler engine tests within the Daimler specifications
- Limits can be absolute or related to reference oil performance
  - High reference
    - Oil known to give good performance
  - Low reference
    - Oil known to show problems in the test

How are engines rated?



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How are engines rated? – Test Measurements

- Quantitative
  - Wear
    - Size change (in microns)
    - Weight loss (in mg)
    - Increase in oil metal levels (ppm)
    - Oil consumption
      - Secondary indicators
  - Oil viscosity change
    - Kv100 (cSt)
  - TBN
    - Electrochemical titration
  - Fuel economy
    - Weight of fuel used

How are engines rated? – Test Measurements

- Qualitative
  - Engine deposits and engine sludge
    - Severity of rating can depend on amount, type and position
  - Can’t be measured quantitatively and requires visual rating based on a set methodology, training and judgement
  - Rating usually expressed as a merit or de-merit figure

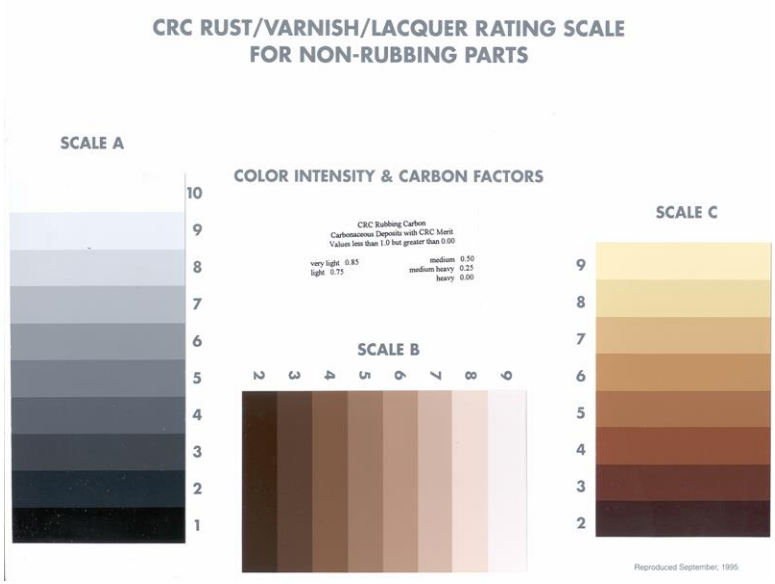
How are engines rated? - Rating

- Rating technicians use a rating system approved by the testing organisation
- Rating technicians regularly attend ratings workshops to make sure ratings are done consistently across the industry
- Different rating systems
  - DIN 51361
    - Method of visual rating of piston cleanliness

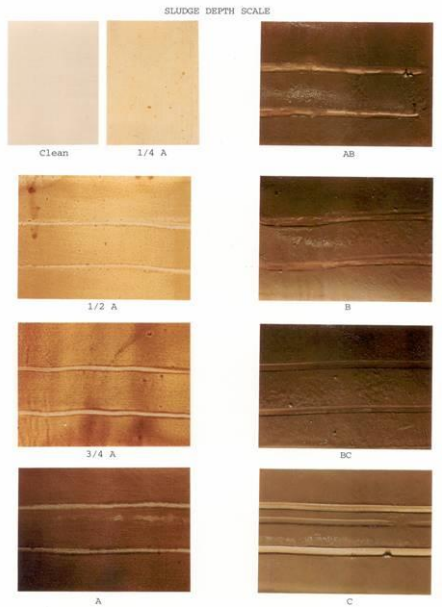
How are engines rated? - Rating

Rating Aids

CRC Manual 14 – CRC Rust / Varnish / Lacquer Rating Scale for Non-Rubbing Parts



CRC Manual 12 – Sludge Deposit Scale



How are engines rated? – Rating

- Sometimes quantitative measurements are combined with qualitative merit figures
  - Mack T-12
    - Wear, metal level and oil consumption measurements are converted into merit figures which are then summed to give a final merit rating

Examples

- Daimler OM501LA
- Mack T-12
- Sequence IIIG
- Daimler M271
- Daimler OM646LA

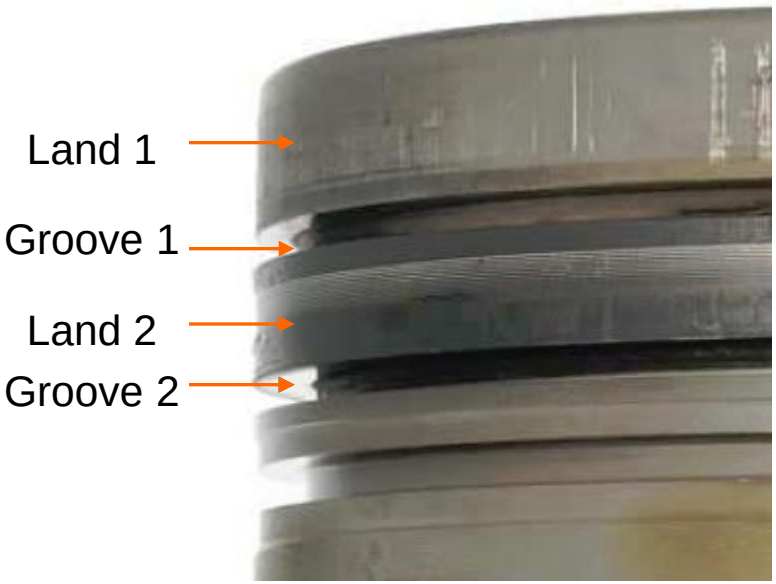
Daimler OM501LA

- 11.9 liters V6 Euro V Diesel 350kW
- 300 hours alternating load
- Engine cleanliness
    - Piston deposits
    - Sludge
- Wear
    - Bore polish
    - Oil consumption
  - For XW-30 oils bearing wear is measured and rated

- Used for MB HDD specs and ACEA E4 to E9
- This engine is also used for the OM501LA fuel economy test

Daimler OM501LA

Pass- overall 36.81 merits



	Rating	Discol.	Black	Carbon	Ring Riding	Sum Points	
	Factor	65	30	-30	-40		
Groove 1	%Area	4	96	35	4		
	Points	2,6	28,8	-10,5	-1,6	19,30	
Groove 2	%Area	72	28	14	0		Avg. 1 35,15
	Points	46,8	8,4	-4,2	0,0	51,00	
Undercr.	%Area	0	100	0	0		
	Points	0,0	30,0	0,0	0,0	30,00	

Fail- overall 15.28 merits

	Rating	Discol.	Black	Carbon	Ring Riding	Sum Points	
	Factor	65	30	-30	-40		
Groove 1	%Area	0	100	86	14		
	Points	0,0	30,0	-25,8	-5,6	-1,40	
Groove 2	%Area	39	61	50	0		Avg. 1 13,63
	Points	25,4	18,3	-15,0	0,0	28,65	
Undercr.	%Area	20	80	0	0		
	Points	13,0	24,0	0,0	0,0	37,00	

Mack T-12

- Mack E7 E-Tech 460 with EGR rated at 460 bhp 300-hrs
  - The first 100 hours are at rated speed and power to generate soot
  - Last 200 hours, the engine is over-fuelled at peak torque to maximize the wear rates on the rings and liners.
- Evaluates
  - Piston ring and liner wear
    - Top ring weight loss
    - Cylinder liner wear
    - Oil consumption
  - Lead bearing corrosion
    - Oil lead level
- Used oil analysis includes:
  - Oxidation
  - Viscosity at 100°C
  - Soot
  - Total base number (TBN)
  - Total acid number (TAN)
  - Lead content
  - Fourier Transform Infrared spectroscopy (FTIR) oxidation
- Used for API CJ-4, ACEA E9 and Mack EO-O+ specs

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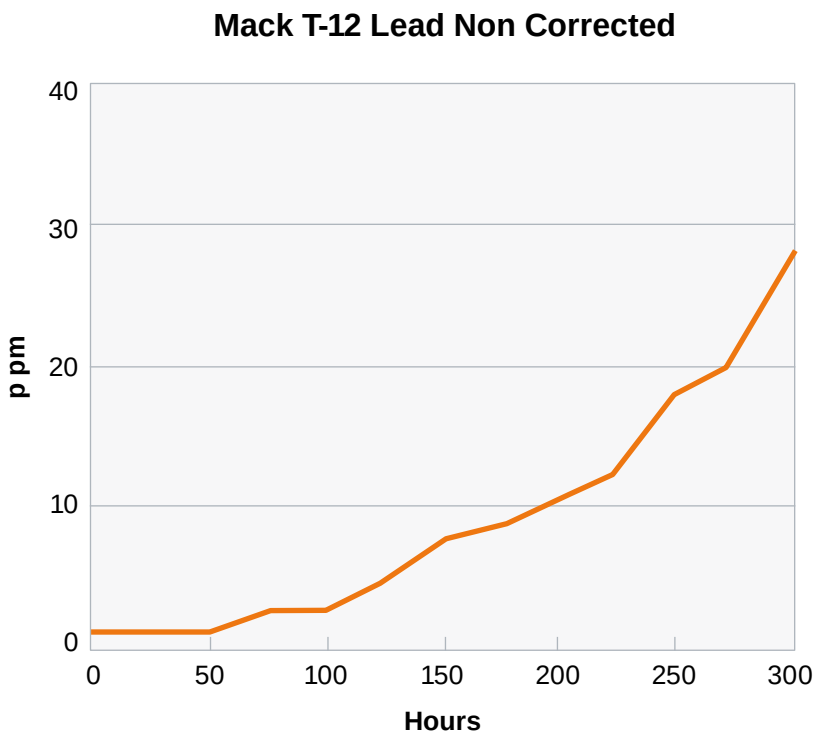
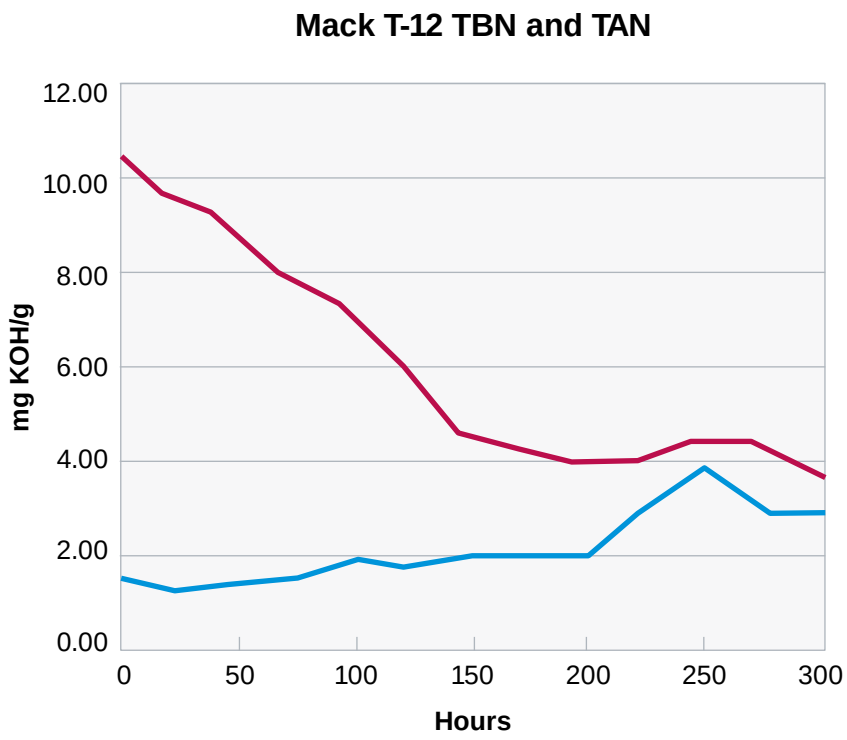
Mack T-12

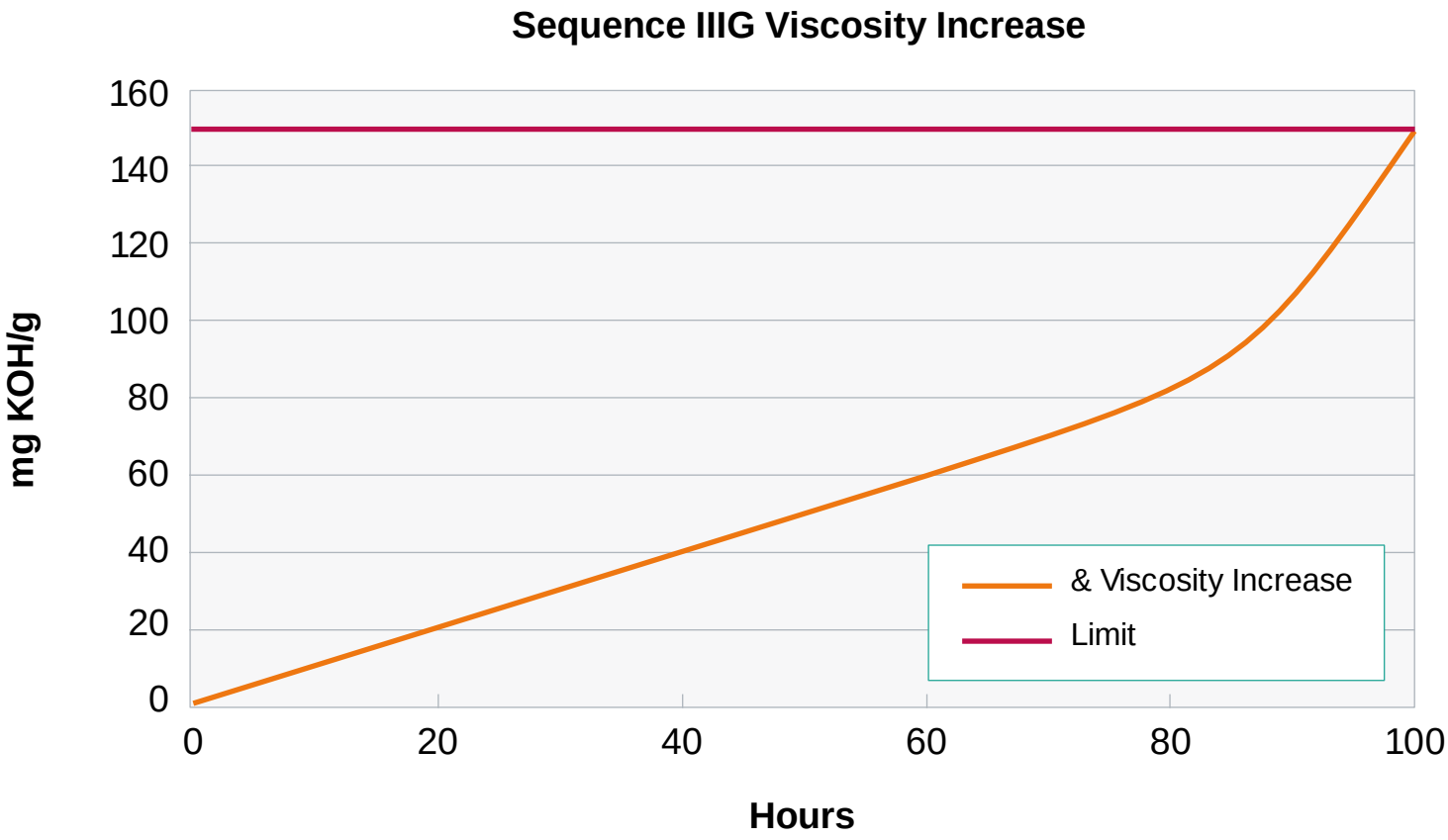




Sequence IIIG

- 3.8 litre GM V6 fuel injected gasoline engine
- 100 hours high power and speed
- Evaluates
  - Oil thickening
    - KV100 viscosity increase
  - Cleanliness
    - Piston deposits
  - Wear
    - Cam lifter wear
    - Oil consumption
- Used for API SM / ILSAC GF-4 and API SN / ILSAC GF-5

Sequence IIIG

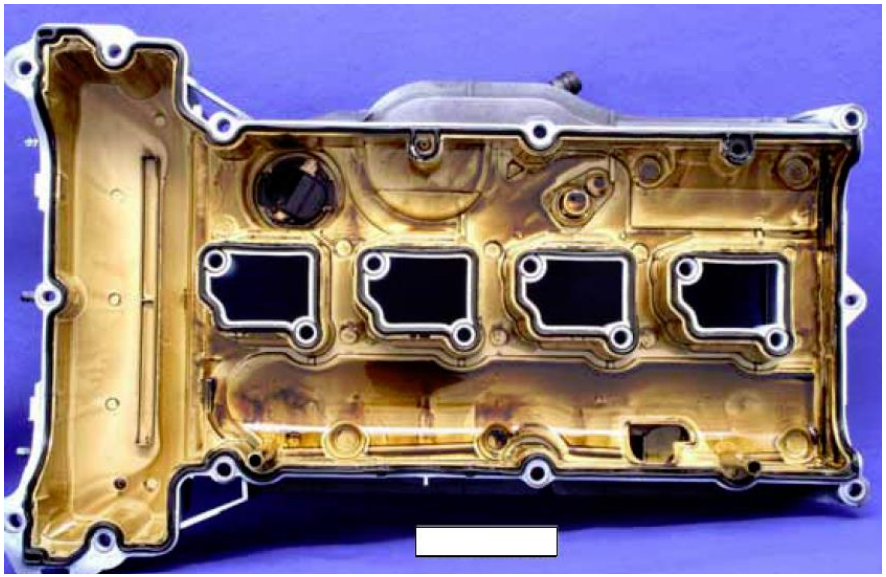


Daimler M271 sludge

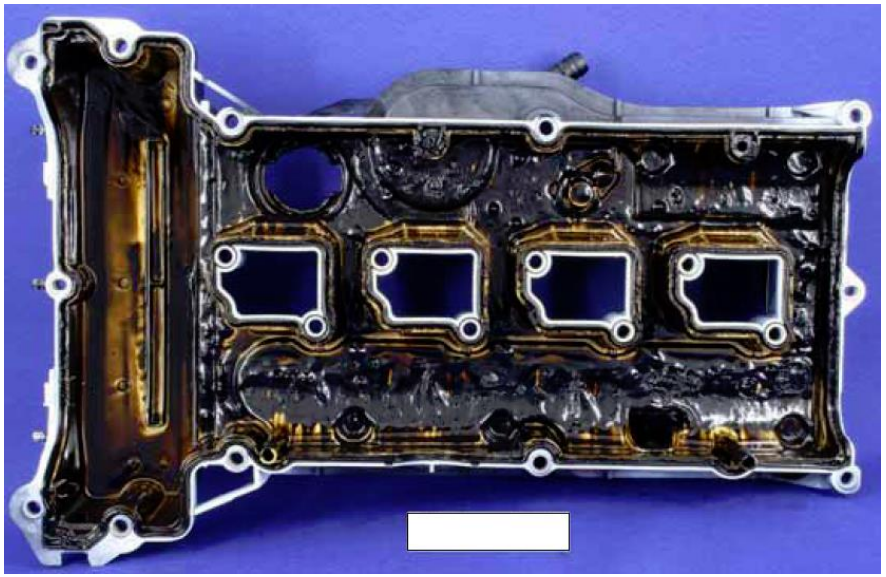
- M271 E-18ML gasoline engine
  - Straight-4 cylinder 1.8 litre 16 valve supercharged / intercooled engine with DOHC and variable valve timing.
  - 250 hrs test duration
- The M271SL test uses special fuel to aid in sludge generation

Daimler M271 sludge

Rocker cover



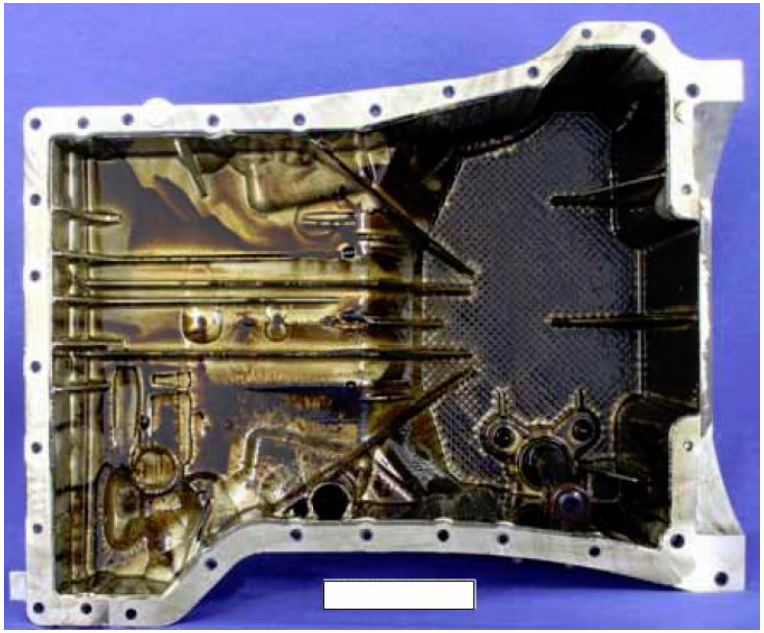
9.38 merits



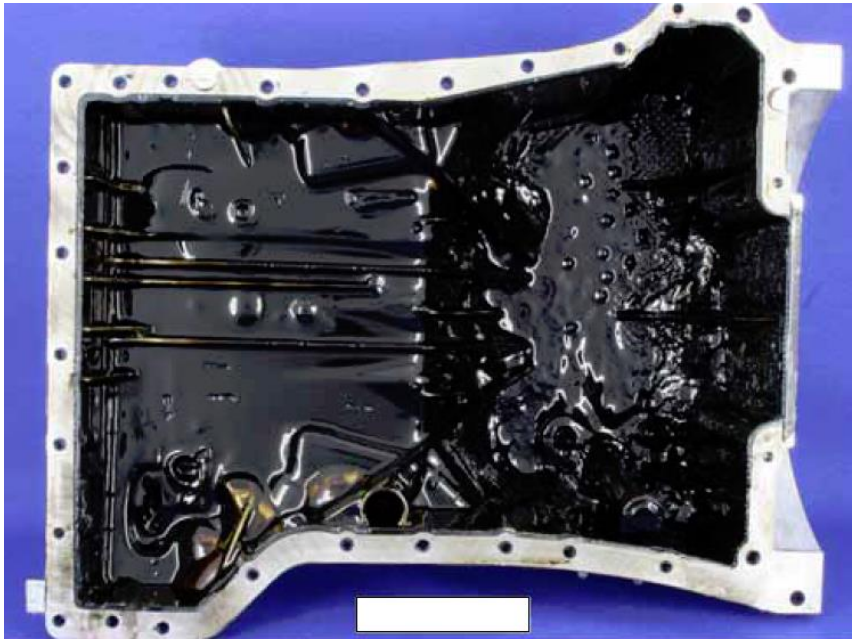
5.08 merits

Daimler M271 sludge

Oil pan



9.18 merits



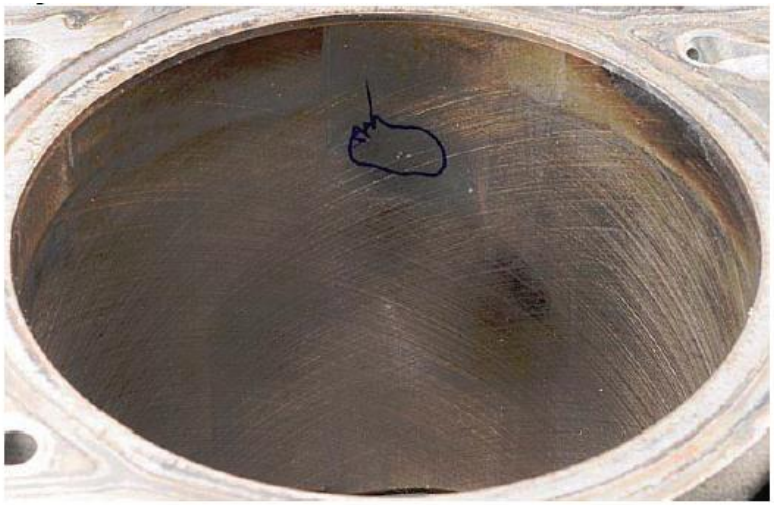
4.01 merits

Daimler OM646LA

- Inline 4-cylinder diesel
  - 2148cc capacity
  - 4 valves per cylinder, double overhead cams
  - 300 hour test duration
  - Evaluates
    - Cam wear
    - Piston cleanliness
    - Also bore polish, tappet wear, liner wear and sludge are reported
- Used for ACEA (A/B, C and E) and Daimler PCMO and HD OEM specifications

Daimler OM646LA

Bore polish



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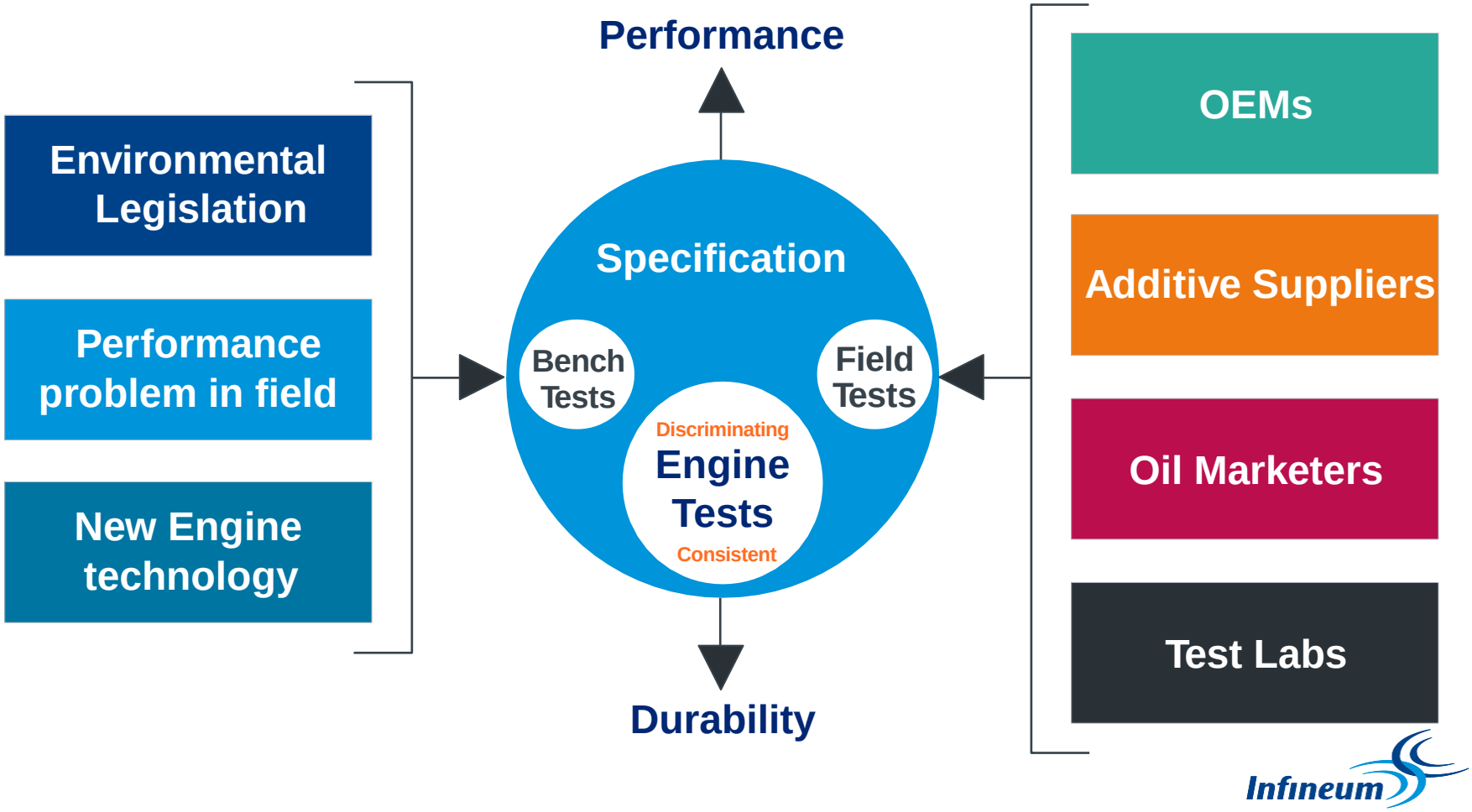
Summary

Well designed Engine tests are realistic and practical Oil performance demonstrator



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