# Condition monitoring



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# Agenda

Oil Analysis Program

Sampling

Recommended Analysis

Techniques

# Oil Analysis Program - Basics

- Step 1
  - Already done……..**Lubrication Chart Preparation**
- Step 2
  - Select the systems/equipment to be monitored
    - Main criteria in selection of the system/equipment is it' s **criticality** and not only oil volume itself !
    - Consider Failure Mode & Effect Analysis
- Step 3
  - Modify the sampling frequency (considering machine and oil age – both are moving targets, readjustments may be required)
- Step 4
  - Determine the cleanliness target of oil sample
  - Ensure proper sampling tools, methods and techniques
  - Ensure a proper evaluation and documentation of sampling results (history and graphical trend analysis are essential parts of the evaluation process)

# Oil Analysis Program – Normal test frequencies

| Equipment | Frequency |
|---|---|
| Hydraulic system | 12 weeks |
| Lubrication system | 12 weeks |
| Speed reducers | 12 weeks |
| Air compressors | 12 weeks |
| Process fan bearings | ** 4 weeks |
| Mill trunion bearings | ** 4 weeks |

- Under normal conditions, critical equipment is normally sampled every three months.
- ** At the beginning frequencies can be high and then readjusted
- If a problem arise, sampling frequency should decrease, until root causes are detected and fixed

# Oil Analysis Program - Focus

- **What Oil Analysis Looks At**

- Lubricant Serviceability
  - Physical & chemical tests
- Machine Wear Behavior & condition
  - Wear debris analysis
- Contaminants
  - Elemental analysis

**Why ?**

# Oil Analysis Program

- **Purpose:**
- To increase reliability & availability of machines
- To avoid surprises
- To be just in time for prepared & programed repairs
- To readjust frequency of testing program

- **The costs of such should be covered by:**
- Life extension of the lubricant
- Life extension of the equipment
- Planned repairs and right preparation will lower maint costs

# Agenda

Oil Analysis Program

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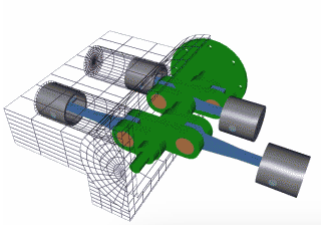
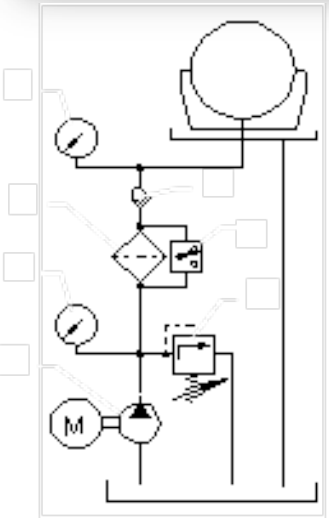
# Sampling

- It is imperative to define
  - The equipment
  - The sampling frequency
  - The sampling procedure
  - The right sampling devices & containers
  - The right sample location

# Sampling – Procedures

- Take it in **normal operating conditions**
- Take it while **mixed and flowing**
- Take it from a sampling port
  - If no sampling port or valve is available, use sample pump with plastic tubing through oil fill port, or from the drain plug **as very last and temporary option**
- Take it **before the filter, Flush** through the valve before taking the sample
- **Avoid pollution** from the surroundings to enter the sample
- Do not take samples **after addition** of large amount of top-up oil





# Sampling – Procedures

- **Identify** and provide the bottle with following data (immediately after sample was taken):
  - Plant name
  - Equipment type and number
  - Sample reference number
  - Date and time of sample
  - System reference e.g. HAC
  - Oil name and type
  - Oil volume
  - Sampling location
  - Service life of oil
  - Last oil change
  - And also **tell the supplier reason/s for the analysis**
    - A routine, a new oil, change oil type?
    - Is it an emergency ? If yes….what would we like to look for ?

# Sampling – Procedures

- Let’s use our oil supplier for oil analysis – see your local contract and the global contract services agreed
- Ask the oil supplier **data related to a new oil** as well as the operational limits
- For big oil quantities sometimes it is good to make the analysis thru an **independent company**

# Sampling devices & containers

- Lubricant cap and deposit have to be perfectly clean
- The bottles must remain closed before the sample taking
- The hoses must be kept clean at all times
- Rap this elements in Zip-lock type bags.

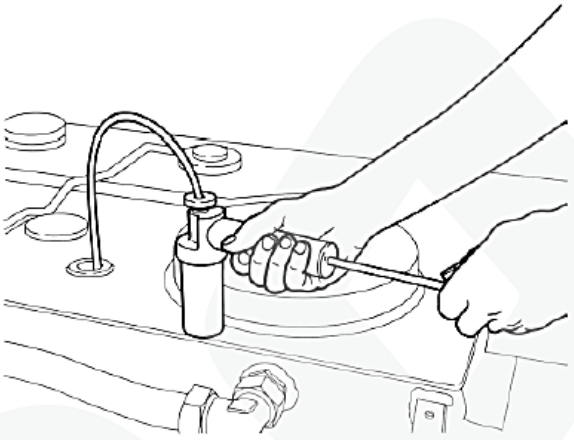
**Not This please**



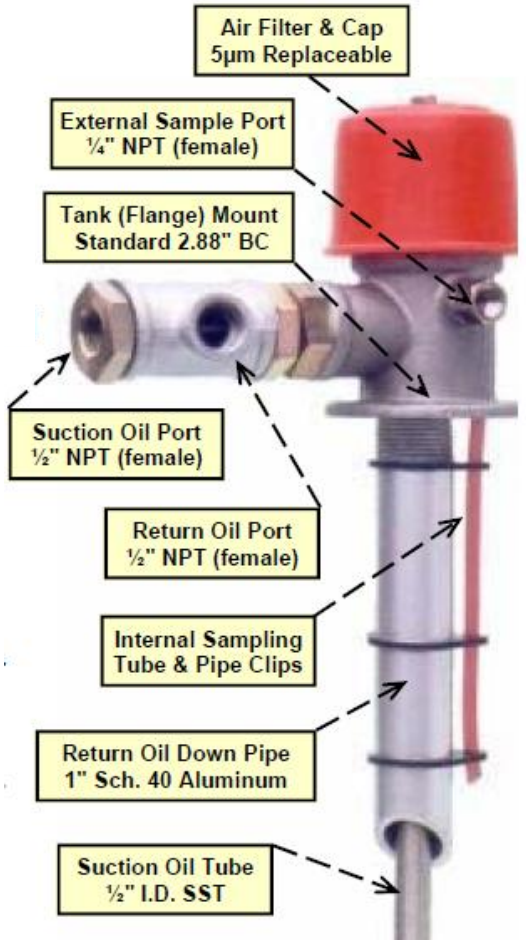

# Sampling devices & containers

## Valve and fittings

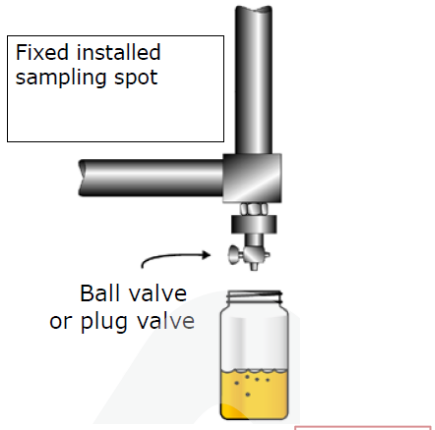
## Suction pump

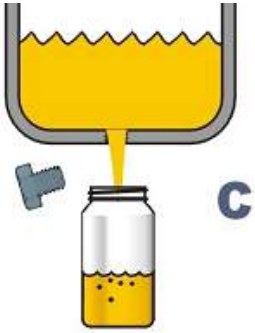


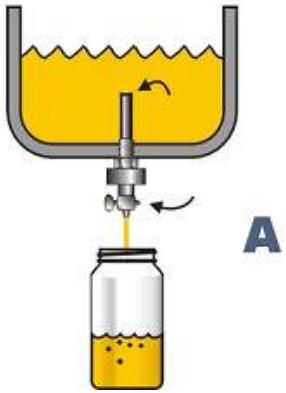
## Filter & sampling port



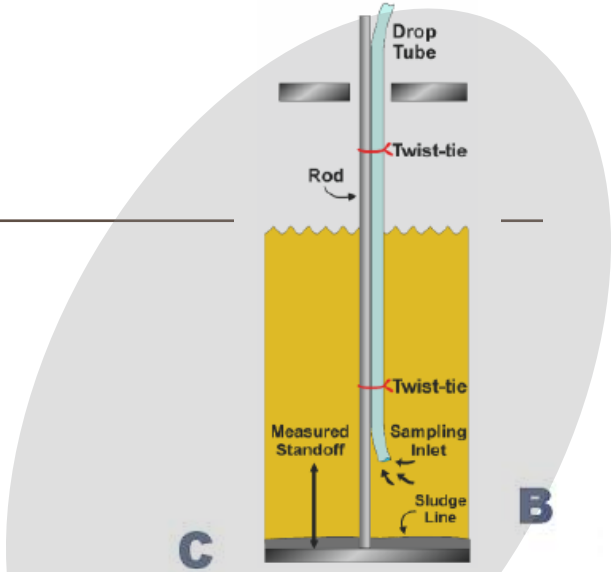
# Sampling location

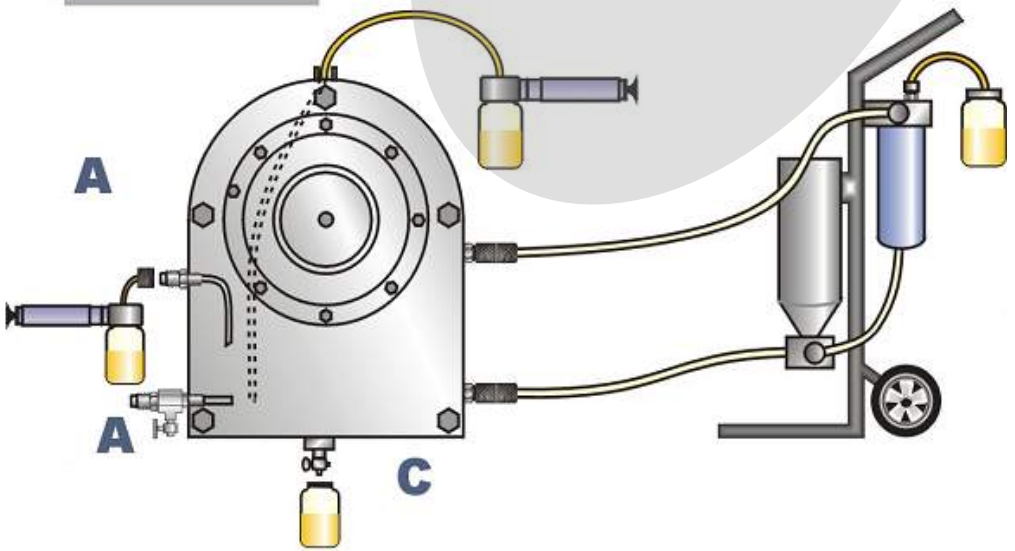


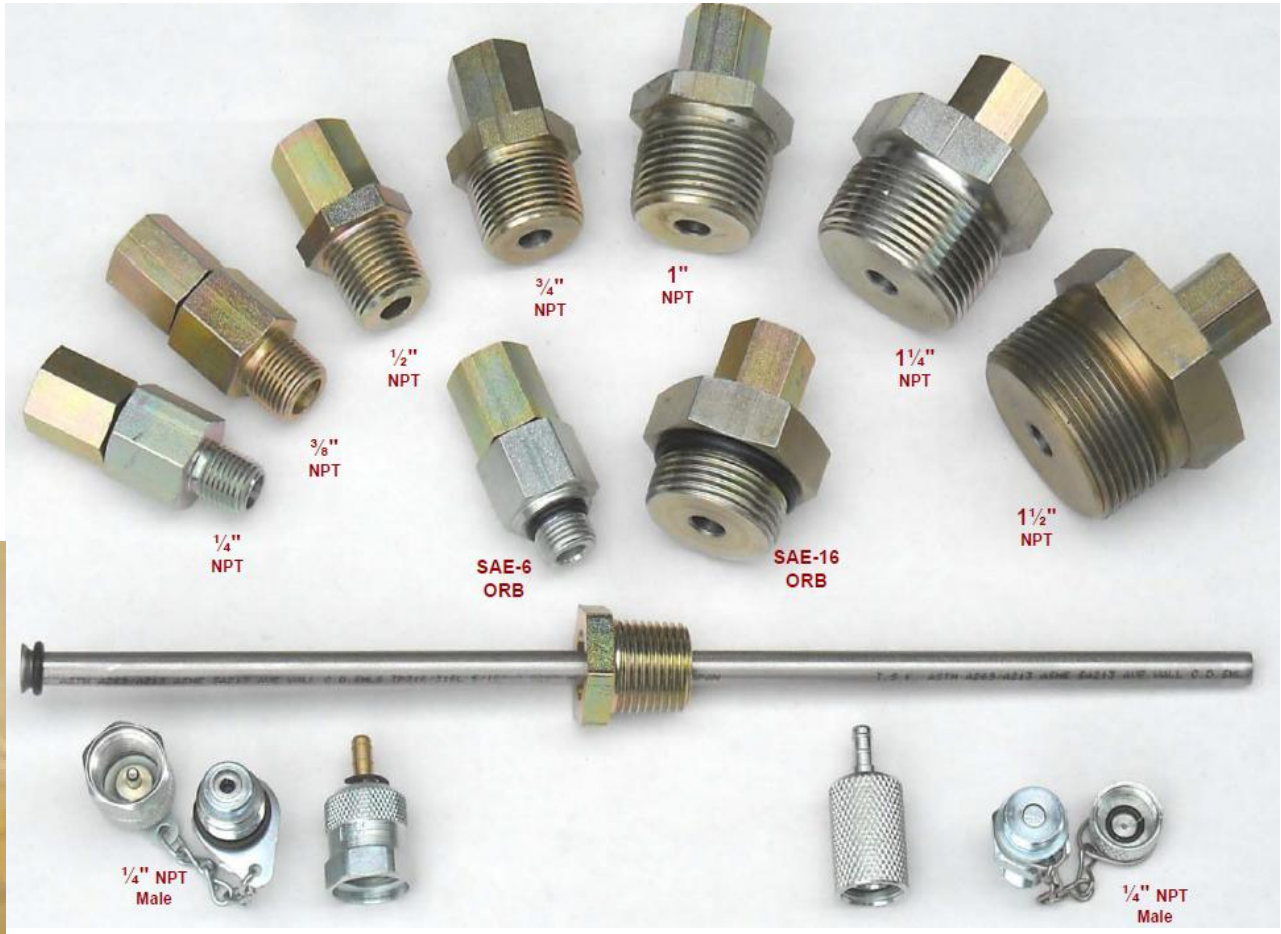




A good
B Acceptable
C Poor (why?)



# Sample fittings



# Agenda

Oil Analysis Program

Sampling

Recommended Analysis

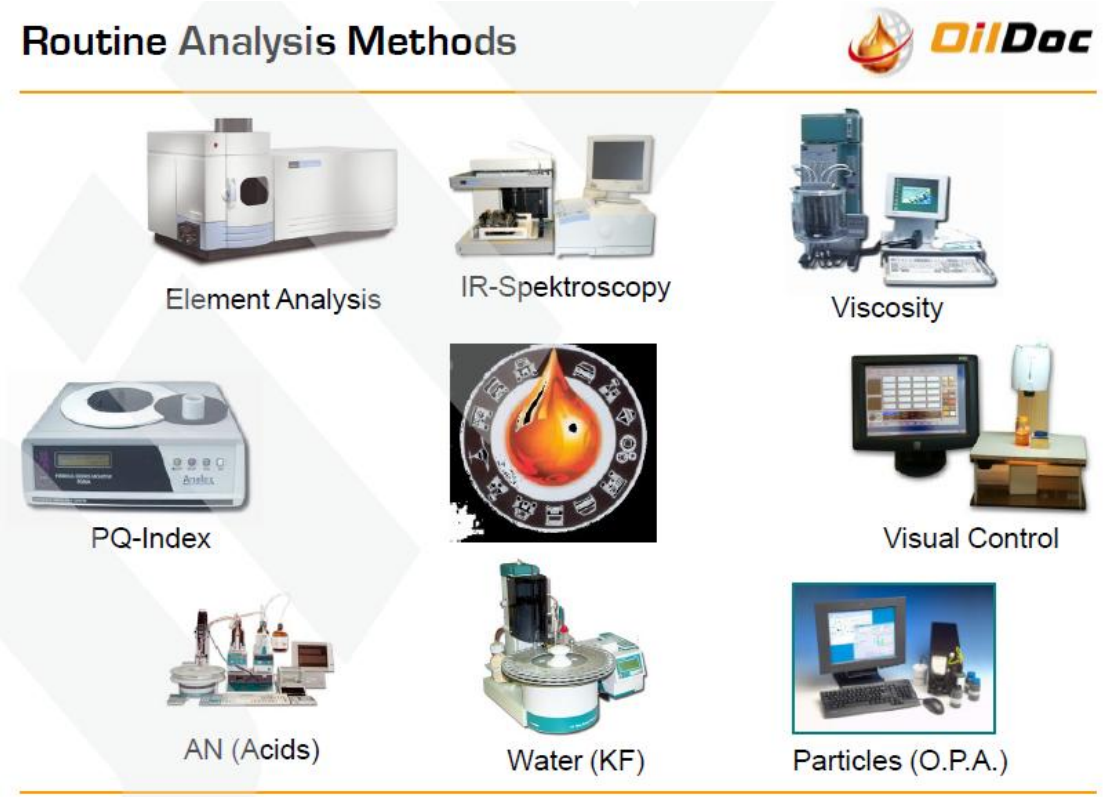
Techniques

# Recommended analysis

- Wear
- Wear is normal
- Size and shape of particles depend on application
- Component (bearings, gears)
- Load, velocity
- Environment
- Material
- Contaminants
- From outside : Dust, fibers, water
- From inside : Oxidation products, acids
- Oil condition
- Base oil aging, mixture…..
- Additives depletion, mixture

# Recommended Analysis

- Appearance / Color
- Viscosity cSt
- Water Content
- TAN – Total Acid Number
- Wear Particle (weight %)
- IR - Infrared Spectrum
- Trace metal analysis (ppm and size) (if needed)
- Particle counting - ISO 4406 (if needed)
- Foam (if needed)



# Additional analysis methods

- BN – Base number
- Brugger (Test rig)
- Chlorine content
- Cloudpoint
- Cold Filter Plugging Point CFPP
- Conradson carbon residue
- Density
- Dielektric dissipation factor
- Break trough voltage
- Color
- Solid cantaminants (gravimetric)
- Filterability
- Flash point
- Dissolved gases (DGA)
- Surface tension
- i-pH value
- Jodine number
- Penetration (Greases)
- Karl-Fischer water content
- Conductivity
- Air release
- MPC test (varnish)
- Optical Particle Analysis (OPA)
- Particle Counting (Laser or microscope)
- Pourpoint
- RPVOT
- RULER
- Foaming tendency
- Shear viscosity (Greases)
- Sulphated ash
- TOST
- Dropping point (Greases)
- Viscosity-Temperature-Profile
- Water separation

# Tests, Warning and Condemning Limits

| Test | Caution | Critical | Possible Technics |
|---|---|---|---|
| **IR Infrared Analysis** | | | Spectrographic analysis |
| **Viscosity Test cSt 40 ºC** ($mm^2/s$) DIN 51562 or ASTM D445 | ± 10 % | ± 15 % | Viscosity/Viscosity Index |
| **TAN - Total Acid No**. (mg KOH/g) DIN 51588 or ASTM D974 | | 1.0 increase from new oil | Acid Number ASTM method - D974, Potentiometric titration, Color indicating titration |
| **Wear Particle** (weight %) DIN 51592 | | > 0.08 % | Spectrographic analysis |
| **Wear Particle Analysis** | | Limits see next page | Spectrographic analysis |
| **Water (weight %)** DIN 51582 or ASTM D1744, D95 | > 0.05 % | 0.1 % Hydraulic Oil 1.0 % Gear Oil | Karl Fischer (ppm) or distillation test |
| Flash Point ºC DIN 51794 or ASTM D 92 | ± 15 % | ± 20 % | Flash Point |
| Density 15 ºC ($g/cm^3$), DIN 51757 | | < 2 % | Direct measurements by Density/Specific Gravity Meter or Concentration Meter |
| Foam (ml) DIN 51566 or ASTM D 892 | No Foam | No Foam | Foaming Tendency |
| Air Entrainment (min. with 50 ºC), DIN 51381 | < 5 min. | < 8 min. | Foaming Tendency |
| ***The mentioned rejection limits are for guidance only, as a final judgment of the oil also will be based on their reciprocally relationship.*** | | | |

# Wear Metals Warning Limits

| Element | Warning Limits | Remarks |
|---|---|---|
| Iron (FE) | > 25 ppm, Hydraulic systems<br>> 50 ppm Gear Boxes | Indicate worn crankshafts, valves, cylinder liners, bearings |
| Chromium (Cr) | > 5 ppm | Indicates worn piston rings, bearings or contamination by antifreeze |
| Copper (Cu) | > 20 ppm | Indicate worn bearings and bushings |
| TIN (Sn) | > 10 ppm | Indicate worn bearings and bushings |
| Aluminum (Al) | > 20 ppm<br>(> 80 ppm Alum. Block Engine) | Indicate worn piston or engine block |
| Lead (Pb) | > 20 ppm | Indicate worn bearing. Where leaded gasoline used, results are meaningless. |
| Boron (B) | > 20 ppm | Indicate antifreeze leak. Some engine oils contain a boron dispersant additive. |
| Silicone (Si) | > 20 ppm | Indicate presence of dust or sand. May also due to high level of silicone anti-foam. |
| Magnesium (Mg), Calcium (Ca), Barium (Ba), Sodium (Na), Phosphorus (P), Zinc (Zn) | | These elements may be part of the additive package. They remain in the oil and do not deplete. |

# Wear metal most common sources

| Metal | Centrifugal Pumps and Compressors | Reciprocating Pumps and Compressors | Gear Pumps and Screw Compressors | Gear Boxes | Electric Motors | Diesel and Gasoline Engines |
|---|---|---|---|---|---|---|
| Iron | Case Corrosion, Roller Elements, Roller Bearing Races, Sleeve Bearing Backing, Shafts | Case Corrosion, Cylinders and Cylinder Walls, Valves, Valve Guides, Springs, Cams, Shafts, Rods, Bearing Backing. | Case Corrosion, Screws or Gears, Roller Bearing Elements and Races, Sleeve Bearing Backing. | Case Corrosion, Gears, Roller Bearing Elements and Races. | Roller Bearing Elements and Cages. | Block Corrosion, Pistons, Cylinders and Cylinder Walls, Shafts, Cams, Valves, Valve Guides, Springs, Rods, Gear Sets. |
| Copper | Roller Bearing Cages, Sleeve Bearing Backings, Cooler Tubes, Slinger Rings | Bushings, Bearing Backings, Roller Bearing Cages, Valve Guides, Thrust Plates | Roller Bearing Cages, Some Gear Pump Gear Sets | Roller Bearing Cages, Worm Gears, Slinger rings | Roller Bearing Cages, Sleeve Bearing Backing. | Main and Rod Bearings, Bushings, and Backings, Some Cylinder Inserts, Some Engine Gear Sets. |
| Tin | Sleeve Bearings, Tubing Solder Joints | Sleeve Bearings, Tubing Solder Joints | Sleeve Bearings, Tubing Solder Joints | Sleeve Bearings, Tubing Solder Joints | Sleeve Bearings | Tubing Solder Joints, |
| Lead | With Tin: Sleeve Bearings<br>Without Tin: Sealing Compounds | With Tin: Sleeve Bearings<br>Without Tin: Sealing Compounds, Corrosion Resistant Paint | With Tin, Sleeve Bearings<br>Without Tin: Sealing Compounds, Corrosion Resistant Paint | With Tin, Sleeve Bearings<br>Without Tin: Sealing Compounds, Corrosion Resistant Paint | Sleeve Bearings | Bearings, Sealing Compounds, Leaded Gasoline. |
| Chromium | With Iron: Shaft metal | With Iron: Shaft Metal, Cams, Rods, Springs, Valves, Valve Guides | With Iron: Shafts | With Iron: Shafts | With Iron: Shafts | With Iron: Shafts, Cams, Rods, Springs, Valve, Valve Guides.<br>Without Iron: Rings |
| Nickel | With Iron: Shaft Metal | With Iron: Shaft Metal, Cams, Rods, Springs, Valves, Valve Guides | With Iron: Shaft Metal | With Iron: Shaft Metal | With Iron: Shaft Metal | With Iron, Shafts, Cams, Rods, Springs, Valve, Valve Guides. |
| Titanium | With Iron: Shaft Metal | With Iron: Shaft Metal, Cams, Rods, Springs, Valves, Valve Guides | With Iron: Shaft Metal | With Iron: Shaft Metal | With Iron: Shaft Metal | With Iron: Shafts, Cams, Rods, Springs, Valve, Valve Guides.<br>Without Iron: Turbo-Charger. |

# Wear metal most common sources

| Metal | Centrifugal Pumps and Compressors | Reciprocating Pumps and Compressors | Gear Pumps and Screw Compressors | Gear Boxes | Electric Motors | Diesel and Gasoline Engines |
|---|---|---|---|---|---|---|
| Antimony | With High Tin: Sleeve Bearing Wear | With High Tin: Sleeve Bearing Wear | With High Tin: Sleeve Bearing Wear | With High Tin: Sleeve Bearing Wear | With High Lead or Tin: Sleeve Bearing Wear | With High Lead: Main Bearing Wear |
| Zinc | With High Copper: Severe Roller Bearing Cage Wear or Slinger Ring Wear. Without Copper: Galvanize piping Corrosion, Sealing Compound | With High Copper: Severe Roller Bearing Cage Wear or Slinger Ring Wear. Without Copper: Galvanize piping Corrosion, Sealing Compound | With High Copper: Severe Roller Bearing Cage Wear or Slinger Ring Wear. Without Copper: Galvanize piping Corrosion, Sealing Compound | With High Copper: Severe Roller Bearing Cage Wear or Slinger Ring Wear. Without Copper: Galvanize piping Corrosion, Sealing Compound | Sealing Compound | With High Copper: Severe Bushing Wear With High Lead: Severe Main Bearing Wear, Possible Gear Set Wear Alone: Sealing Compound |
| Aluminum | Thrust Collars and Rings. | Thrust Collars and Rings, Shims and Spacers | Sleeve Bearing Overlay | Case Corrosion | Seldom Seen | Pistons, Block Corrosion, Sealing Compounds |
| Silver | Seldom Seen | Seldom Seen | Seldom Seen | Seldom Seen | Seldom Seen | EMD Bearings |

# Agenda

Oil Analysis Program

Sampling

Recommended Analysis

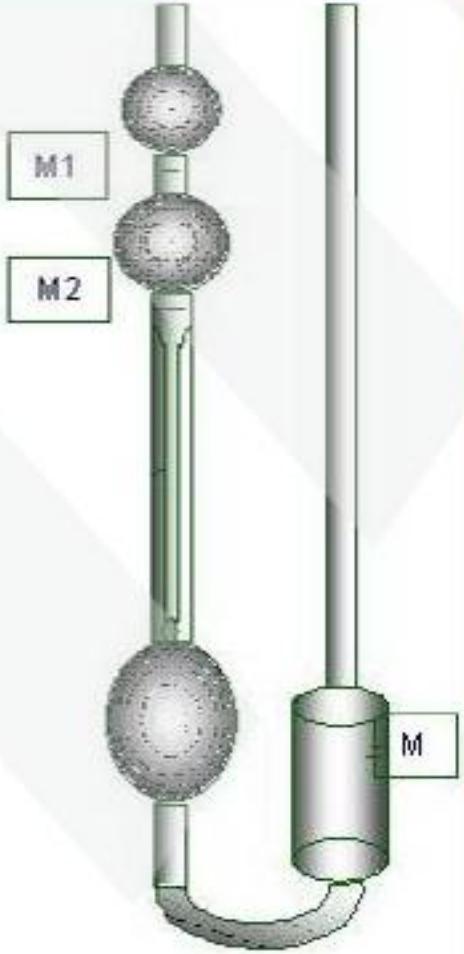
Techniques

# Visual control

- Visible Contaminants
- Free water
- Traces of other fluids
- Cloudiness


**1 ppm = 1lt on 1.000.000 lts  or 1lt on swimming pool of 10x50x2 m**

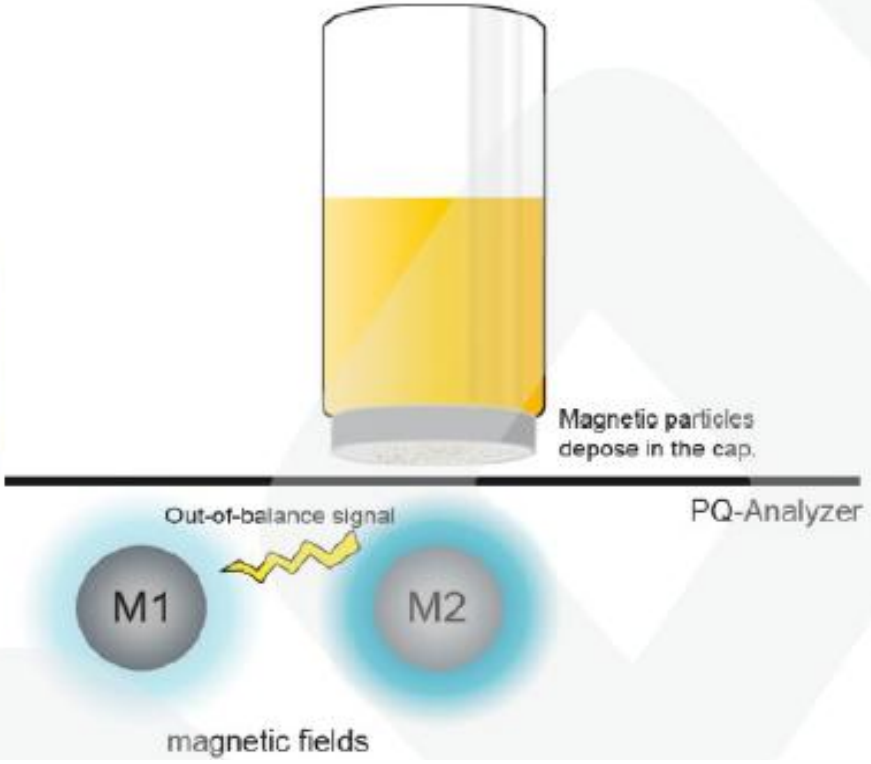
# Viscosity, ISO 3104




Kinematic viscosity

Dynamic viscosity

# PQ-Index

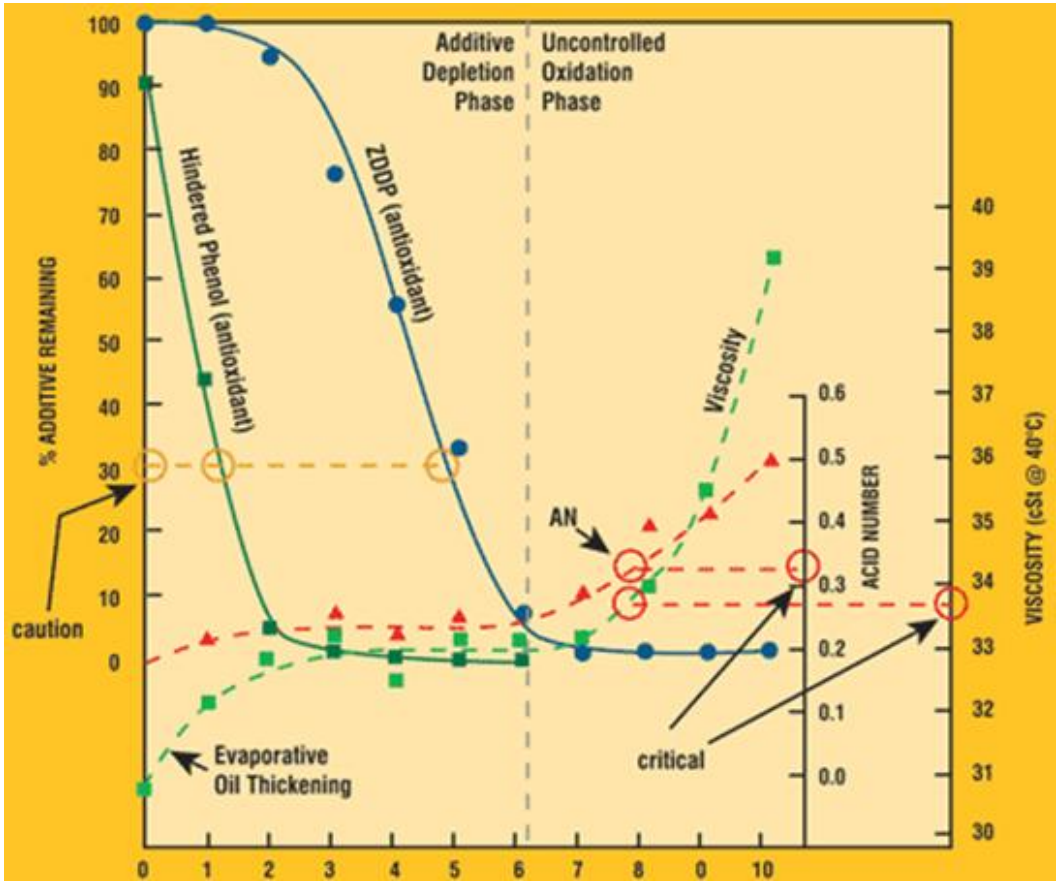




Measurement of the total ferrous metal content of an oil.
Oil samples are subjected to a strong magnetic field
The PQ Index picks up all sizes of ferrous particles, not just up to 8 - 10 microns.

# Acid Number (AN) – Neutralization Number (NZ)

**Acid Number** (or "neutralization number" or "acid value" or "acidity") is the mass of potassium hydroxide (KOH) in milligrams that is required to neutralize one gram of chemical substance

Test shows oil oxidation or contamination degree



# Ferrography

- Provides early detection of abnormal wear
- Analyzes the debris in lubricant systems
  - Size (in a very wide range: 0,1 to 500 microns)
  - Shape
  - Color
  - Quantity
  - Identify which component is wearing, it’ s degree and causes

# Ferrography

**DR direct reading Ferro graph** measures quantitatively the concentration of ferrous particles in a lub or hidr oil.
Precipitates particles onto bottom of a glass subject to a strong magnetic field.
Light passing through the glass is reduced in relation to the number of particles deposited
**Analytical Ferro graph** prepares a fixed slide of wear parts for microscopic examination and photographic examination. A wash fluid which evaporates is used to eliminate all oil residues from the glass, particles remain attached to the glass and ready for microscopic examination
The microscope **(Ferro scope)** is used then to distinguish: size, shape, texture and composition of metallic and nonmetallic parts, key component for proper diagnostic

Figure 1: Direct Reading Ferrograph

Figure 2 Ferrogram Maker

Figure 3 Ferroscope

# Examples of a Ferro scope analysis

- Cutting wear due to metal to metal contact
- Gear wear
- Bearing wear
- Severe sliding wear > 15 microns

- Spherical particles can be produced in fatigue cracks in rolling spherical bearings (around 5 microns size) as well as due to welding or grinding processes (frequently > 10 microns size)

Figure 4 - Cutting Wear

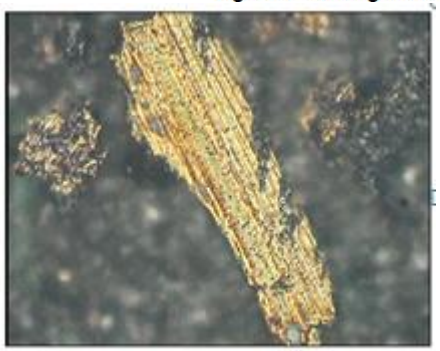


Figure 6 Severe Sliding

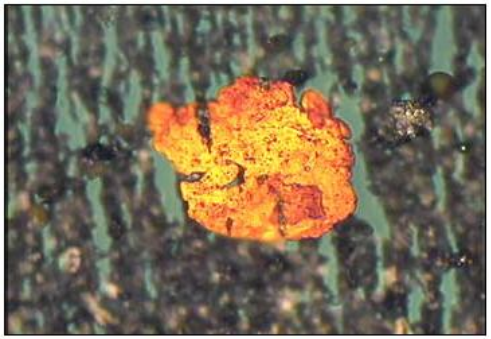


Figure 7 Bearing Wear

Figure 8 Gear Wear

Figure 5 Fatigue Spalling Eminent

# Spectrographic analysis methods

Popular due to speed and cost are

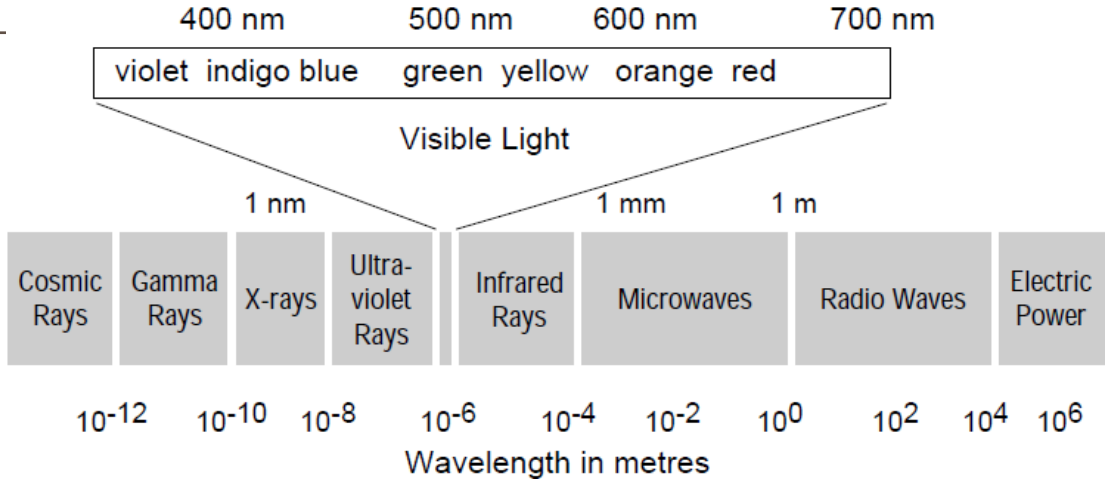
- atomic emission spectroscopy (AES)
- inductively coupled plasma emission spectrometer (ICP)

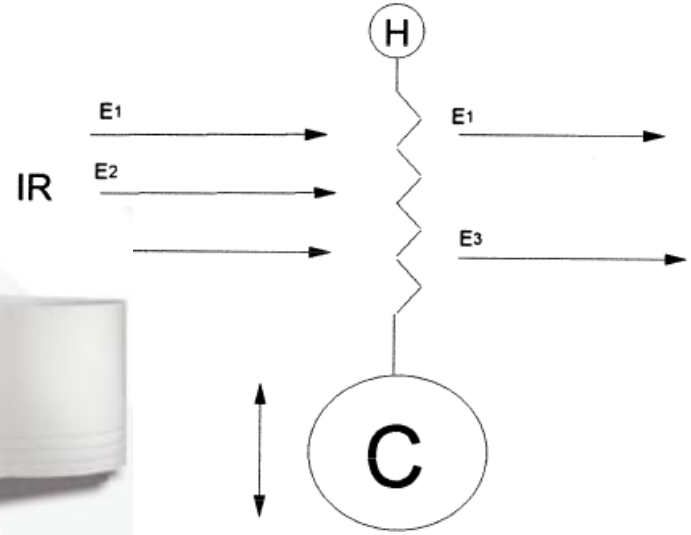
Both use the detection of light emitted by the elements

**Limitations for particle size > 8-10 microns**

More than 30 elements can be identified, wear, additive metals and contaminants

- Fe, Cr, Cu, Pb, Sn, Mo, Ni, Al, Zn, Ag, Be
- Si, Na, K, Li
- P, S, Ca, Mg, B, Ba, Mo, Co, Cd




ICP - OES

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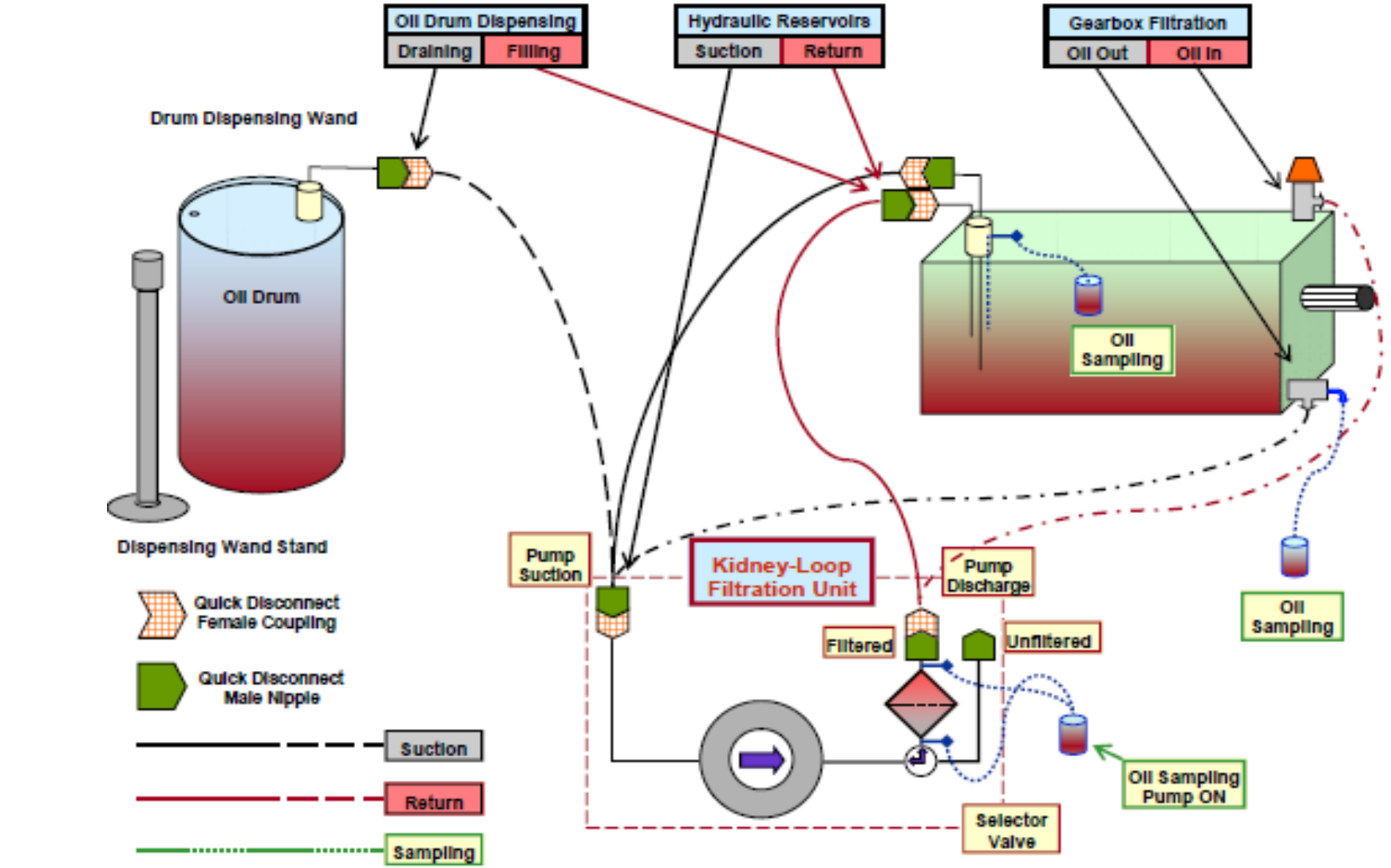
# Sampling location



# On site oil analyser

# On site oil analyser

- **Wear Metals** – pistons, rings, cylinders, bearings, gears, and more.
- **Silicon** – Time to check the PCV (Positive Crankcase Ventilation) filter, change the air filter, or check the sealant.
- **Oxidation** – Correlates to sludge and varnish formation.
- **Coolant Leaks** – Major cause of engine failure.
- **Fuel Dilution** – Reduces viscosity and ruins engines.
- **Viscosity** – Oil's ability to flow and lubricate moving parts.
- **Water** – Condensation due to a cold running system or coolant leak.
- **Nitration** –Corrosive combustion by-product.
- **Soot** – (Diesel Only) By-product that impacts performance and is an indicator of air/fuel ratio.
- **Total Base Number (TBN)** – Oil alkaline reserve (additive) used to neutralize
- combustion acids helping to maintain oil life.
- **Particle Count -** determines fluid and system cleanliness. (Micro Lab only)

# On site oil analyser

**Spectro Lab**: 17’ X 22’ (374 Sqf) and $324,000 for instruments. (Des not include the cost of space, trained lab technician(s) to split samples, run them on different instruments, and to collect data, analyze and write the diagnostic reports.)

24” X 24” (4 Sqf)
Less than $100,000

- No Trained Technicians
- No splitting of samples
- No large space to rent
- No human error
- No misinterpretation of analysis
- Results in minutes, not hours, days or weeks.

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