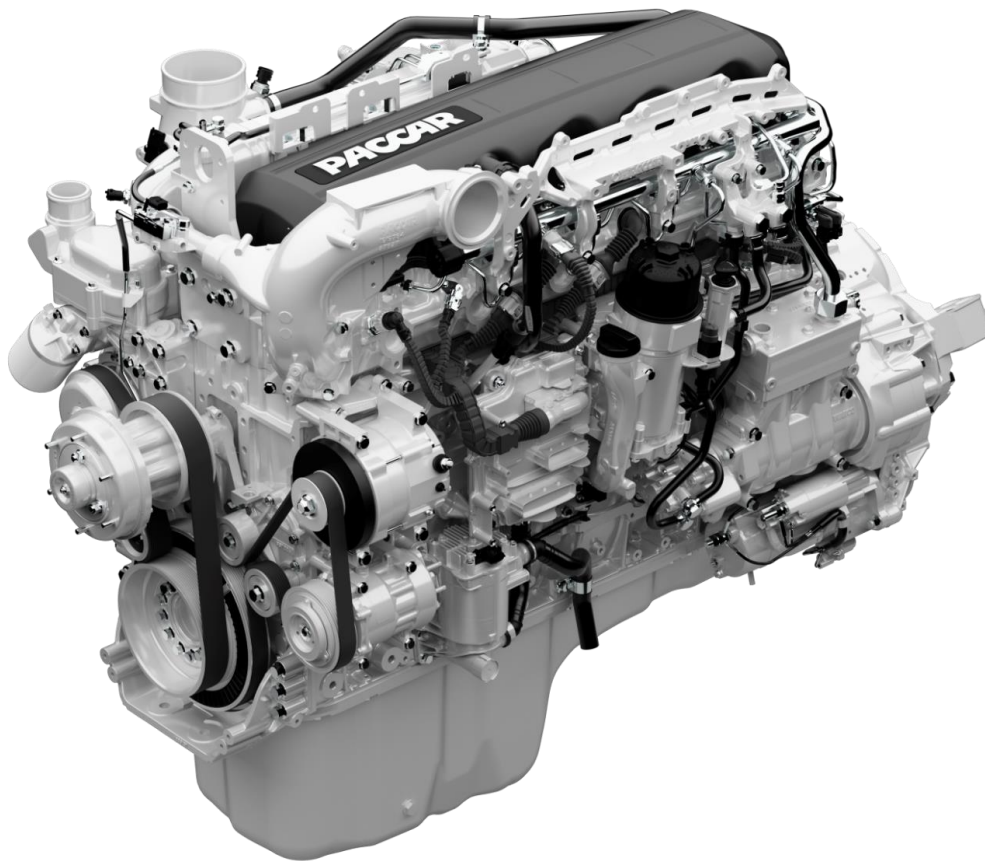


PACCAR ENGINES

EPA13

PACCAR MX

Oil Analysis Guidelines



1. Introduction

Oil analysis is a method of tracking the long-term lubrication characteristics of oil types being used in an engine and monitoring the state of wear in the lubricated areas of the engine. There are many factors that may impact the accuracy or relevance of the values reported. These include the calibration of the analysis equipment, secondary contamination of the sample, and test method. Adding oil to adjust engine oil levels during operation, or varying the time or mileage when samples are taken may also affect the values reported.

In reviewing all data, but particularly wear and additive element data, remember that although sharp up or down shifts may indicate a serious problem, caution should be exercised before reaching conclusions. PACCAR recommends verifying the initial findings with additional samples before taking corrective actions. Keep in mind, multiple samples that reflect multiple oil changes are required to indicate a trend.

2. Engine Oil Recommendations

Please refer to the engine documentation provided with your vehicle for the engine oil specifications, viscosity requirement, etc. for your engine. EPA13 certified engine lubricant must meet SAE 10W30 for temperatures above 5°F (-15°C) and SAE 5W30 for temperatures below 5°F (-15°C) and be compliant with API-4 CJ-4 standards. PACCAR Engines does not specify additional engine oil requirements.

Synthetic lubricants, synthetic blends, and other oil additives are not currently validated to offer improved performance in the PACCAR engine. Use of these oils is at the risk of the owner.

3. Oil Filtration

PACCAR engines are designed with a high performance lubricant delivery system that fully conditions the lubricant before delivering it to the working parts in the engine. Oil filters should be changed according to the service intervals recommended for the vehicle application's duty cycle. This can be determined by referencing the Engine Operator's Manual, provided with the vehicle.

PACCAR filters are appropriately sized for the recommended service intervals. If complete plugging of a filter is observed at the recommended service interval, further investigation to the source of contamination is required.

PACCAR only recommends the use of PACCAR genuine replacement parts.

4. Oil Collection and Analysis

To be of value, oil samples must be collected at a consistent interval such as the regular oil change interval for the application. Detailed information should be documented to allow trend analysis.

PACCAR recommends tracking the following information:

- Engine Model/Serial Number
- Miles/Hours of Use for Oil
- Miles/Hours of Use Since New or Major Components Rebuild
- Oil Used (Brand, Viscosity Grade, Performance Category)
- Date of Sample Collection
- Vehicle/Engine Application
- Amount of Oil Added Since Last Oil Change
- Recent Engine Maintenance Performed
- Analysis of New (Unused) Oil for Comparison

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Oil samples should be collected after the engine has been operated and brought to operating temperature. This will ensure the contaminants are more equally dispersed within the sample. Take the oil sample before adding any oil to the engine to prevent dilution.

Oil samples should be collected in a clean and dry container, with the appropriate volume for analysis required by the analysis laboratory. Many oil analysis labs provide clean containers with proper sizing for their requirements.

Oil samples should be taken from a pressurized port upstream of the engine oil filter while the engine is idling and warm. To ensure consistent oil samples, the sample location shown in Figure 1 is recommended. PACCAR Engines has not validated a permanently installed quick-sample port that can be used in this location.

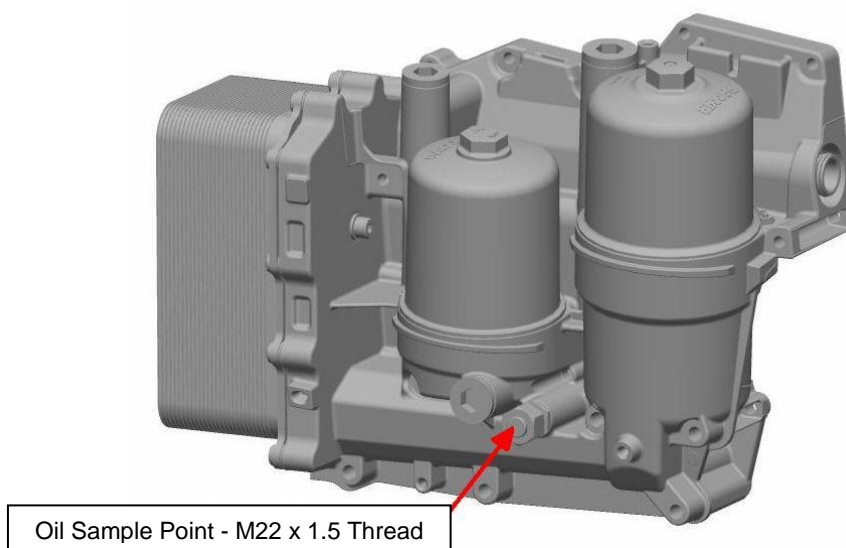


Fig 1. Pressurized Oil Sample Port Upstream of Filters

In cases where samples must be taken without the engine operating, the following alternative method is recommended:

Use the dipstick to determine the oil level in the pan

1. Using the dipstick length as a guide, cut a new, clean piece of tubing to the correct length to ensure the tubing is submerged 1-2" (25-50mm) into the oil in the pan.
2. Insert the tube to the correct depth in the oil pan through the dipstick tube.
3. Use a dipstick oil hand pump to draw the oil sample from the oil pan into the clean sample bottle. Ensure the oil hand pump is empty before drawing the sample, or cycle approximately ½ quart (½ liter) of oil through the pump before gathering the sample.

Using the same analysis laboratory for the engine over the engine's lifetime will ensure consistent oil analysis methods are used and support comparison between oil samples.

Contamination guidelines contained in this document were determined using the methods and equipment outlined in Section 6, Test Methods.

5. Contamination Guidelines

5.1 Guideline Values

The limit for every parameter baseline is either a common industry oil limit (viscosity, TBN, oxidation, nitration) or a limit that has been found to be acceptable after rigorous testing by PACCAR. In setting the acceptable values, engine damage, accelerated wear, or deviation of the trend was observed and documented. These limits were established based on engine tests in advanced engine test cells or in field test.

Severe Duty Vocational - Amounts at 25,000 mile service interval

	Category	Maximum Allowable Levels	Unit	Method
Viscosity	Oil condition	Stay in grade per SAE J300 (+/-10% from Base)	mm ² /s	ISO 3104 / ASTM D445
Total Base Number (TBN)	Oil condition	> 2	Potassium hydroxide per gram (KOH/g)	ASTM D4739
Total Acid Number (TAN)	Oil condition	< 6	Potassium hydroxide per gram (KOH/g)	ASTM D664
Soot	Oil condition	2.5	Max Elevation allowed % by weight	Infrared with oil express method universal-2
Oxidation	Oil condition	20	A/cm (Absorbance per centimeter)	
Nitration	Oil condition	15	A/cm (Absorbance per centimeter)	
Iron (Fe)	Wear indicator	55	Parts per million	X-Ray Fluorescence 9400XP Oil wear ASTM D4927
Aluminum (Al)	Wear indicator	50**	Parts per million	
Copper (Cu)	Wear indicator	35***	Parts per million	
Silicon (Si)	Contamination	100	Parts per million	X-Ray Fluorescence 9400XP Oil wear ASTM D4927
Chromium (Cr)	Contamination	10	Parts per million	
Lead (Pb)	Contamination	10	Parts per million	
Tin (Sn)	Contamination	10	Parts per million	
Antimony (Sb)	Contamination	10	Parts per million	
Sodium (Na)	Contamination	200	Parts per million	
Potassium (K)	Contamination	10**	Parts per million	
Nickle (Ni)	Contamination	5	Parts per million	
Mangenes (Mn)	Contamination	10	Parts per million	
Vanadium (V)	Contamination	10	Parts per million	
Fuel Dilution	Contamination	2.0****	% by Volume	ASTM D3542
Water	Contamination	1	% by Volume	Aquatest
Glycol	Contamination	0.1	% by Volume	ASTM D4291
Initial service level		@ first 25,000 Service		
Iron (Fe)	Wear indicator	90	Parts per million	X-Ray Fluorescence 9400XP Oil wear ASTM D4927
Aluminum (Al)	Wear indicator	50	Parts per million	
Copper (Cu)	Wear indicator	70	Parts per million	

** Values may be significantly higher due to Charged Air Cooler solder flux abrasion. This is to be recognized by a 3:1 ratio K:Al. For Al values up to 100 ppm and K up to 300 ppm can be observed. (Coolants using K as a carrier salt instead of Na could see elevated levels of K due to coolant dilution.)

*** Dramatic elevated levels of copper can be observed, when the copper brazed oil cooler is subject to chemical attack, assumedly initiated by sulfites present in the engine oil. Usually this effect decreases over time when the copper surface passivizes. Values as high as 600 ppm for MX13 and 300 ppm for MX11 have been observed under these conditions.

**** When vehicle is fueled with EN590 or ASTM D975 diesel.

Normal Duty Line Haul - Amounts at 40,000 mile service interval

	Category	Maximum Allowable Levels	Unit	Method
Viscosity	Oil condition	Stay in grade (+/-10% from Base)	mm ² /s	ISO 3104 / ASTM D445
Total Base Number (TBN)	Oil condition	> 2	Potassium hydroxide per gram (KOH/g)	ASTM D4739
Total Acid Number (TAN)	Oil condition	< 6	Potassium hydroxide per gram (KOH/g)	ASTM D664
Soot	Oil condition	1	Max Elevation allowed % by weight	Infrared with oil express method universal-2
Oxidation	Oil condition	20	A/cm (Absorbance per centimeter)	
Nitration	Oil condition	15	A/cm (Absorbance per centimeter)	
Iron (Fe)	Wear indicator	100	Parts per million	X-Ray Fluorescence 9400XP Oil wear ASTM D4927
Aluminum (Al)	Wear indicator	50**	Parts per million	
Copper (Cu)	Wear indicator	50***	Parts per million	
Silicon (Si)	Contamination	100	Parts per million	X-Ray Fluorescence 9400XP Oil wear ASTM D4927
Chromium (Cr)	Contamination	10	Parts per million	
Lead (Pb)	Contamination	10	Parts per million	
Tin (Sn)	Contamination	10	Parts per million	
Antimony (Sb)	Contamination	10	Parts per million	
Sodium (Na)	Contamination	200	Parts per million	
Potassium (K)	Contamination	10**	Parts per million	
Nickle (Ni)	Contamination	5	Parts per million	
Mangenes (Mn)	Contamination	10	Parts per million	
Vanadium (V)	Contamination	10	Parts per million	
Fuel Dilution	Contamination	2.0****	% by Volume	ASTM D3542
Water	Contamination	0.1	% by Volume	Aquatest
Glycol	Contamination	0.1	% by Volume	ASTM D4291
Initial service level *		@ first 40,000 Service		
Iron (Fe)	Wear indicator	25	Parts per million	X-Ray Fluorescence 9400XP Oil wear ASTM D4927
Aluminum (Al)	Wear indicator	25	Parts per million	
Copper (Cu)	Wear indicator	25	Parts per million	

* Note that initial service for the engine has increased wear indicator levels. This reflects initial wear associated with tolerances in the manufacturing processes used during engine manufacturing. These values will normalize during and after the initial service interval and should not be considered abnormal wear.

** Values may be significant higher due to Charged Air Cooler solder flux abrasion. This is to be recognized by a 3:1 ratio K:Al. For Al values up to 100 ppm and K up to 300 ppm can be observed.
(Coolants using K as a carrier salt instead of Na could see elevated levels of K due to coolant dilution.)

*** Dramatic elevated levels of copper can be observed, when the copper brazed oil cooler is subject to chemical attack, assumedly initiated by sulfites present in the engine oil. Usually this effect decreases over time when the copper surface passivizes. Values as high as 600 ppm for MX13 and 300 ppm for MX11 have been observed under these conditions.

**** When vehicle is fueled with EN590 or ASTM D975 diesel.

Normal Duty Line Haul - Amounts at 60,000 mile service interval

	Category	Maximum Allowable Levels	Unit	Method
Viscosity	Oil condition	Stay in grade (+/-10% from Base)	mm ² /s	ISO 3104 / ASTM D445
Total Acid Number (TAN)	Oil condition	< 6	Potassium hydroxide per gram (KOH/g)	ASTM D4739
Total Base Number (TBN)	Oil condition	> 2	Potassium hydroxide per gram (KOH/g)	ASTM D4739
Soot	Oil condition	1	Max Elevation allowed % by weight	Infrared with oil express method universal-2
Oxidation	Oil condition	20	A/cm (Absorbance per centimeter)	
Nitration	Oil condition	15	A/cm (Absorbance per centimeter)	
Fuel Dilution	Contamination	2.0****	% by Volume	ASTM D3542
Water	Contamination	0.1	% by Volume	Aquatest
Glycol	Contamination	0.1	% by Volume	ASTM D4291
Iron (Fe)	Wear indicator	100	Parts per million	X-Ray Fluorescence 9400XP Oil wear ASTM D4927
Aluminum (Al)	Wear indicator	50**	Parts per million	
Copper (Cu)	Wear indicator	50***	Parts per million	
Silicon (Si)	Contamination	100	Parts per million	X-Ray Fluorescence 9400XP Oil wear ASTM D4927
Lead (Pb)	Contamination	10	Parts per million	
Tin (Sn)	Contamination	10	Parts per million	
Antimony (Sb)	Contamination	10	Parts per million	
Manganese (Mn)	Contamination	10	Parts per million	
Nickel (Ni)	Contamination	5	Parts per million	
Vanadium (V)	Contamination	10	Parts per million	
Initial service level *		@ first 40,000 Service		
Iron (Fe)	Wear indicator	25	Parts per million	X-Ray Fluorescence 9400XP Oil wear ASTM D4927
Aluminum (Al)	Wear indicator	25	Parts per million	
Copper (Cu)	Wear indicator	25	Parts per million	

* Note that initial service for the engine has increased wear indicator levels. This reflects initial wear associated with tolerances in the manufacturing processes used during engine manufacturing. These values will normalize during and after the initial service interval and should not be considered abnormal wear.

** Values may be significantly higher due to Charged Air Cooler solder flux abrasion. This is to be recognized by a 3:1 ratio K:Al. For Al values up to 100 ppm and K up to 300 ppm can be observed.
(Coolants using K as a carrier salt instead of Na could see elevated levels of K due to coolant dilution.)

*** Dramatic elevated levels of copper can be observed, when the copper brazed oil cooler is subject to chemical attack, assumedly initiated by sulfites present in the engine oil. Usually this effect decreases over time when the copper surface passivizes. Values as high as 600 ppm for MX13 and 300 ppm for MX11 have been observed under these conditions.

**** When vehicle is fueled with EN590 or ASTM D975 diesel.

5.2 Using the Guidelines

Oil sample analysis can be used to distinguish normal wear from severe wear. A parameter that is out of specification does not necessarily mean that there is an issue with the change interval or type of oil being used. It also does not indicate that the engine is failing. Proper interpretation of oil analysis reports depends on interpretation across multiple parameters and trends over multiple oil change intervals.

PACCAR recommends the interpretation of an oil analysis be done by specialists. Many oil analysis laboratories will provide training on interpretation for their customers. The following guidelines may assist in the initial analysis.

TAN and TBN performance can vary by engine oil brand because of differences in additives used by the oil manufacturer.

- Low TBN can indicate acidification of the engine oil by nitric acids (EGR triggered), sulfuric acids (high sulfur diesel), or organic acids (oxidation, biodiesel).
- TAN provides an indication of acid concentration, but not acid strength. It cannot always be relied upon to provide a dependable indication of corrosion potential of the oil.
- Small deviations beyond the limits are acceptable, and should be investigated if they are coupled with excessive wear metal values.

Idling generates more soot in the engine oil. If excessive levels are observed, check the engine idle time percentage in the DAVIE chart recorder function first.

Comparing the results of oil sampled after extended engine operation to the same oil sampled prior to engine operation will result in values that reflect the engine's operation. Comparison to other oil samples or published values for new oil may result in added variation due to normal variation within the oil manufacturing process.

5.3 Potential Wear Metal Sources

There may be multiple sources for wear metals in the engine oil. The following table outlines potential sources for wear elements in PACCAR engines:

Symbol	Element	Possible Sources
Fe	Iron	Cylinder Liners Camshaft Crankshaft Valve Train
Cr	Chromium	Piston Rings / Piston Ring Plating Valve Stems / Valve Stem Plating Steel Alloying Element
Ni	Nickel	Valves Piston Rings Stainless Steel Alloying Element
Al	Aluminum	Main Bearings Connecting Rod Bearings Oil Cooler Flux Residue Charge Air Cooler Flux Residue Air Compressor
Cu	Copper	Connecting Rod Journal Bearings Oil Cooler Thrust Washers Rocker/Roller Pins
Pb	Lead	Main Bearings Connecting Rod Bearings
Sn	Tin	Rocker Shaft Axle Main Bearings Connecting Rod Bearings Bronze Alloying Element

It may be difficult to identify a potential failure based on trends in oil analysis reports. The following table lists wear metal sources and the elements they contain which may appear in combination at elevated levels on multiple consecutive oil analysis reports, and may be helpful in identifying a failing engine component.

Wear Metal Source	Possible Wear Elements	
	Elements	Symbol
Cylinder Liners	Iron	Fe
Camshaft	Iron	Fe
Crankshaft	Iron	Fe
Valves / Valve Train	Iron	Fe
	Chromium	Cr
	Nickel	Ni
Piston Rings	Chromium	Cr
	Nickel	Ni
Connecting Rod Bearings	Aluminum	Al
	Copper	Cu
	Lead	Pb
	Tin	Sn
Main Bearings	Aluminum	Al
	Copper	Cu
	Lead	Pb
	Tin	Sn
Oil Cooler	Aluminum	Al
	Copper	Cu
Charge Air Cooler	Aluminum	Al
Air Compressor	Aluminum	Al
Thrust Washers	Copper	Cu

6. Best Practices

It is important to use clean equipment to collect and store oil samples to prevent unwanted cross-contamination. PACCAR Parts provides test kits to aid in the proper collection and safe transportation of collected oil samples, in order to ensure the integrity of the sample is maintained. The testing kits will also help to measure appropriate quantity of sample oil for analysis. The table below lists the parts recommended by PACCAR for collecting engine oil for analysis.

Part Description	Part Number
Advanced Oil Test Package	FT1000A
Basic Oil Test Package	FT1000B
Oil Vacuum Pump	VPUMP0

When sending oil to a lab for analysis, ensure the testing facility has the current information related to:

- Vehicle chassis and engine information for accurate recordkeeping
- Engine mileage or hours since the previous oil change
- Brand and type of oil being analyzed (used to identify oil additive composition)
- Type of vehicle application

Testing facilities typically allow for the creation of online accounts that can be associated with a company, fleet, group of vehicles, or a dealership. PACCAR recommends creating an account with the testing facility, which can assist in identifying trends in the change of oil contaminants or wear elements across several oil changes.

7. Test Methods

In the tables located in section 5.1, the recommended test processes are listed. There is risk of added variation in the results when analyses are done by different labs, due to the use of different equipment and analysis methods performed according to different standards. This may lead to results that could be interpreted as “Not OK” while analysis by a different method or lab could result in “OK”. If possible, it is recommended that oil analysis be performed consistently by the same laboratory to limit variation of the testing procedure.