VOLVO PENTA

AB Volvo Penta
SE-405 08 Göteborg
Sweden

Service Bulletin

Group	Number	Version
17-0	**2**	**6**

Engine Oil & Oil Analysis

Industrial Engines, Marine Diesel Engines

This bulletin describes the various types as well as the additives and specifications of Engine Oil. However, maintenance should always be carried out in accordance with the Operator´s Manual and the Maintenance Schedule.

p0017150

Engine oil

General

The main function of an engine oil is to reduce friction and thereby minimise wear between the moving parts of the engine.
The oil should also absorb heat from parts that are exposed to extreme heat loads, and keep the engine components free from impurities by transporting these to the filter, from where they can be removed from the engine.
Engine oil should also assist in sealing between the cylinder wall and the piston.

Hazards

Engine oil should be treated as a hazardous material. The instructions for introduction and use of such materials must be strictly adhered too.

Formulation

An engine oil consists of a base oil and additives, where the base oil is either a mineral oil or a synthetic oil. The additives comprise a DI packet (detergent-inhibitor), a viscosity modifier (VM), and so-called pour point depressant (PPD). The DI packet comprises a combination of many components, of which the most important are:

Anti-wear
Anti—wear is normally based on zinc-dialkyl-dithio phosphate (ZDDP), which creates a protective, lubricating film on metal surfaces at high temperatures and at high pressure. A modern engine oil normally contains 0.1–0.15% zinc (Zn) and phosphor (P).

Detergents
Detergents help to keep the engine clean from coatings, for example in the piston ring grooves, and neutralize acidic combustion products, that otherwise attack and corrode metal parts such as cylinder liners and ball bearings. Detergents contain metals, normally calcium (Ca) and/or magnesium (Mg) in quantities of 0.2–0.5%.

Dispergents
Dispergents are additives that are often free from metals and are added to hold contaminants, mainly soot, suspended in the oil and thus avoid flocking, blockage of the lubricating system and abrasive wear.

Anti-oxidants
Anti-oxidants delay oxidation of the oil by counteracting reactions with by-products that are formed during incomplete combustion.
The DI packet can even comprise other constituents, such as corrosion inhibitors, foam dampers and drip point retarders.

Viscosity modifiers
Viscosity modifiers are products with a high molecular weight (polymers) that combat viscosity reduction at high temperatures.

Engine oil specifications

Engine oil specifications defined for the On-Road Applications.
It is both technically and economically important to choose the correct oil for every specific purpose.

The following information describes some of the modern norms for lubrication oil quality.
It is then up to the oil manufacturers to ensure that their products meet these demands. It is therefore always a good idea to use well known makes of oil.

API system

API CB -
Typical for diesel engines working in favour able to slightly harsh conditions and using lower quality fuel which places higher demands on protection against wear and deposits. Can also be used for petrol engines working in favour able conditions.
These oils provide necessary protection against bearing corrosion and high temperature regression in normally aspirated engines when using a fuel with higher sulphur content.

API CC -
Typical for normally aspirated engines with a high output per litre and low pressure forced induction diesel engines working in slightly harsh to harsh conditions and also for certain heavily loaded engines.
These oils provide protection against high temperature regression in the above named engines and also provide protection against corrosion and deposits created at low temperatures in petrol engines.

API CD -
Typical for high speed, forced induction diesel engines with high power output that require effective protection against wear and deposits.
These oils protect against bearing corrosion and high temperature regression, regardless of the fuel quality.

API CD-II -
Typical for two-stroke diesel engines in heavy applications, needing highly effective protection against wear and deposits. These oils also meet all the demands for API-CD.
Typical for two-stroke diesel engines in heavy applications, needing highly effective protection against wear and deposits.
These oils also meet all the demands for API-CD.

API CE -
Typical area of use is with many forced induction or high performance forced induction diesel engines working at both low speed/high loading and high speed/low loading.
Oils with this designation have been available since 1984 and provide protection against thickening of the oil, wear, deposits in the piston system and also provide improved control of oil consumption compared with oils in category CD.

The above named grade designations are obsolete, but API CC, API CD and API CE oils can still be found in certain markets.
NOTICE! Oils corresponding to API CG-4 or lower shall not be used in Volvo engines.

API CF - Primarily for off road vehicles with swirl-chamber diesel engines. Oils of this type are suitable for engines for which CD is specified, since it provides protection against piston deposits, wear and bearing corrosion, irrespective of fuel quality.
NOTICE! Oils corresponding to API CG-4 or lower shall not be used in Volvo engines.

API CF-2 – Effectively replaced CD-II in 1994 and is primarily intended for two-stroke diesel engines.

API CF-4 – Replaced CE in 1991 and is particularly suitable for high performance four-stroke diesel engines.

API CG-4 – Intended for high performance four-stroke diesel engines when using fuel with a sulphur content of max 0.05%. CG-4–oils reduce wear, foaming, oxidation, soot accumulation and carbon deposits on pistons, that are created at high surface temperatures.
NOTICE! Oils corresponding to API CG-4 or lower shall not be used in Volvo engines.

API CH-4 — Designates oils for use in light to heavily laden, high speed four-stroke diesel engines that are intended to meet 1998 and earlier emission standards. These oils are recommended for use where the sulphur level in the fuel is lower than 0.05%. Engine oil corresponding to API CH-4 is expected to maintain the life span of an engine even in unfavourable applications that effect the ability of the oil to protect against wear, its high temperature stability and soot handling characteristics.
In addition, API CH-4 gives the engine optimal protection against corrosion, oxidation and insoluble thickening, aeration and viscosity reduction due to sheering forces. These oils make it possible to apply more flexible oil change intervals in accordance with the engine manufacturers recommendations for each engine type respectively.
Generally, these oils can be used in applications where API CG-4 and CF-4 oils where previously recommended.

API CI-4 — Designation for oils for use in high speed four-stroke diesel engines manufactured to meet 2004 emission demands from the USA. These oils are intended for all applications when using diesel fuel with a sulphur content up to 0.05%.
The oils are specially formulated to maintain the life span of the engine when EGR is used, but the effect of the oils on other emission equipment has not yet been determined.
Optimal protection is obtained against corrosive and soot-related wear tendencies, piston deposits, degradation of viscosimetric characteristics at low and high temperatures caused by soot accumulation, thickening due to oxidation, foaming, degradation of sealing materials, viscosity reduction due to oil sheering and improved control of oil consumption. API CI-4 oils are superior to oils corresponding to API CH-4 and CG-4 and effectively lubricate engines with these grade requirements.

API CJ-4 — API Service Category CJ-4 describes oils for use in high-speed four-stroke cycle diesel engines designed to meet 2007 model year on-highway exhaust emission standards (US) as well as for previous model years. These oils are compounded for use in all applications with diesel fuel ranging in sulphur up to 500 ppm (0.05% by weight). However, the use of these oils with greater than 15 ppm (0.0015% by weight) sulphur fuel may impact exhaust after treatment system durability and/or oil drain interval.
These oils are especially effective at sustaining emission control system durability where particulate filters and other advanced after treatment systems are used.
Optimum protection is provided for control of catalyst poisoning, particulate filter blocking, engine wear, piston deposits, low- and high-temperature stability, soot handling properties, oxidative thickening, and viscosity loss due to shear.

API CK-4 — API Service Category API CK-4 oils are especially effective at sustaining emission control system durability where particulate filters and other advanced aftertreatment systems are used. API CK-4 oils are designed to provide enhanced protection against oil oxidation, viscosity loss due to shear, and oil aeration as well as protection against catalyst poisoning, particulate filter blocking, engine wear, piston deposits, degradation of low- and high-temperature properties, and soot-related viscosity increase.

ACEA system

ACEA (Association Constructeurs Européens d' Automobiles) is the name of the European automobile manufacturing members organization. ACEA has developed its own engine oil specifications, which are specially adapted to European engines and applications. The current system is called ACEA specifications and replaced the earlier, CCMC series, in 1996. The ACEA series for heavy diesel engines consists of the following categories:

ACEA E1 — Oil intended for use in normally aspirated engines and low pressure forced induction diesel engines, for light to normal operating conditions and with normal oil change intervals. ACEA E1 was superceded in 1999.
NOTICE! ACEA E1 shall not be used in Volvo engines.

ACEA E2 — Oil for general use in normally aspirated engines and forced induction heavy diesel engines, for normal to harsh operating conditions and with normal oil change intervals.
NOTICE! ACEA E2 shall not be used in Volvo engines.

ACEA E3 — These oils are effective when it comes to piston cleanliness, cylinder glazing, wear, soot handling and lubricant stability.
This category is recommended for diesel engines used in difficult operating conditions and which should meet the emission demands of Euro 1 and Euro 2.
Suitable for use with increased oil change intervals when recommended by engine manufacturer.

ACEA E4 — A stable, stay-in-grade oil that gives even more effective control of piston cleanliness, wear, soot handling and lubricant stability, when compared with E3 oils.
Recommended for diesel engines that meet emission demands for Euro 1, Euro 2 and Euro 3 and which operate in very harsh conditions, i.e. with considerably extended oil change intervals in accordance with the manufactures recommendations.

ACEA E5 — A stable, stay-in-grade oil with effective protection regarding piston cleanliness and cylinder glazing. These oils provide increased protection against wear and deposits in turbochargers, increased soot handling characteristics and improved lubricant stability when compared with E3.
Recommended for diesel engines that meet emission demands for Euro 1, Euro 2 and Euro 3 and which operate in harsh conditions, i.e. with considerably extended oil change intervals in accordance with the manufactures recommendations.

ACEA E6 — A stable, stay-in-grade oil providing excellent control of piston cleanliness, wear, soot handling and lubricant stability.
It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under very severe conditions, e.g. significantly extended oil drain intervals according to the manufacturer's recommendations.
It is suitable for EGR engines, with or without particulate filters, and for engines fitted with SCR NOx reduction systems.
E6 quality is strongly recommended for engines fitted with particulate filters and is designed for use in combination with low sulphur diesel fuel.
However, recommendations may differ between engine manufactures so Operator`s Manuals and/or Dealers shall be consulted if in doubt.

ACEA E7 — A stable, stay-in-grade oil providing effective control with respect to piston cleanliness and bore poliishing. It further provides excellent wear control, soot handling and lubricant stability. It is recommended for highly rated diesel engines meeting EuroI, Euro II, Euro III, Euro IV and Euro V emission requirements and running under severe conditions, e.g. extended oil drain intervals according to the manufacturer's recommendations.
It is suitable for engines without particulate filters, and for most EGR engines and most engines fitted with SCR NOx reduction systems.
However, recommendations may differ between engine manufactures so Operator´s Manual and/or Dealers shall be consulted if in doubt.

Volvo Drain Specification (VDS)

P0017431

VDS places additional demands upon the engine oil specifications listed above and is based on field tests performed by Volvo Trucks.
NOTICE! It applies for Volvo Penta engines as well.

Low-emission engines place extremely high demands on engine oils and Volvo has developed the earlier requirement specifications VDS and VDS-2 to adapt them to Euro 3 engines, VDS-3.

- VDS was first introduced in 1982, and has been successively developed to adapt to current engine design.
- VDS-2 was introduced in 1992 and revised 1995.
- VDS-3 was introduced in 2000 and revised 2002.
- VDS-4 was introduced in 2014
- VDS-4.5 was introduced in 2017

The most important test parameters during field tests are piston deposits and cylinder glazing, although even other parameters such as piston ring and bearing wear, engine cleanliness and oil degradation are also examined.

VDS — Field test performed on a F12 trucks (TD121–, TD122–engines). The lowest oil grade used was API CD. Since the introduction of VDS-3 (2000), no new VDS approvals are given. Older VDS oils still exist in the market, however.

VDS-2 — Field test performed primarily on a F12 trucks (D12A engines), and lowest oil grade ACEA E3 or API CG-4. Since the introduction of VDS-3 (2000), approval for VDS-2 is obtained via the VDS-3 test, see below.

VDS-3 — Field test performed on a FH12 trucks (D12C or D12D engines). Lowest oil grade is ACEA E5 or API CH-4. Approval for both VDS-3 and VDS-2 can be received through the VDS-3 tests.

VDS-4 — VDS-4 is the first VDS specification that is not based on field test. It was decided to abandon field tests since these are time consuming (2-3 years) and do often provide inconclusive results. VDS-4 is now built on API CJ-4 but with additional requirements adapted to suit the particular needs of Volvo Powertrain engines. VDS-4 oils are particularly intended for EGR engines equipped with diesel particulate filters and/or SCR systems but can also be used in all other engines. The full requirements are described in Volvo Corporate Standard 417-0001.

VDS-4.5 — VDS-4.5 is fully backwards compatible and can be used in engines where Volvo Penta Engine Oil VDS, VDS-2, VDS-3 or VDS-4 oils are currently recommended. Volvo Penta Engine Oil VDS-4.5 has been specifically designed for modern high performance, low emission engines with Exhaust Gas Recirculation (EGR), Selective Catalytic Reduction (SCR) and/or Diesel Particulate Filter (DPF) after-treatment systems. The full requirements are described in Volvo Corporate Standard 417-0003.

NOTICE! Oil change intervals for an engine are dependant on Oil Quality, Fuel Quality, Engine Type and Application.
Volvo Penta recommendations are based on quality designations: VDS, VDS-2, VDS-3, VDS-4, VDS-4.5

Maintenance should always be carried out in accordance with service schedule/ service protocol.

Lubricant additive elements

Element	Significance
Boron (B)	Dispersant
Calcium (Ca)	Detergent
Magnesium (Mg)	Detergent
Molybdenum (Mo)	Anti-wear and/or Anti-Oxidant
Phosphorous (P)	Anti-wear
Silicon (Si)	Anti-foam
Zinc (Zn)	Anti-wear

Oil Analysis

P0003451

WARNING!
Please pay attention to the safety instructions in the Operator's and Workshop Manuals concerned.

This Service Bulletin is to be considered as technical information only and is not subject to any reimbursement programs outside normal warranty.

Volvo Penta Oil Analysis

Simply put, oil analysis is a basic engine ”health check”. The anaysis provides early warnings which make possible the timely replacement of components before problems appear and damage occurs.

Cause and action

The Volvo Penta oil analysis program is a comprehensive tool for analysing oils in our engines.
Volvo Penta detailed knowledge about the specific components included in the systems and the monitoring limits are set based on this knowledge.

Various companies carry out oil analysis on Volvo Penta engines but there is a great risk to do this. Without knowledge about our systems the monitoring limits will in most cases be different than ours.
This means that customers receive alarm reports and are worried entirely unnecessarily, or vice versa..

We do **not** recommend that an engine is disassembled only on the basis of oil analysis values.
Use the values of the oil analysis as an indication that something abnormal is happening.
Combine other methods of diagnosis to confirm that something is abnormal.

Oil sampling should be carried out in accordance with instruction publ no 47701342

NOTICE! Important to fill in the submission form correctly, in order to receive a correct report. More information could be found in Partner Network (VPPN).

When in doubt as to what action should be taken as a result of the oil analysis, read the following pages, and use Argus for support if needed.

Other aspects of oil analyses

All oils contain a varying degree of different additives in order to achieve required quality and performance requirements.

These additives also contain the metals which show up in the analysis.
Various amounts of metals occur depending on:

1 What types of oil.
2 Oil brand.
3 Market where the oil is sold.
4 Customer demands, eg VDS specification.

Limits Volvo Penta - Oil Analysis Report

(Industrial & Marine Comm. Engines)

Parameter	Possible Origin/Cause	Limit	Unit
Sodium, Na	Coolant leak	≤ 20	ppm
Silicon, Si	Sand, dirt, etc	≤ 30	ppm
Aluminium, Al(1)	Pistons, charge air cooler, dirt	≤ 15	ppm
Chrome, Cr	Piston rings, valve stems	≤ 15	ppm
Copper, Cu(2)	Big-end and main bearing shells, piston pin bushes, oil cooler, heat exchanger	–	ppm
Iron, Fe	Crankshaft, cylinder liner, camshaft, cam follower, valve guides	≤ 130	ppm
Lead, Pb	Big-end and main bearing shells	≤ 30	ppm
Tin, Sn	Outer surface of sliding bearings	≤ 15	ppm
Nickel, Ni	Layer between surface and cooper layer on sliding bearings, rocker arm bushes	≤ 20	ppm
Molyedenum, Mo(3)	Piston ring	≤ 15	ppm
KV100	-	<9 & >8 above unused	cSt
Soot	Incomplete combustion (D11, D13, D16) Incomplete combustion (Other engines)	Max: 1,3 Max: 2,5	% %
TBN	TBN indicates remaining alkalinity after acid neutralisation	≥ 4	—
Water	Coolant, condensation	≤ 0,2	%
Fuel(4)	Incomplete combustion, internal leak on fuel system, etc	≤ 6	%
Viscosity	Reduction: Fuel dilution, oil shearing Increase: Oxidation, contamination by soot	Min: 9	cSt

1) Can be considerably higher during running-in.

2) Several 100 ppm copper can be found during the early life of the engine. This copper is flushed out from the oil cooler and is not harmful to the engine.

3) Certain oils contain molybdenum, which can cause an increased value (Compare with fresh oil)

4) If fuel dilution is > 6% AND viscosity is > 9 cSt then engine is OK. If fuel dilution is > 6% AND viscosity is < 9 cSt continue with “Fault Tracing: Fuel Dilution”.

In cases where oil analysis shows a high PPM content, carry out:

1 Oil change and filter replacement.

2 Further oil analyses:
– at a few no of running hours, after the oil change and filter replacement.
– and then three oil analyses at intervals of 100 hours.

These oil analyses provides an answer to the tendency (after oil & filter replacement) It may turn out as follows:

1 PPM content drops. Wear is normal.

2 PPM content remains at a high but stable level. Wear is normal.

3 PPM content continues to rise. This indicates abnormal wear and the customer should be informed.

4 PPM content varies greatly up and down. This indicates presence of foreign particles caused by working environment storage of oil etc.

It is important to note that iron content rises with faulty air cleaner system before it is possible to note rising silicon content, that is in the case of rising iron content, the air cleaner system should be checked.

A new engine shows tendency to have a high level of Fe (iron), Pb (lead) and Cu (copper) during running-in.

Cause: Particles from the manufacturing process (sand from the moulds, casting swarf) scratch the bearings in the stage.

- Scratches of this kind are normal and shall not lead to any repairs.
- Wait and see if oil analysis No. 2 and 3 show any changes.

Fe (iron)

Fe (iron), (or any other single metal) can suddenly show high values in later tests, e.g. in No. 5 or 7.
Await the next test.

Cause: Sampling carried out wrongly.

- Cold engine, Fe sinks to the bottom. The sample has been taken too quickly.
- Warm engine, but it has been stopped somewhat, so that the temperature has sunk.
  The sample has been taken form the first oil drained out and not after the oil has been allowed to run a few seconds, as should have been done.
- Can be abnormal wear, but it is uncertain where.

Si (silicon)

Sand and similar.

Cause: If Si has a high value, it mainly increases Fe, but also Pb (Cu) and Cr.

- The air filtering is not satisfactory.
- Leakage on the inlet system.

NOTICE! Al + Si = Piston material. A seizing of the piston skirt often gives high Si and Al contents.
A light seizing of the skirt can be ignored as it will disappear.

Soot (carbon)

If the value is higher than normal.

- Too long oil change interval, or oil grade is too low.
- Incomplete combustion
- Faulty injectors.
- Incorrect injection angle.

H_2O (water)

If the test shows water, H_2O.

- Condensation: Sample has been taken before the engine has been run warm enough.
- Pre heater malfunction or sample has been taken after incorrect starting procedure.

NOTICE! Water leakage causes increased Pb (poss. Cu). If it continues, then the Fe and Cr also increase.

Dilution, Fuel

Incomplete combustion due to:

- Fuel system leakage.
- Pre heater malfunction or and sample has been taken after incorrect starting procedure.
- Faulty injectors
- Injection angle incorrect

NOTICE! Fuel dilution could be difficult to trace. Follow the fault tracing check list on the following pages.

Fault Tracing: Fuel Dilution

This checklist should be used as a procedure to find the reason why indicated fuel content in the engine lubrication oil exceeds the permissible deviation.
This procedure determines the type of possible cause. Continue troubleshooting according to the next item in the checklist methodically until the main cause is found

NOTICE! One or more tests may be required for this fault tracing.

1:1

Does the customer have correct lubrication oil Specifications?	**Yes**	**No**
Is the oil of proper type for the current oil change intervals?	**Yes**	**No**

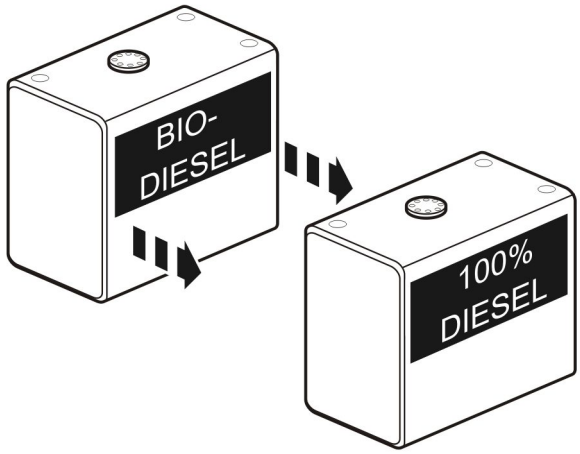
- **If no,** end the fault tracing process and use an oil which is suitable for the particular application. Inspect the dilution and viscosity of the two following oil change intervals.
- **If yes**, continue troubleshooting by checking the oil. Take an oil sample according to instruction: Oil Analysis. Sample taking instructions 47701342.

The Oil Analysis Report:

1:2
If fuel dilution is ≤ 6% (5) and the kinematic viscosity is > 9 cSt, engine is **OK**. *Exit the fault tracing.*

If fuel dilution is > 6 % and the kinematic viscosity is < 9 cSt, proceed with troubleshooting and control methodically until the main cause is found.

NOTICE! An oil analysis should be combined with other diagnostic methods in order to confirm possible problems.



P0017635

Diagnostic methods:

2:1
Type of fuel?

- If bio-diesel fuel was used, test if 100% diesel solves the problem.
- At next service, new oil and fuel sample test. For correct engine oil, oil quantity, oil grade and viscosity, refer to the Operator's Manual.

Fuel dilution after the second oil change (%):

Kinematic viscosity after the second oil change:

NOTICE! Low-volatility fuel components, which for biodiesel are essentially the entire fuel, are slow to vaporize after injection into the cylinder. Some of these low-volatility compounds will be deposited on the cylinder wall and can then be swept down into the crankcase by the normal scraping action of the piston's oil control rings.

2:2

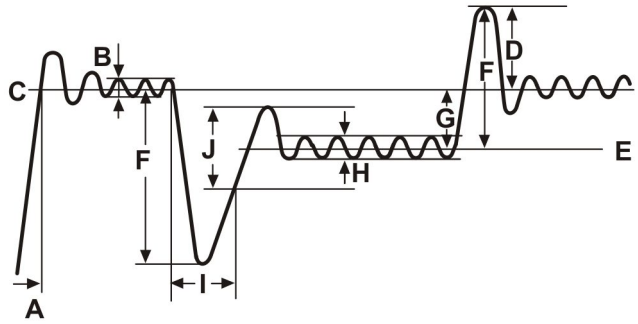
Black exhaust smoke?

- Check if there is an unusual amount of black exhaust smoke. This may indicate a faulty injector.

NOTICE! Worn injectors may cause engine oil dilution, incorrect fuel dispersal, from excessive plunger to body clearances. Dilution may also result from a cracked injector body or cup or a damaged o-ring.
Refer to 3:6.

2:3

Low load or cold application?



P0017638

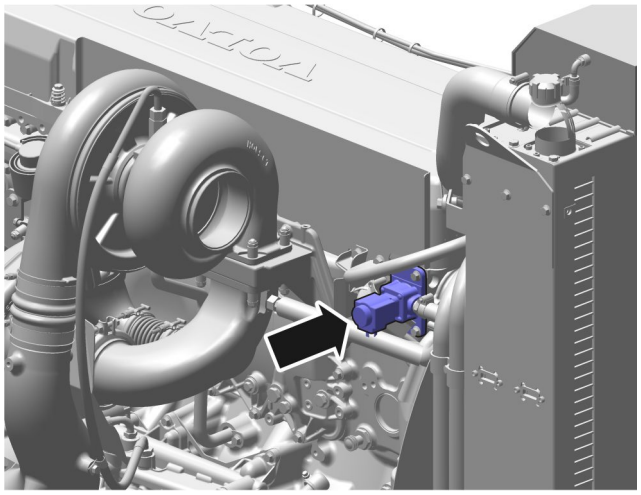
- Collect info regarding drive cycle, engine history.
- Try to change running cycle and increase load.

NOTICE! Frequent starts of an engine, excessive idling and cold running conditions can lead to moderate fuel dilution problems.

2:4

- Check thermostat.

NOTICE! Low coolant temperature can be caused by: Faulty thermostat



P0017639

2:5

(**TWD only**)

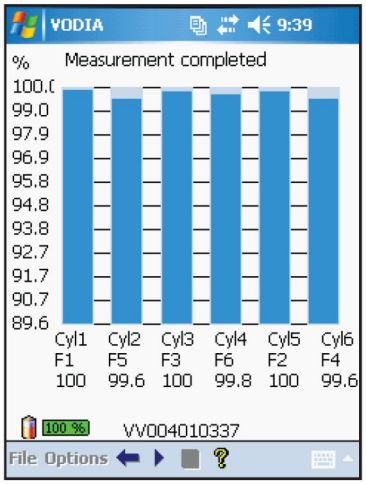
- Check cold start valve, possible cold running condition.

NOTICE! The cold start valve is primarily opened when the thermostat is closed (cold engine) which when closed completely blocks the flow to the radiator assembly.

3:1
High position on fuel tank requires shut-off valve.

- Check tank position / shut-off valves.
- Shut-off valves must be installed at both the inlet and outlet side.
- Verify function.

NOTICE! If the maximum fuel level in the tank is above the engine cylinder head a shut-off valve must be installed in the fuel line to prevent fuel from running back and mixing with lubricating oil while the engine is at rest.

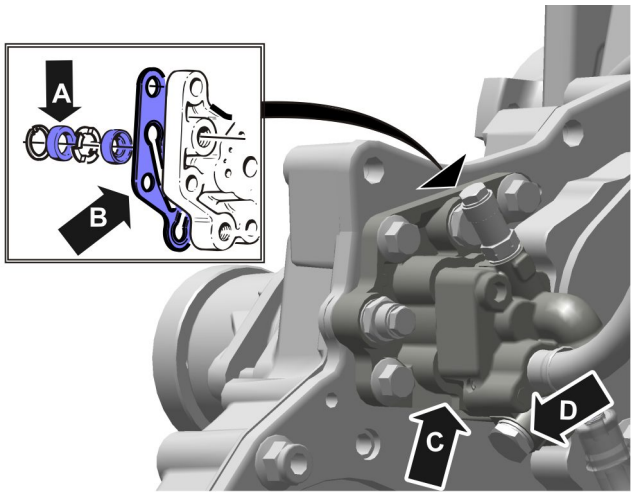


P0017640

3:2
Make sure engine firing properly at all cylinders.

- Check cylinder compression (Vodia) / Diagnostic Trouble Codes.

NOTICE! This test shows whether a cylinder deviates in compression compared with the others. Refer to, *Low Compression, Fault Tracing*.



P0017641

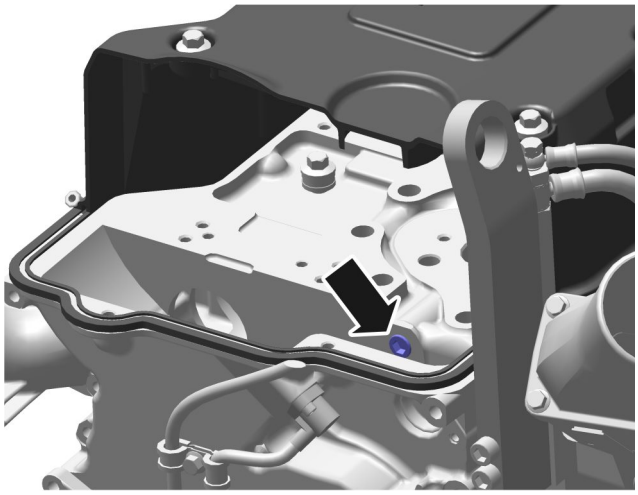
3:3
(**D12 only**)

Leakage through the “overflow hole” (**C**) indicates that the seals in the fuel feed pump drive is worn.

- Check if the seals (**A**) from the impeller shafts at the fuel feed pump need to be replaced. Check that it seals properly.

Is the gasket (**B**) between the fuel feed pump and the transmission plate flawless?

- Check for fuel leaks around the fuel feed pump attachment to the transmission plate.
- Check for leakage at fuel feed pump drain hole (**D**).
- If fuel leakage, repair or replace pump.



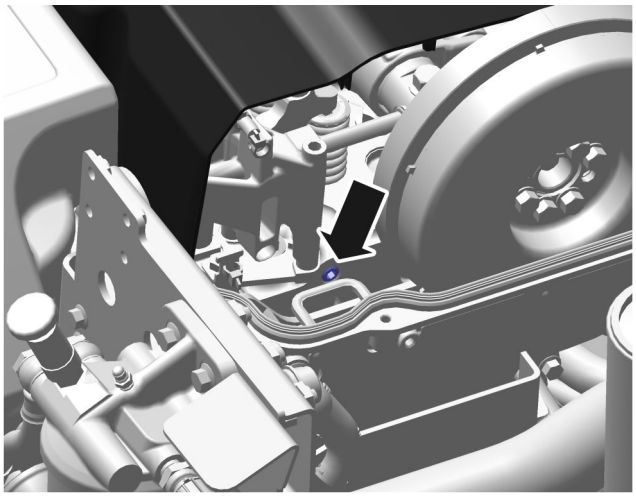
P0017642

3:4
(**D12 only**)

Is the fuel rail plug tight and intact?

- Check for leakage at front sealing cylinder head.

NOTICE! The fuel channel to the unit injectors is drilled lengthwise through the cylinder head and has a machined, ring-shaped space around each unit injector.



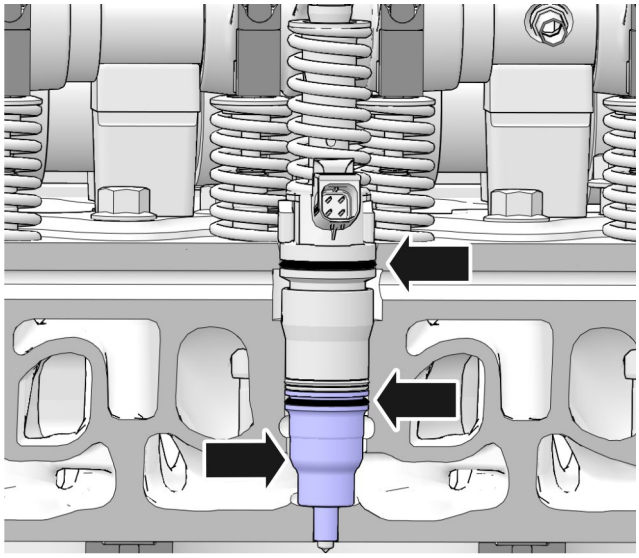
P0017643

3:5
(**D9,D11,D13,D16 only**)

Is the fuel rail plug tight and intact?

- Check for leakage at rear sealing cylinder head.

NOTICE! The fuel channel to the unit injectors is drilled lengthwise through the cylinder head and has a machined, ring-shaped space around each unit injector.



P0017644

3:6

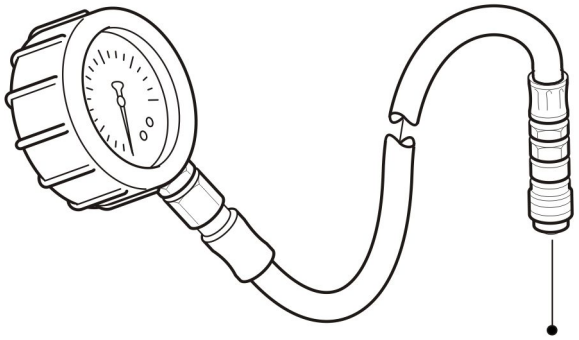
Is the unit injector sealing flawless, and/or the-o-ring groove on the injector without any damage along these lines?

- Check for leakage at rear sealing cylinder head.

In case of leakage:

- Remove the unit injector and replace o-ring.
- Check copper sleeve and o-ring.
- Inspect the o-ring groove.

NOTICE! The lower injector section is separated from the cooling jacket by the copper sleeve and the o-ring.



P0017645

4:1

Too high pressure creates leakage.

- Measure fuel pressure in cylinder head then running, *refer to the Workshop Manual, for actual engine.*

NOTICE! The overflow valve governs the pressure available in the system (any surplus is released to the return line).

4:2

Remove the unit injectors. Mark the injectors and fit protective sleeve to them.

- Send the injectors Volvo Penta for further investigation.