# Oil Analysis

# Maintenance Management Tool

# Questions And Answers

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# HOW TO USE OIL ANALYSIS EFFECTIVELY

Used oil analysis is very effective when used as a part of your maintenance management program. However, never rely on oil analysis test results alone when making maintenance decisions!

Obtain information from all sources before making your final maintenance decision. Typical sources of information to consider are:

- Driver Logs/Information
- Equipment Manufacturer
- In Shop Diagnostic Test Information
- Lubricant Suppliers
- Operating Conditions/Environment
- Equipment Maintenance History
- Visual Inspection
- Compare Current Sample Results With Previous Samples
- Evaluate Fuel Source Quality
- Age of Equipment
- Evaluate Impact of Recent Maintenance Repairs
- Compare Individual Units to Fleet Trend

Oil analysis is a reliable and effective maintenance management tool and the information provided by the laboratory can assist you in making more informed maintenance decisions. The laboratory, lubricant supplier and equipment manufacturer are an important part of your team and should be involved in your program.

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# KEYS TO EFFECTIVE OIL ANALYSIS RESULTS

- Determine Goals and Objectives

- Verify Lab Capabilities and Responsiveness
- Ensure Samples are Taken Correctly
- Take Samples on a Regular Basis
- Fill Out Laboratory Sample Information Forms Completely
- Do Not Hold Samples. Send to Laboratory ASAP
- Tell the Lab of Recent Maintenance or Unusual Problems
- Use Manufacturers Guidelines
- Involve Your lubricant Supplier
- Ensure Good Communications Between Laboratory, Maintenance Personel and Maintenance Managers
- Train Maintenance Personnel About Using Oil Analysis Effectively
- Use Oil Analysis as a part of your maintenance Planning and Practices
- Evaluate Cause and Effect Relationships in Test Results and Determine Possible Solutions



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# VISCOSITY

Viscosity is the single most important property of lubricating oils. A viscosity test measures the lubricants internal resistance to flow. Put simply, how thick or thin the lubricant is. Test results are reported in Centistokes (cSt). SAE viscosity or Saybolt Universal Seconds (SUS).

Viscosity test are typically run at one of two temperatures i.e. 100º Centigrade or 40º Centigrade. The laboratory and your lubricant supplier can advise you in determining the best temperature range to select.

Viscosity test results are typically recorded three ways:

___ Normal ___ High ___ Low

High or low results should be investigated to determine the cause and maintenance should be initiated to correct the problem.

Changes in the viscosity indicate the degree of aging, by-product contamination, dilution, the possibility of mixed products, and other abnormalities that affect the serviceability of the lubricant.

CAUSES of Viscosity Problems:

- Fuel Dilution
- High Levels of Soot
- Water Contamination
- Anti-freeze Contamination
- Blow-by
- Oxidation Varnish/Sludge
- Overextended Oil Drains
- Mixed Lubricants
- Additive Shearing/Breakdown
- Incorrect Lubricant Use

MAINTENANCE ACTIONS:

- Check Operating Temperature
- Check for Contaminated New Oil
- Check Oil Grade
- Evaluate Equipment Operations
- Check for Excessive Idling or Lugging Conditions
- Repair/Replace Defective Seals
- Test for Solids in the Lubricant
- Check for Anti-freeze Contamination
- Check for Varnish and Sludge Formation
- Check Air to Fuel Ratio
- Check for High Soot Loading
- Check for Fuel Dilution
- Evaluate Oil Drain Intervals
- Check for Water Contamination
- Change Oil and Filters
- Check for Leaking Injectors
- Ensure Equipment is Operated Properly
- Ensure Correct Lubricants are in use

Abnormal changes in viscosity are serious and require immediate maintenance action. Viscosity problems can shorten equipment life, cause breakdowns, increase maintenance costs and affect productivity.

Many variables must be taken into consideration when evaluating viscosity problems. Some of these variables are:

- Age of Equipment
- Environmental Factors
- Cost of Repair vs. Replacement
- Operator/Driver Training
- Warranty Claim Potential
- Operating Conditions
- Equipment Applications
- Type of Equipment
- Maintenance Scheduling
- Cause of the Abnormal Viscosity

- Effect of Wear Metals
- Miles or Hours on Lubricant
- Miles or Hours on Equipment
- Company Maintenance Goals

As a standard, increase or decrease in viscosity by one grade, depending on variables involved, should be evaluated for maintenance for maintenance action or inspection. Always check with the lubricant supplier and the equipment manufacturer to determine the properly specified viscosity and type of lubricant you should use. Properly specified oil, kept clean and free of contaminants will provide good serviceability and help to ensure long equipment operation and life at a reduced cost.



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# FUEL SOOT

Measuring the amount of fuel soot in diesel engine oils is an excellent method used to determine the combustion efficiency of an engine. The fuel soot test will help you determine if air to fuel ratios are incorrect or if other abnormalities exist. Excessive levels of fuel soot can cause many problems and maintenance action should be taken as soon as possible to make corrections. Fuel soot, also, may cause excessive exhaust emissions resulting in violation of state and city emissions standards.

CAUSES

- Improper Air to Fuel Ratio
- Improper Equipment Operation
- Poor Fuel Quality
- Worn, Stuck Compression Rings
- Intake/Exhaust Valve Guide Problems
- Low Compression
- Excessive Idling
- Injector Adjustment Incorrect
- Clogged Air Filters
- Defective Injectors
- Stuck Oil Rings
- Out of Round Cylinders
- Overextended Oil Drains
- Defective Oil Cooler

EFFECTS

- Increased Viscosity
- High Engine Temperature
- Oxidation
- Restricted Oil Flow
- Clogged Filters
- Lacquer Build-up

- Loss of Power/Performance
- Excessive Emissions
- Shortened Oil Drains
- Engine Life May Be Shortened
- Increased Maintenance Cost
- Loss of Productivity

MAINTENANCE ACTIONS

- Ensure Air to Fuel Ratios are Correct
- Ensure Air Filters are Changed
- Evaluate Fuel Quality
- Change Oil Filters
- Train Drivers/Operators
- Check Compression
- Shorten Oil Drain Intervals
- Replace Rings
- Avoid Excessive Idling
- Check/Correct Timing
- Ensure Piston Crowns are Clean and Free of Carbon Build-up
- Ensure Operating Temperatures are correct
- Check Injector Spray Patterns
- Check Fuel Metering
- Replace/Repair Injectors
- Check/Adjust Governor
- Check/Adjust Exhaust Valve Clearance
- Check Supercharger Operation

Fuel soot problems can be the result of many things, however, if the tune-up procedure of the manufacturer are followed and proper lubricants are used, these should be corrected.

The effects of high soot loading are varied and depend on the composition of the soot.

The amount of fuel soot detected is reported as % weight. Typical warning levels start around 1.5%. However, depending on the engine type, the application, and the way the fuel soot is developed, its effects on the lubricant, engines and filters can be significantly different. Soot from improper air to fuel ratios may have a different effect than soot caused by compression problems.

Fuel soot levels combined with viscosity results provide an excellent indication of the lubricant condition and the efficiency of the engine.



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# FUEL DILUTION

When excessive fuel dilution occurs, the effectiveness of the lubricant is reduced. As the fuel thins the lubricant, the viscosity goes down and may allow increased wear which in turn may cause overheating. Oil needs to keep the metal parts separated, to provide sealing from combustion products and transfer heat from the engine for cooling. When the oil is diluted by the fuel, its ability to perform is diminished and the effects can lead to engine failure.

**CAUSES**

- Leaking/Defective Injectors
- Excessive Idling
- Incomplete Combustion
- Worn Liners/Rings
- Improper Timing
- Inexperienced Drivers/Operators
- Driving Conditions
- Leaking Fuel Pump/Lines
- Equipment Application
- Incorrect Air to Fuel Ratio
- Poor Fuel Quality
- Equipment Use vs. Design

To avoid fuel dilution problems it is necessary to ensure the causes are corrected. Refer to the fuel section for more solutions

If possible, another sample should be sent to the laboratory to verify results. Samples may be contaminated during the oil drain and sampling. Always ensure clean, uncontaminated sampling materials are used. Do not drop the oil into a fuel contaminated container when sampling. If using sample pumps, do not reuse the sample tubing.

Fuel dilution problems require immediate attention! Fuel dilution can effect all other test results and may interfere with proper maintenance evaluation of equipment and lubrication condition. Depending on the variables involved, fuel dilution of 2.5% to 5.0% is considered excessive and requires maintenance action and/or repair.



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# WATER/ANTIFREEZE CONTAMINATION

Many problems cause water/coolant contamination in engine or gear lubricants.

**CAUSES**

- Low Operating Temperatures
- Blown Head Gasket
- Head bolt Torque Incorrect
- Defective Seals
- New Oil Contamination
- Improper Storage of New Oil

- Holes in Liners
- Contamination from Maintenance
- Head and Block Surfaces Improperly Machined
- Combustion Products
- Oil Cooler Leaks
- Sample Contaminated During Sampling

Used oil analysis will seldom detect water in engine oils because engine oils are hot enough to evaporate the water. However, the chemical components of anti-freeze remain in the oil and are detected as parts per million (ppm) of Sodium (Na), Boron (B), and Potassium (K). When elevated amounts of Na, B, or K are detected in crankcase oils, it usually means anti-freeze contamination has occurred. Some lubricants contain these elements and used oil results must be compared to new results to determine if contamination is present.

The effects of water and/or anti-freeze contamination are well known to mechanics and equipment operators.

**EFFECTS**

- Engine/Equipment Failure
- Ineffective Lubrication
- High Operating Temperatures
- Power Loss
- Metal Corrosion
- Lubricant Additive Properties become ineffective
- Acid Formation
- Weld Spots
- High Levels of Wear Metals
- Increased Viscosity
- Coolant Loss
- Milky Appearance of Lubricant

Solutions to Water/anti-freeze contamination are many and varied and depend on the engine involved.

MAINTENANCE ACTIONS

- Check Torque on Head bolts
- Check or Change Gaskets
- Check Internal and External Seals
- Inspect Heads and Block for Damage
- Always Change Oil and Filters When Contamination is Suspected
- Inspect Oil Coolers
- Check New Oil for Contamination
- Evaluate Operating Conditions
- Avoid Intermittent Use
- Ensure Correct Lubricant is in Use

Laboratory analysis is an effective method for identifying water or anti-freeze contamination before problems occur. Infrared analysis is used to determine the amount of water by % volume in used oil. For equipment application with greater sensitivity to moisture, the Karl Fischer apparatus will measure amounts in parts per million.

These contaminants are serious and their causes should be investigated and corrected. However, always consider the cause of the problem when determining the need for repairs or maintenance. Verify lab results by inspection, resample and other tests, if possible.



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# OXIDATION

Engine Oil and oil in various other components can, under certain conditions, undergo a chemical change resulting in oxidation. This process can cause harmful by-products and affects the oils ability to lubricate.

Common problems resulting from high oxidation and by-products are:

- Lacquer Deposits
- Metal Corrosion
- High Viscosity

the oil analysis lab can compare a sample of used oil to a sample of new oil and determine the extent of oxidation problems. Oxidation breakdown is considered to be one of the most important problems affecting the serviceability of a lubricant.

## CAUSES

- High Operating Temperatures
- Wrong Oil in Service
- Combustion By-products/Blow-by
- Extended Oil Changes

Overextended oil drains are probably the most common cause of increased oxidation.

## EFFECTS

- Increased Oil Viscosity
- Lacquer Build-up
- Filter Plugging
- Metal Parts Corrosion
- Over Heating
- Increased Wear
- Engine Performance Problems
- Sludge Deposits

## MAINTENANCE ACTIONS

- Shorten Oil Drains
- Control High Temperatures
- Use Correct Lubricants
- Change Oil and Filters
- Ensure Equipment is used Properly and Under Proper Operating Conditions
- Ensure Oxidation Results and Accurate. Changes in the Blend of a Product May Affect the Lab Results. Typically, Oxidation Tests are not Performed on Synthetic Lubricants.
- Ensure Products are not Mixed by Brand Types. Mixtures May Indicate Oxidation Problems When None Exist.



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# NITRATION

The products of Nitration are highly acidic, cause deposits can increase the effects of oxidation.

These products are performed during the fuel combustion process when combustion by-products mix with the engine oil. This occurs during normal operation or as a result of abnormal blow-by.

The standard method of measuring the amount of nitration occurring is by Infrared analysis. Increase in the Total Acid Number (TAN), a measure of the acid in the oil, can also occur when high levels of nitration are present.

When high nitration levels are present, the serviceability of the lubricant is affected.

Nitrogen compounds are often found in the fuel, especially fuel having a high sulfur content.

**CAUSES**

- Turbo/Super charger Problems
- Scavenge Pump Problems
- Compression Problems
- Fuel Problems
- Improper Scavenge
- Low Temperature Operations
- Abnormal Blow-by
- Air/Fuel Ratio Incorrect
- Defective Seals
- Bad Rings

**EFFECTS**

- Acid Increase
- Accelerated Oxidation
- Ring Sticking
- Carbon Deposits
- Increased Maintenance Expense
- Wear Metal Corrosion
- Increase Wear
- Oil Viscosity Increase
- Lower Productivity
- Environmental Contamination from Nitrous Oxides

### MAINTENANCE ACTIONS

- Correct Operating Temperatures
- Correct Scavenge Problem
- Check Fuel
- Change Oil Filters
- Ensure Correct Oil is Used
- Perform Compression Checks
- Check Crankcase Venting
- Correct Air/Fuel Ratio
- Correct Other Problems
- Replace Compression Rings



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# TOTAL SOLIDS

Total solid contamination usually indicates in system contamination or lubricant degradation. The type detected depends on the system. Typically, solid components come from sources such as fuel soot, wear debris and oxidation products.

High levels of solids indicate other problems are affecting the lubricant and the reason for the solids should be investigated and corrective action should be accomplished.

### CAUSES

- Air/Fuel Ratios Incorrect
- Extended Oil Drains
- Fuel Soot
- Blow-by
- Over Heating
- Environmental Contaminants
- Wear Debris
- Oxidation/Nitration
- Bad Rings

### EFFECTS

- Power Loss
- Viscosity Increase
- Sludge Build-up
- Lacquer Formation
- Increased Wear
- Plugged Filters
- Higher Operating temperature
- Poor Lubrication
- Solids will affect the lubricant and equipment in many ways. Solids interfere with the flow of the oil and can keep many parts from receiving proper lubrication.

**MAINTENANCE ACTIONS**

Correct and/or repair all components that contribute to the causes. Control the cause and most of the effects will be eliminated.

- Use Equipment Correctly
- Control Operating Conditions
- Always Change Oil
- Always Change Filters
- Check with the oil supplier and lubricant manufacturer to ensure correct lubricants are in use and to obtain information regarding preventative maintenance action.

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# TOTAL BASE NUMBER (TBN)

Depending on the application and use, an oil will have additives added to protect the lubricant properties and the equipment.

Base (alkaline) additives are in the oil to neutralize acidic products. The additives have a limit to their ability neutralize acids. Over use of a lubricant, i.e. extended oil drains, will cause the base additives to lose their ability to neutralize acids.

New oils start with the highest TBN they will possess. Depending on the equipment, application and operation lubricants are developed with different amounts of these additives.

Measuring the TBN is very important when extending oil drain intervals. The levels of the TBN will indicate the capability of the additives to neutralize the acids.

When the TBN is reduced to 1/2 of its original value an oil change is advisable.

Calcium (Ca) and Magnesium (Mg) are the additives blended with oil to neutralize acids and acid by-products. Calcium and Magnesium levels indicate the amount of these additives in new oil. These levels will remain in the oil even though they can no longer neutralize acids. TBN testing is the only way to determine if these additives remain effective.

**CAUSES** (of low TBN readings)

- Incorrect Oil in Use
- Acid Build Up
- Fuel Sulfur
- Nitration
- Overextended ODI's
- Over Heating
- Blow-by
- Improper Operations

**EFFECTS**

- High Acid Levels
- Additive Depletion
- Corrosion
- Shortened Oil Life
- Increased Repair Expense
- Improper Operations

**MAINTENANCE ACTIONS**

- Ensure Low Sulfur Fuel is Used
- Use Correct Lubricants
- Verify TBN of New Product
- Change Oil
- Add Fresh Oil, if Possible
- Test Fuel Quality
- Repair/Replace Worn or Defective Engine Parts
- Shorten Oil Change Interval



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# TOTAL ACID NUMBER (TAN)

The TAN test measures the amount of acid or acid-like contaminants in the oil. Increase in the TAN above the level in new lubricants should be monitored.

TAN increases normally indicate lube oxidation or contamination with acidic products has occurred.

New oils normally have a low level of acids. This is because some additives used in the development of new oils are acidic in nature.

Acids and/or acidic by-products affect the serviceability of lubricants and may cause other related problems. Corrective action is required.

**CAUSES** (high TAN results)

- Poor Fuel Quality
- High Sulfur Fuel
- Over Extended Oil Change
- Wrong Oil use
- Additive Depletion
- Excessive Blow-by
- High Temperature Operation
- Environmental Sources
- Worn/Defective Engine Parts

**EFFECTS**

- Increased Wear
- Metal Corrosion
- Increased Viscosity
- Increased oxidation
- Increased Maintenance Expense
- Overheating

**MAINTENANCE ACTIONS**

- Reduce Oil Drain Intervals
- Change Oil
- Ensure Correct Oil is Used
- Replace/Repair Worn Parts
- Control Environmental Contaminants
- Correct Overheating Problems



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# WEAR METALS/ELEMENTAL ANALYSIS

Equipment as it operates will deposit microscopic amounts of wear metals in the lubricant. Under normal conditions, wear will be very gradual and will increase slowly as the equipment is used. Samples taken regularly, allow the development of a baseline for each piece of equipment and subsequent samples are checked against the baseline for unusual increases or changes. Unusual increases or changes from established trends should be evaluated to determine the cause and possible effect.

Included in the oil analysis element testing are elements representing additives and contaminants. The additive elements can help to ensure the correct lubricant is in use and the contamination elements help to pinpoint specific problems.

The cause and effect relationship of the various wear elements to each other, to the additive elements, to the contamination elements and to changes in lubricant properties must carefully be considered when making maintenance decisions.

A short list of cause and effect relationships is as follows:

- Dirt (Silicon) ingestion may cause increase wear metals.
- Copper, Tin, and Lead wear may indicate bearing wear.
- Iron, Aluminum, and Chromium wear may indicate cylinder wear.
- Low or high additive elements may indicate the incorrect oil is in use.
- Contamination elements, Sodium, Potassium, and/or Boron, may indicate coolant leaks and explain changes in viscosity.
- High wear metals (elements) with a low (abnormal) viscosity may indicate a fuel dilution problem.
- High wear metals (elements) may occur because of abnormally high viscosity, high soot loading and water or anti-freeze contamination.
- High or low additives may indicate contamination or the incorrect lubricants in use.
- Additives are useful in determining the capability of lubricant to neutralize acid.
- Silicon without wear metals may indicate a contaminated or improperly taken sample or may be from a lubricant using silicon as an anti-foam agent.
- High levels of cylinder wear may allow increases in the amounts of blow-by or soot.
- Increased levels of soft metals i.e. Copper, Lead. and Tin may result from poor lubrication because of water and/or anti-freeze contamination.
- High acid levels may cause corrosion of wear metals.
- Over extended oil drains, overheating, improper operation and many other factors can affect the wear metals present in the lubricant.

It is very difficult to pinpoint the source of wear metals, however, by determining abnormal problems causing the wear and correcting these problems, many times the wear can be controlled or prevented.

Wear metal elements, additive elements and contamination elements come from many different sources. Typical sources are as follows.

# IRON (Fe)

**Engines**

cylinders, liners, blocks, crankshafts, gears, camshaft, valve train

**Differentials - Final Drives - Planetarys - Etc.**

gears, shafts, bearings, housing, PTO's

**Transmissions**

gears, discs, housings, bearing, pumps, brake bands

**Hydraulic Systems**

pump/motor, vanes, gears, pistons,bearings, rods, housing metal

**Compressors**

crankshafts, housing, screws, bearings, oil pumps, piston rings, cylinders,

shafts, blocks



# COPPER (Cu)

**Engines**

bushings, bearings, cam bushings, oil coolers, valve train bushings,

thrust washers, oil pumps

**Differentials - Final Drives - Planetarys - Etc.**

bushings, thrust washers, oil pumps

**Transmissions**

clutch plates, discs, oil coolers, bearing/thrust washers

**Hydraulic Systems**

pump pistons, cylinder guides, bushings, oil coolers (some)

thrust plates, power steering systems

**Compressors**

wear plates, bushings, wrist pin bushings, bearings, thrust washers,

cylinders, shafts, blocks



# ALUMINUM (Al)

**Engines**

pistons, bearings, blocks (some), bushings, housing, oil pumps, blowers,

thrust bearings, cam bearings/bushings

**Differentials - Final Drives - Planetarys - Etc.**

pump bushings, thrust washers, oil pumps

**Transmissions**

pumps, clutches, thrust washers, bushings

**Hydraulic Systems**

pump/motor housing, cylinder systems

**Compressors**

rotors, pistons, blocks, housing metal, thrust washers



# CHROMIUM (Cr)

**Engines**

rings, roller/taper bearings (some), liners, exhaust valves, wear treatment

**Differentials - Final Drives - Planetarys - Etc.**

roller/taper bearings (some)

**Transmissions**

roller/taper bearings (some), water treatment (oil cooler)

**Hydraulic Systems**

rods, spools, roller/taper bearings (some)

**Compressors**

rings, roller/taper bearings (some), water treatment (oil cooler)



# LEAD (Pb)

**Engines**

bearings, gasoline, octane improver

**Differentials - Final Drives - Planetarys - Etc.**

oil additives (some)

**Transmissions**

oil additives (some)

**Compressors**

bearings



# SILICON (Si)

**Engines**

anti-foam additives, ingested dirt

**Differentials - Final Drives - Planetarys - Etc.**

ingested dirt

**Transmissions**

disc lining

**Compressors**

ingested dirt

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## SODIUM (Na)

**Engines**

oil additives (some), anti-freeze, road salt, ingested dirt

**Differentials - Final Drives - Planetarys - Etc.**

ingested dirt

**Transmissions**

oil additives, anti-freeze, road salt, ingested dirt

**Hydraulic Systems**

oil additives, anti-freeze, ingested dirt

**Compressors**

oil additives, ingested dirt, anti-freeze

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## NICKEL (Ni)

certain types of bearings, valve and valve guides

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## SILVER (Ag)

certain types of bearings, solder in some oil coolers

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## MOLYBDENUM (Mo)

plating or surface hardening agent in certain bearings, rings

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## MAGNESIUM (Mg)

case and/or body wear of certain engines, cases of certain accessory gear boxes,

oil additives (usually as detergent-dispersants)

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In addition to wear metals, there are other metallic additives present to a certain degree in most modern lubricants. They include:

## BORON (B)

anti-wear agents, antioxidants, constituent of deodorant cutting oils,

grease, brake fluids

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## CALCIUM (Ca)

detergents, dispersants, acid neutralizers

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## BARIUM (Ba)

corrosion inhibitors, detergents, rust inhibitors

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## ZINC (ZN)

anti-oxidants, corrosion inhibitors, anti-wear additives,

detergents, extreme pressure additives

# PHOSPHORUS (P)

anti-rust agents, spark plug and combustion chamber deposit reducers