BEST PRACTICES FOR AN EFFECTIVE OIL ANALYSIS PROGRAM

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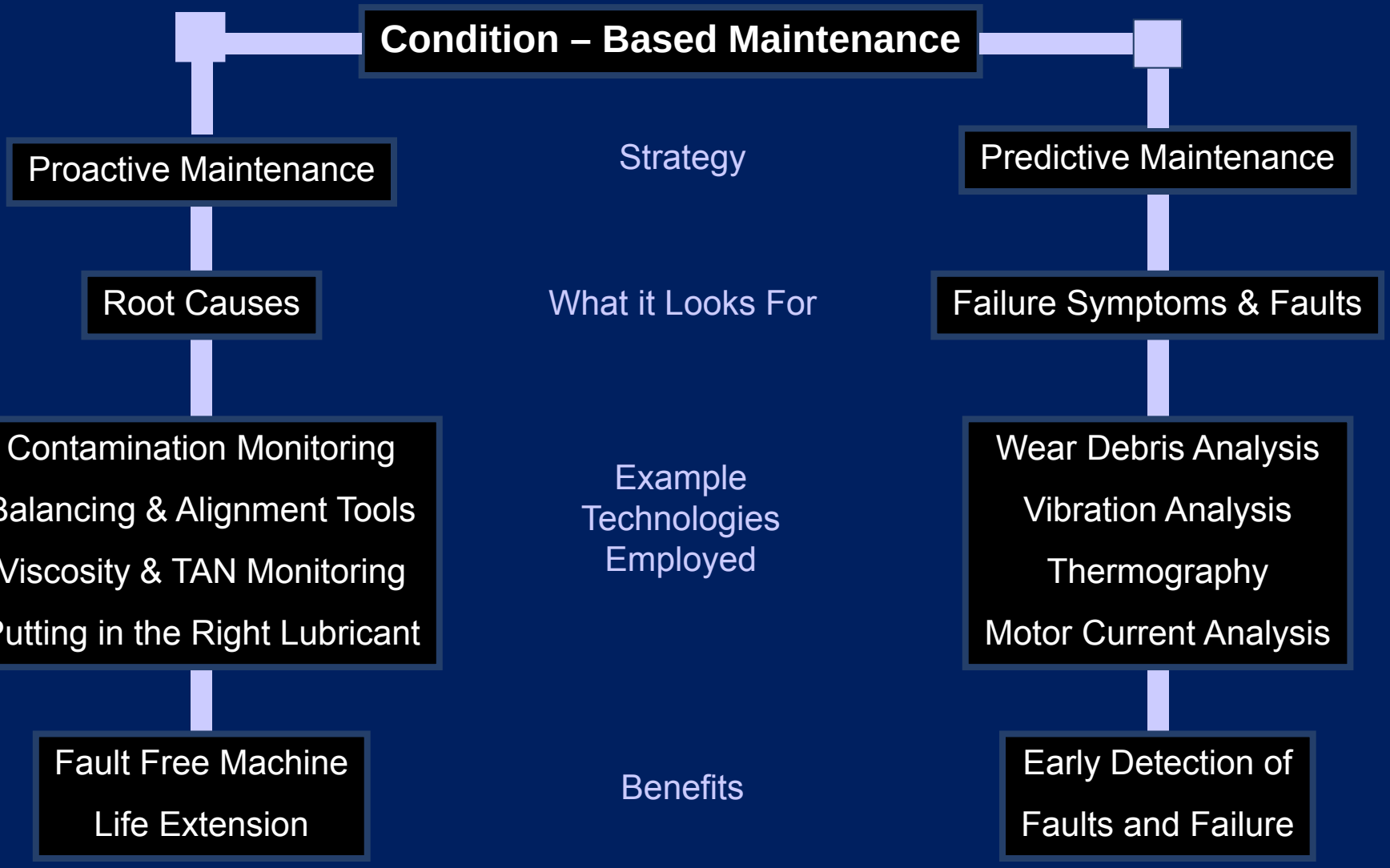
MAINTENANCE PROGRAMS

EQUIPMENT MAINTENANCE STRATEGIES

Maintenance Strategy	Activity	Strategy Action
CM Reactive Maintenance (Breakdown)	Equipment Failure Reactive Run to failure	Repair or replace upon failure Firefighting / Breakdown maintenance
PM Preventive Maintenance	Time Based Discard or restoration	Repair or replace on time cycles
PdM Predictive Maintenance	Condition Based On-condition maintenance	▪ Employs condition monitoring technologies to detect early stage failures ▪ Replacement or repairs are scheduled by equipment condition
PaM Proactive Maintenance	Experienced Based Redesign and control conditions	▪ Fix once and for all ▪ Condition monitoring detects the presence of root causes of failure
Redundancy	Failure Diversion	Deploy active shared load or standby redundant systems

MODERN MAINTENANCE STRATEGIES



Courtesy: Trico

CONDITION MONITORING TOOLS

- **Thermal analysis**
- **Ultrasonic analysis**
- **Vibration analysis**
- **OIL ANALYSIS**

EFFECTIVENESS OF CONDITION MONITORING TECHNIQUES

Condition	Oil Analysis	Wear Debris Analysis	Vibration Analysis	Thermography
Contamination	Excellent	Good	Poor	Poor
Wear	Excellent	Excellent	Fair	Poor
Misalignment	Poor	Fair	Excellent	Good
Heat Problems	Fair	Fair	Poor	Excellent
Gear/Bearing Defects	Poor	Poor	Excellent	Poor
Electrical Breakers	Can't	Can't	Can't	Excellent
Air Flow	Can't	Can't	Excellent	Excellent
Cavitation	Poor	Poor	Excellent	Poor

WHAT DOES OIL ANALYSIS TELL US?

- **Determine condition of the oil**
- **Determine level and type contaminants in the oil**
- **Determine condition of the equipment**

DEVELOPING AN EFFECTIVE OIL ANALYSIS PROGRAM

ESTABLISHING OBJECTIVES

- Where are you now?
- Where do you want to go?
- How do you get there?

IDENTIFY OBJECTIVES & STRATEGY

- Improve asset reliability
- Identify and eliminate repetitive problems
- Reduce unscheduled maintenance
- Obtain maximum use of lubricants in service
- Reduce maintenance & lubrication costs
- Achieve fault free component life extension
- Utilize proactive maintenance flanked by predictive maintenance technology
- Achieve Condition Based Maintenance (CBM)

PROGRAM IMPLEMENTATION STEPS

- Identify objectives & strategy
- Develop equipment list of units to be sampled
- Determine sampling strategy
- Select appropriate test packages
- Allocate personnel
- Obtain vendor support
- Training
- Tracking and documenting cost benefit

EQUIPMENT INFORMATION

Providing the required equipment information and keeping it up to date is essential to the success of your oil analysis program.

The following equipment information is important

- **Equipment Identification**
- **Component Type**
- **Component Make and Model**
- **Lubricant Brand and Grade**
- **Oil Reservoir Capacity**
- **Was Oil Change**
- **Time on oil & machine**

Proper Equipment Information will ensure:

- **Quick turn-around on sample diagnosis**
- **Proper QC on laboratory testing**
- **Meaningful and detailed recommendations**

Courtesy: ALS

MASTER EQUIPMENT LIST

Customer: Location: Email:

Industry Application: Completed by: Phone:

Unit No.	Component Type Description	Make	Model	Fluid Brand	Fluid Type	Fluid Grade SAE or ISO	Filtered? Circle	Filter Type	Micron Rating	Sump Capacity	Sampling Frequency
							Yes No			Gal	
							Yes No			Gal	
							Yes No			Gal	
							Yes No			Gal	
							Yes No			Gal	
							Yes No			Gal	
							Yes No			Gal	
							Yes No			Gal	
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							Yes No			Gal	
							Yes No			Gal	

Company:	**Comp. Descr.:** GEARBOX	**Fuel Type:**	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
	Make: LUFKIN	**Oil Brand:**	
	Model:	**Oil Type:**	
Customer No: 20408761	**Equip. Make:**	**Fluid Grade:** 220	**End User:**
Unit No: CDUH-118	**Equip. Model:**	**Ser.No:** G81573M-399417	**End Loc:**

			WEAR METALS (ppm)										ADDITIVES							
Lab No / Condition	Date Taken / Tested	Time on Oil / on_Unit	IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
61102	08/07/08	_____	421	2	16	5	0	2	0	0	0	0	0	1	9	0	206	5	0	6
Abnormal	08/20/08		A																	
79961	10/02/07	_____	253	1	8	1	0	2	0	0	0	0	0	0	7	0	178	4	0	4
Normal	10/14/07																			
74262	08/26/05	_____	162	2	18	6	0	2	0	0	0	0	1	0	10	0	211	7	0	5
Normal	09/02/05																			

Lab No	CONTAMINATION								PHYSICAL PROPERTIES			
	Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	Visc100	Visc40	Oxidation	TAN
61102	2	8	0	0	N/A	N/A	N/A	0.2	N/A	212.16	N/A	0.35
79961	2	7	0	0	N/A	N/A	N/A	0.1	N/A	211.76	N/A	0.75
74262	2	10	1	0	N/A	N/A	N/A	0.1	N/A	203.78	N/A	0.56

Lab No	ADDITIONAL
	W-KF
61102	0.62% A
79961	<0.05%
74262	<0.05%

Lab No	Brand	Product	Grade	Recommendation

GEAR BOX STATISTICAL EVALUATION

Gearbox	250

PPM

Iron

Flagging

Point

Courtesy: Staveley

GEAR BOX STATISTICAL EVALUATION

Gearbox	250
Herringbone	98

PPM

Iron

Flagging

Point

Courtesy: Staveley

GEAR BOX STATISTICAL EVALUATION

Gearbox	250
Herringbone	98
Philadelphia	116

PPM Iron Flagging Point

Courtesy: Staveley

GEAR BOX STATISTICAL EVALUATION

Gearbox	250
Herringbone	98
Philadelphia	116
AGF2779	80

PPM

Iron

Flagging

Point

Courtesy: Staveley

GEAR BOX STATISTICAL EVALUATION

Gearbox	250
Herringbone	98
Philadelphia	116
AGF2779	80
150 Gal	65

PPM Iron Flagging Point

Courtesy: Staveley

GEAR BOX STATISTICAL EVALUATION

Gearbox	250
Herringbone	98
Philadelphia	116
AGF2779	80
150 Gal	65
10µm Filter	50

PPM Iron Flagging Point

Courtesy: Staveley

GEAR BOX STATISTICAL EVALUATION

Gearbox	250
Herringbone	98
Philadelphia	116
AGF2779	80
150 Gal	65
10µm Filter	50

PPM Iron Flagging Point

Courtesy: Staveley

ALLOCATE PERSONNEL

- Who takes the samples
- Who receives the reports and makes maintenance decisions
- Who integrates the oil analysis data with other technologies
- Who interfaces with the lab
- Who manages the data, tracks effectiveness, provides feedback and develops cost benefit analysis

OBTAIN VENDOR SUPPORT

- Your vendors have decades of experience and staff with the expertise to assist you
- Involve your vendors
- Listen to their suggestions
- Lean on their expertise
- Obtain training from them
  - Lubrication fundamentals
  - Contamination control
  - Oil analysis
  - Coolant analysis
  - Fuel analysis
  - Metalworking fluids

TRACK PERFORMANCE & COST BENEFIT

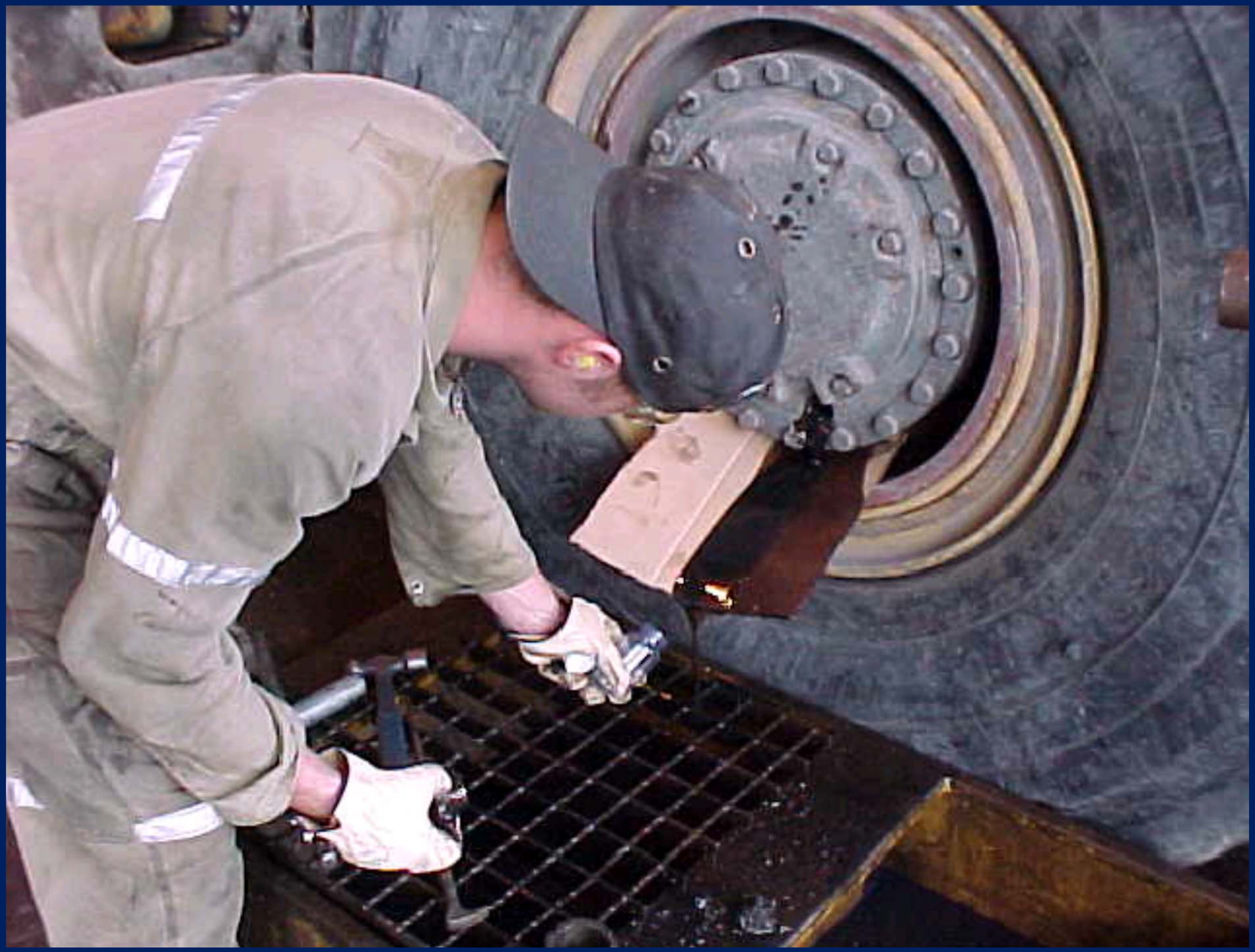
- Use oil analysis to ensure oil condition targets are being met
- Use oil analysis to track compliance with contamination control targets
- Use oil analysis data in conjunction with asset management information to evaluate cost benefits of program
- Continually review and improve program to optimize reliability goals through oil analysis

SAMPLING

FLUID SAMPLING BASICS

- Warmed up Machine
- Clean process
- Properly documented
- Send immediately to lab

good input supports good output



Courtesy:Adrian Moore WMC

SAMPLING

- **Objectives**
  - Maximize data density
  - Minimize data disturbance
  - Proper frequency
- **Sampling considerations**
  - Sampling location
  - Sampling hardware
  - Sample bottle
  - Sample procedure

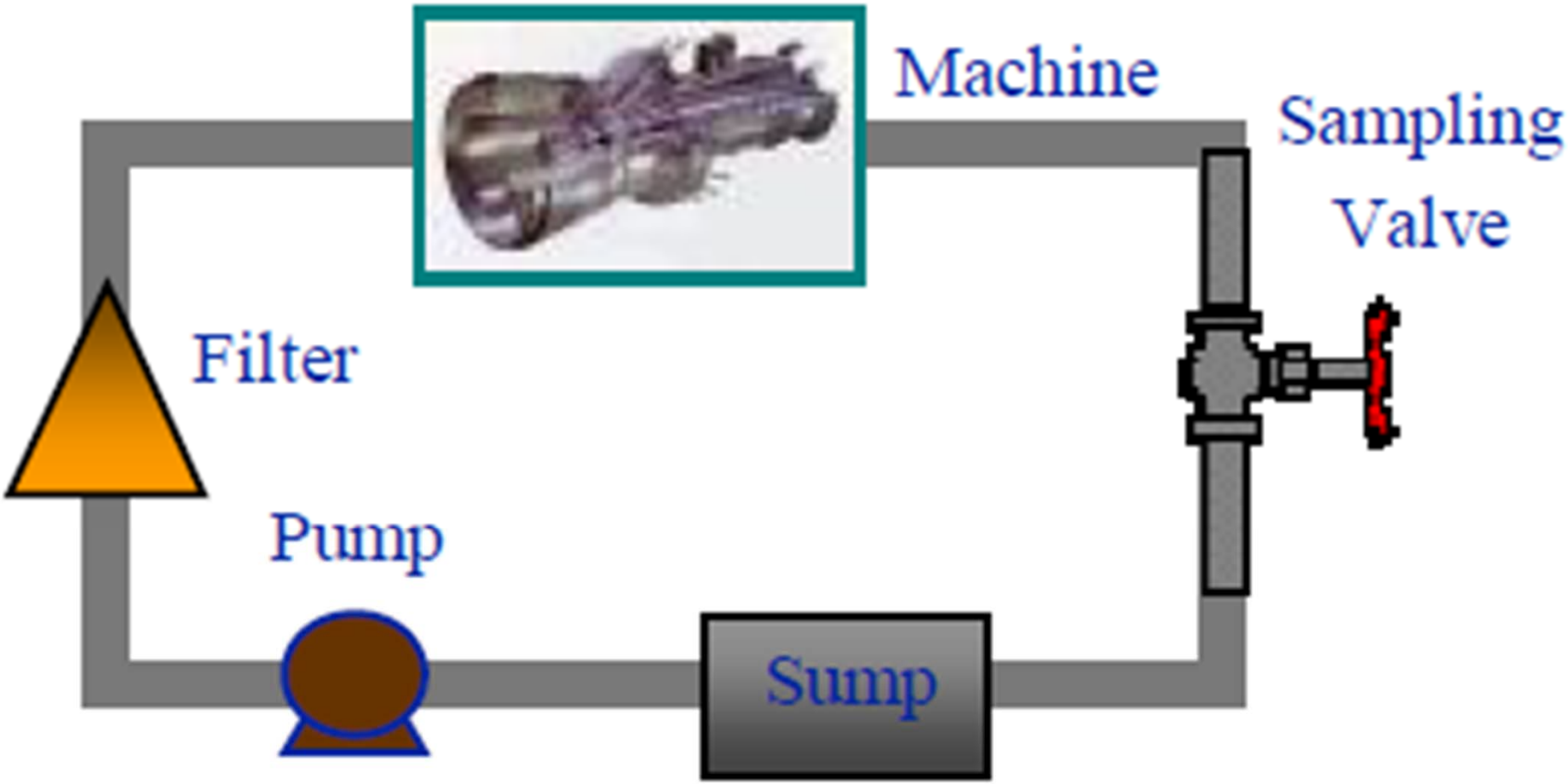
ACTIVE ZONE SAMPLING

- Sample from live fluid zones
- Sample from turbulent zones such as elbows
- Sample downstream of bearings, gears, pumps, cylinders, and actuators
- Sample machine during typical working conditions and no more than 30 minutes after shutdown
- Sample from same location each time

ACTIVE ZONE SAMPLING DON'T

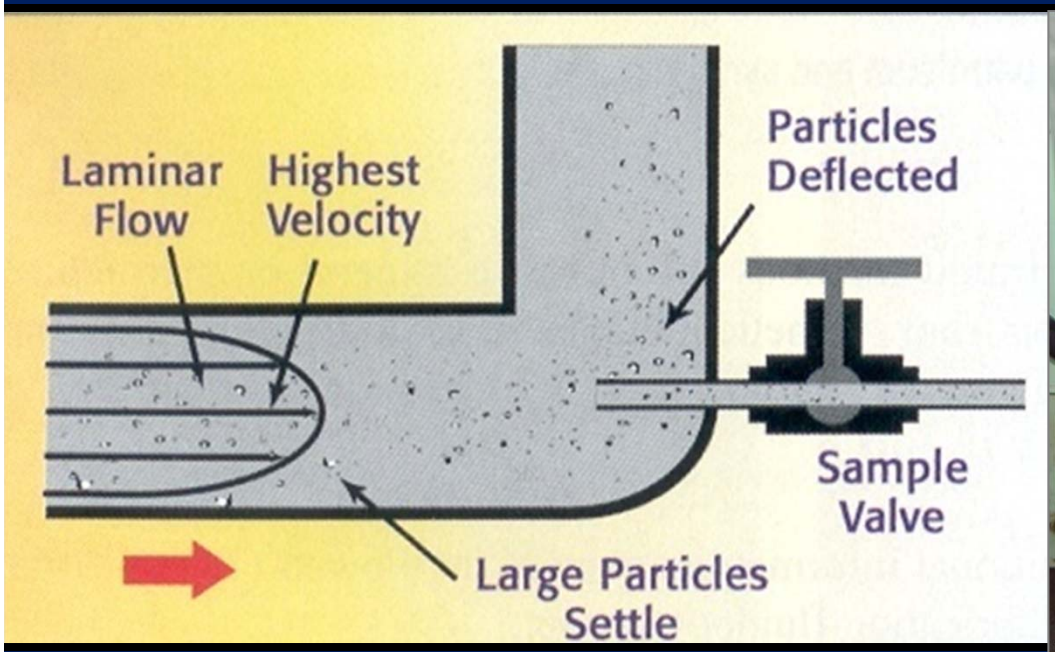
- Sample from dead pipe legs or hoses
- Sample from laminar zones
- Sample after filters or from sumps
- Sample when machine is cold or not operating

ACTIVE ZONE SAMPLING



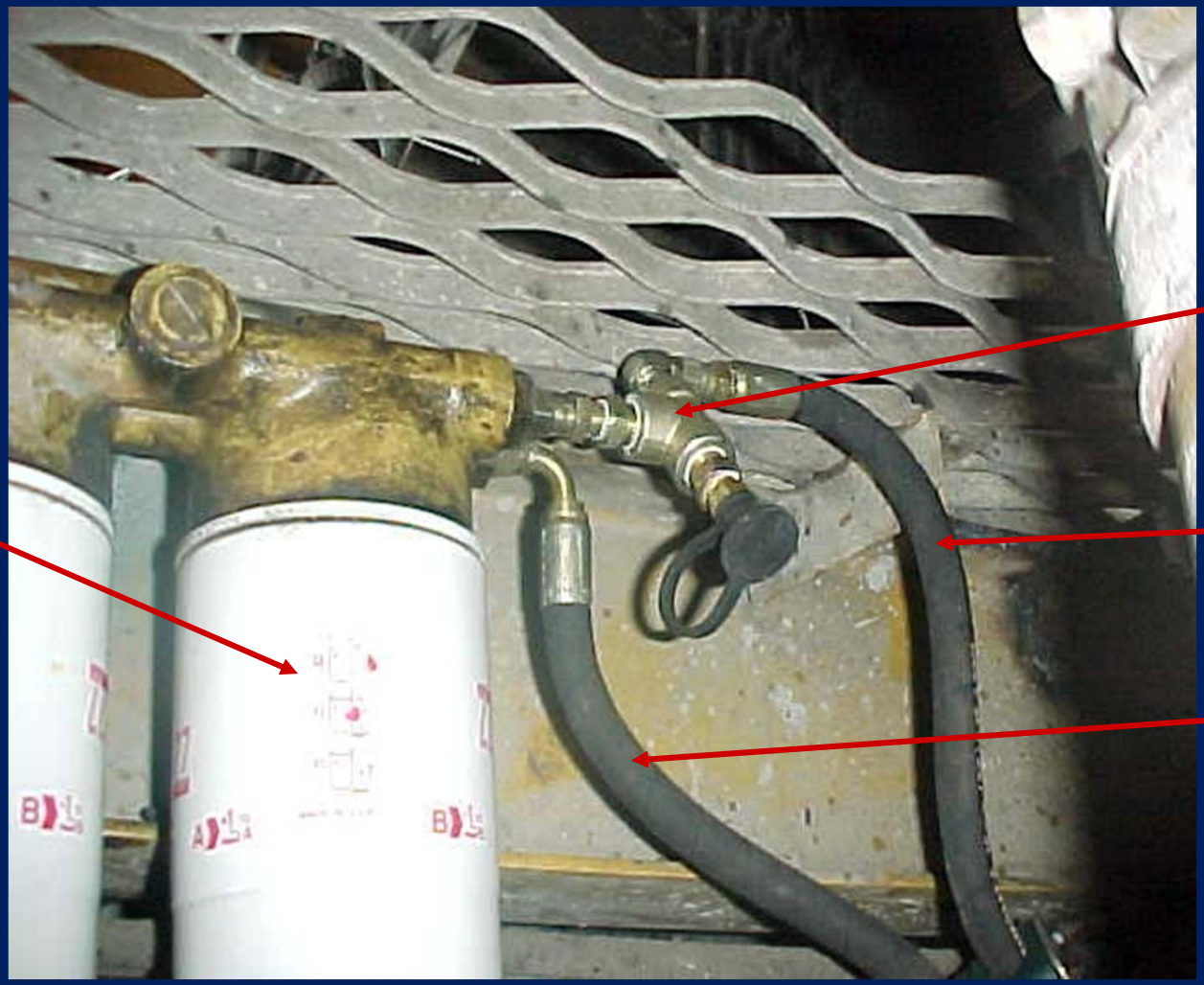
Courtesy: Spectro

ACTIVE ZONE SAMPLING



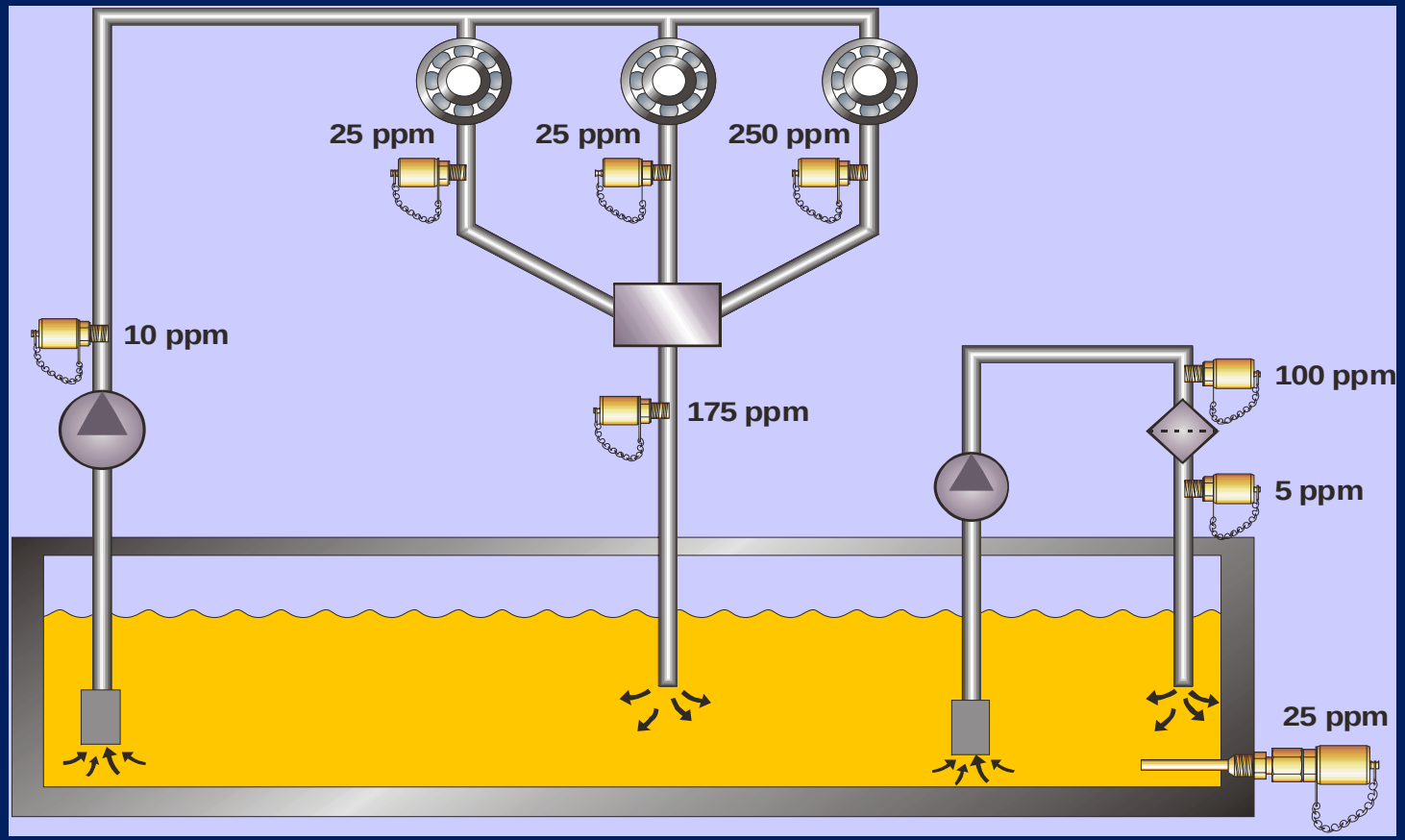
Courtesy of: Noria

WISEDA K2000E ENGINE



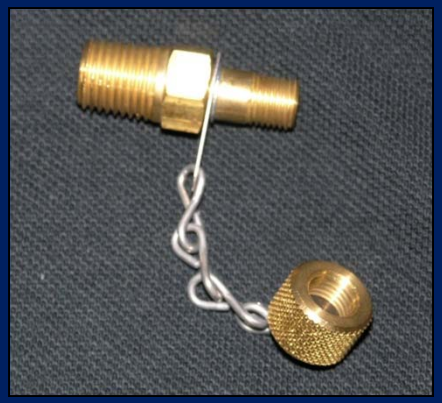
Courtesy: ALS

PRIMARY AND SECONDARY SAMPLING



Courtesy: Slater Trico

SAMPLING DEVICES



Needle valve port

Uses needle probe cap

SAMPLE VALVES

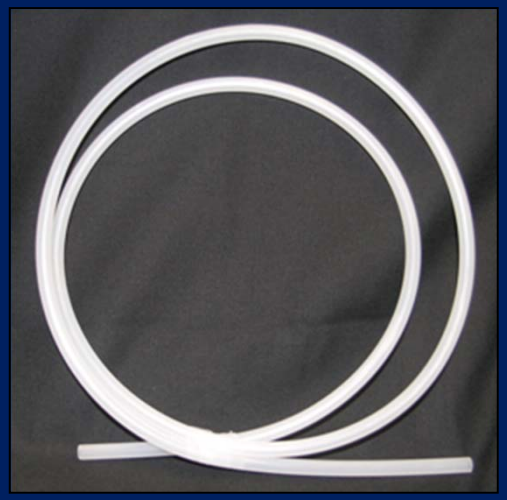
A lot of different sampling valves are available from different vendors

A simple ball valve, properly installed is usually more than adequate.

STATIC SAMPLING DEVICES

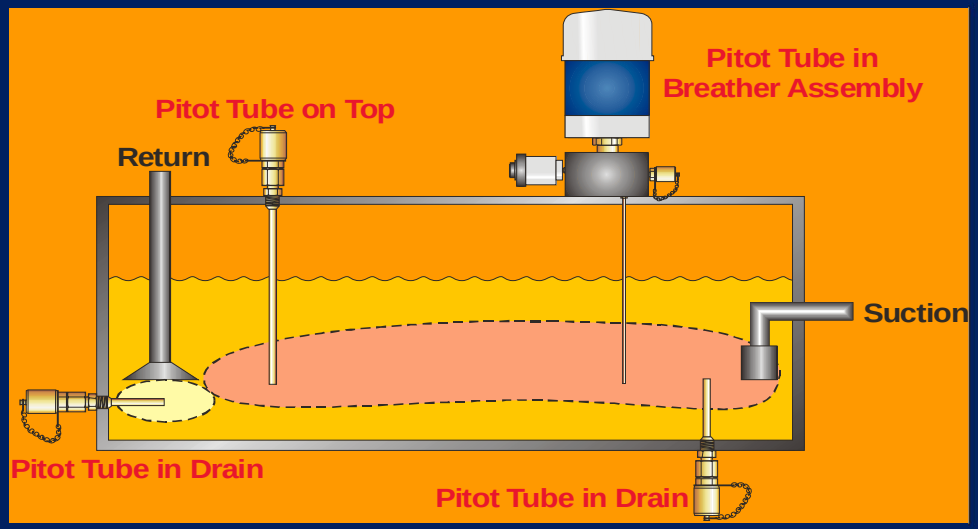
Vacuum Pump

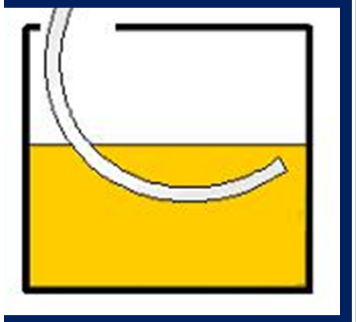
- Disposable plastic tubing

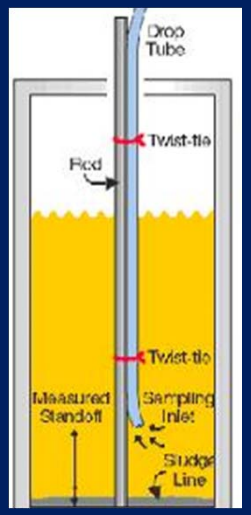


SAMPLING THROUGH DIPSTICK

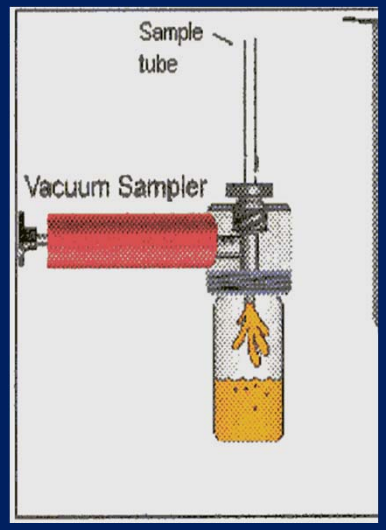
RESERVOIR SAMPLING







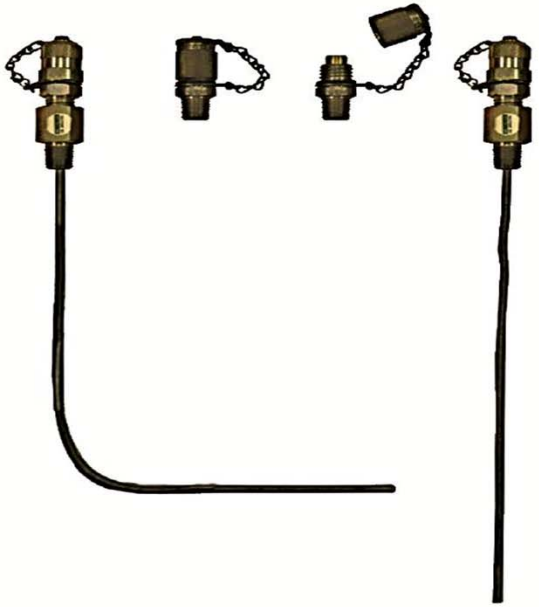
Bad Practice



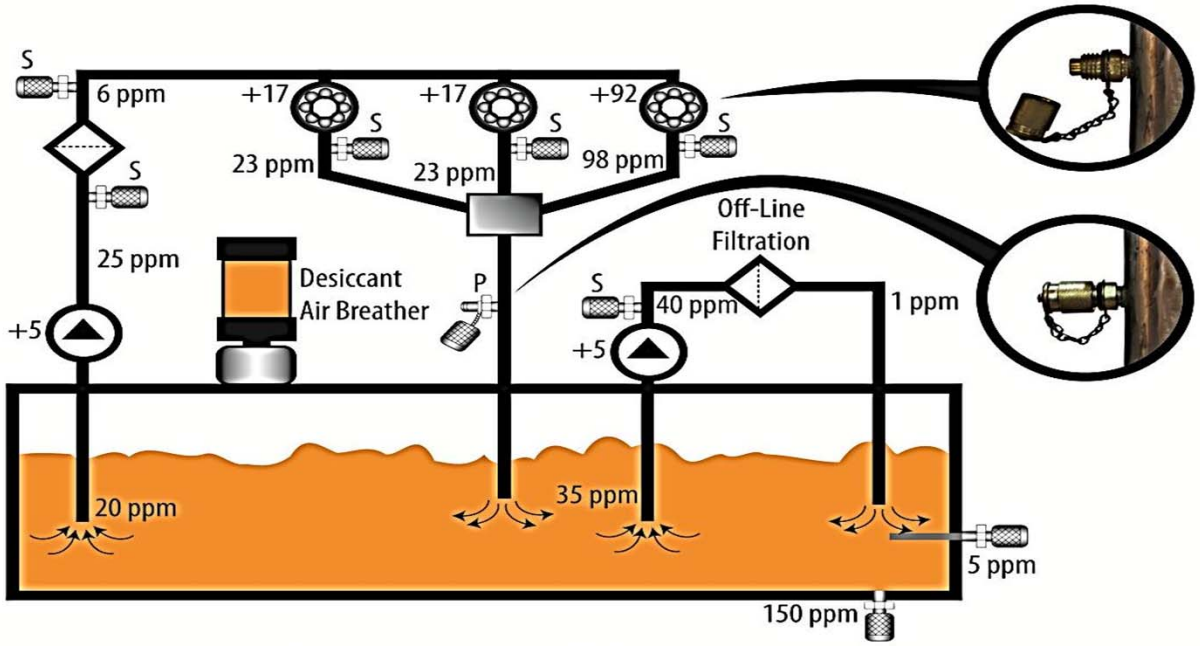
Vacuum Gun

3/8” SS thin wall tubing bent 90°to set depth of collection point in the reservoir and ¼” polyethylene tubing.
Polyethylene tubing inserted inside of 3/8”S S tubing.
After inserting polyethylene tubing snip off 1-2 inches to remove any possible debris accumulation coming from the inside of the SS tubing.
Connect sample rig to vampire pump for use.

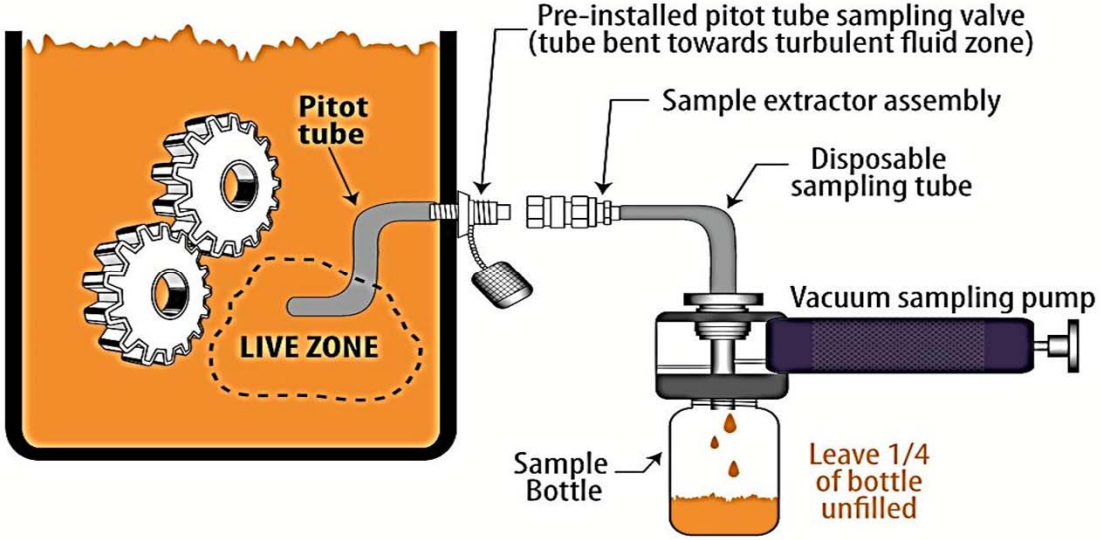
BREATHER WITH PITOT TUBE



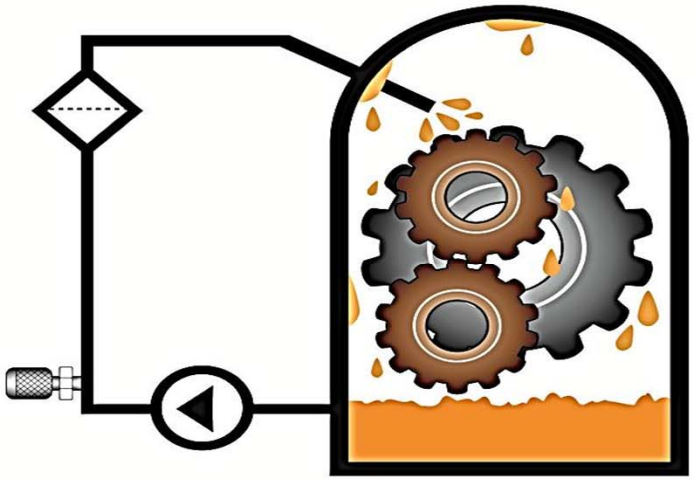
Sampling Valves



Primary "P" and Secondary "S" Sampling Ports



Static Sampling from sump, tank or reservoir

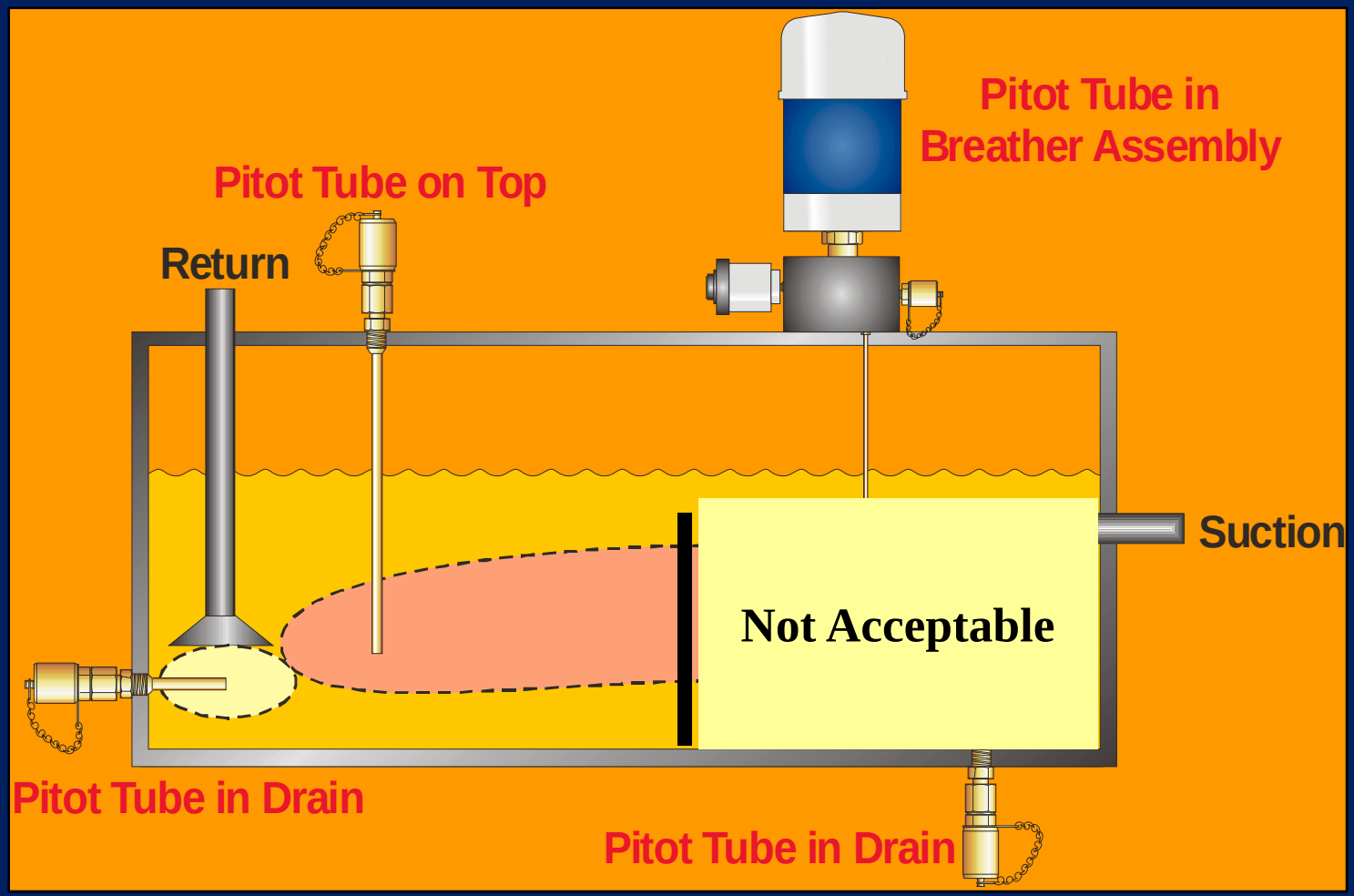


Dynamic Sampling from circulating line

PITOT TUBE SAMPLE COLLECTION

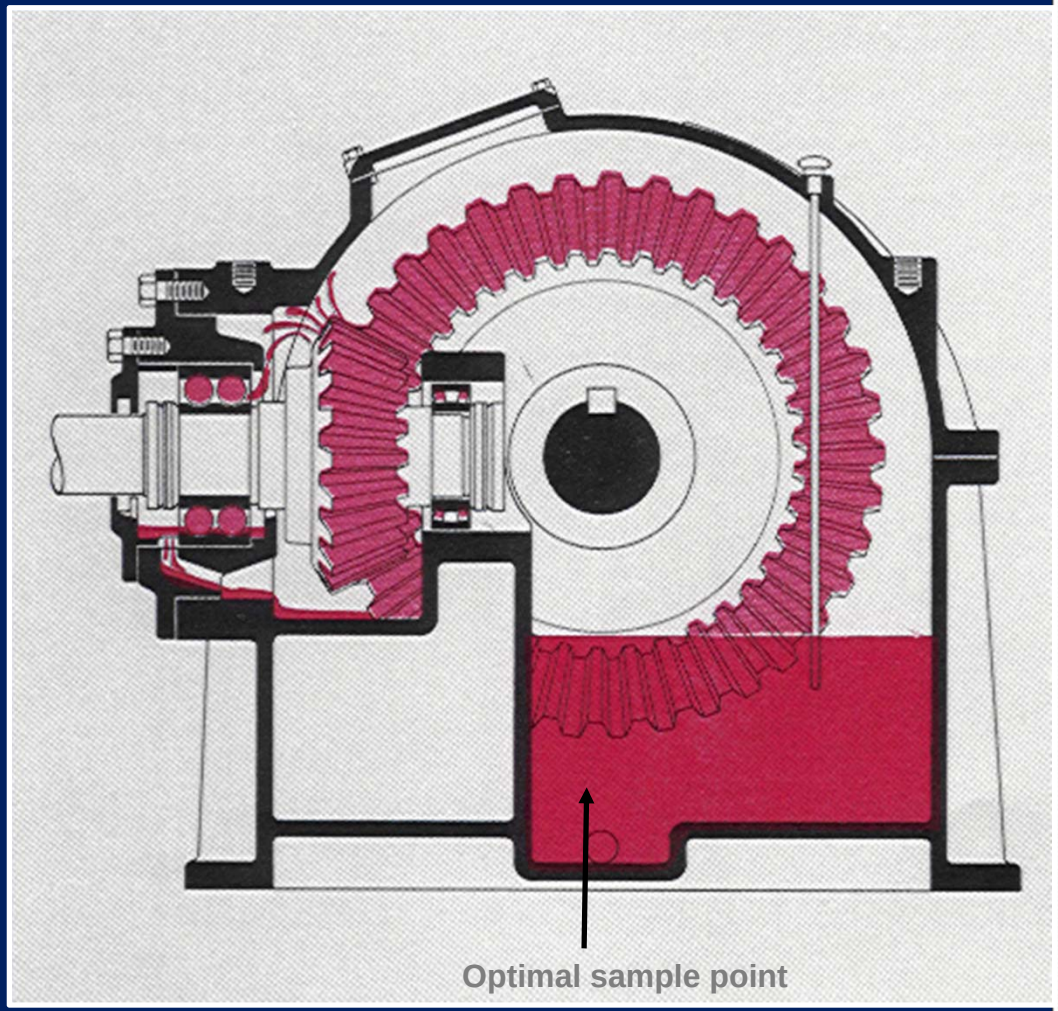
TUBE EXTENDERS (PITOT)

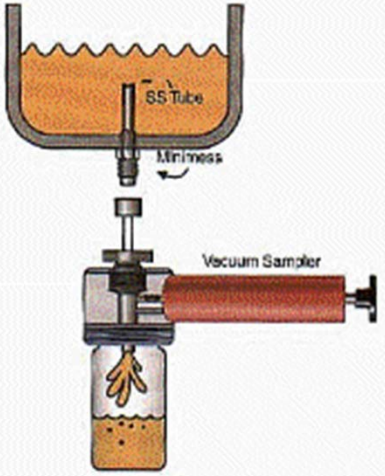
RESERVOIR SAMPLING WITH A BAFFLE

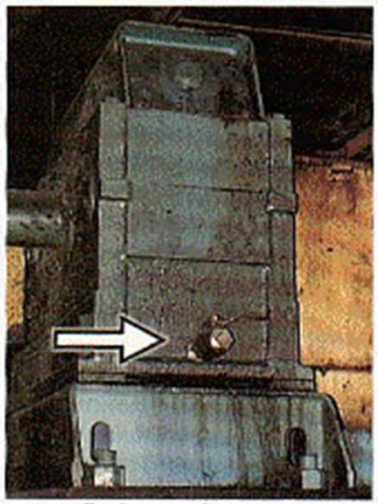


Courtesy of: Slater Trico

SPLASH LUBRICATED SYSTEM

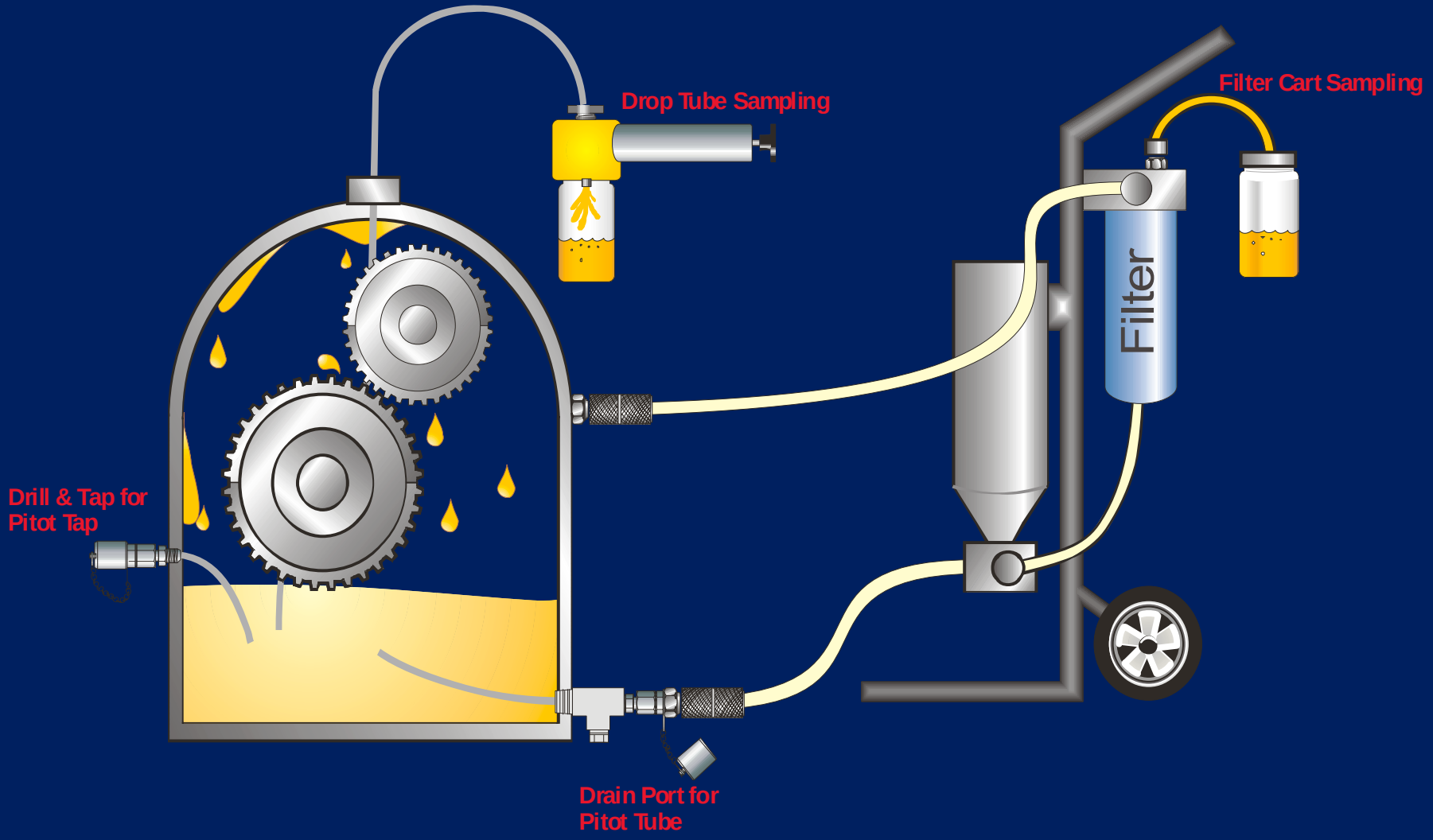




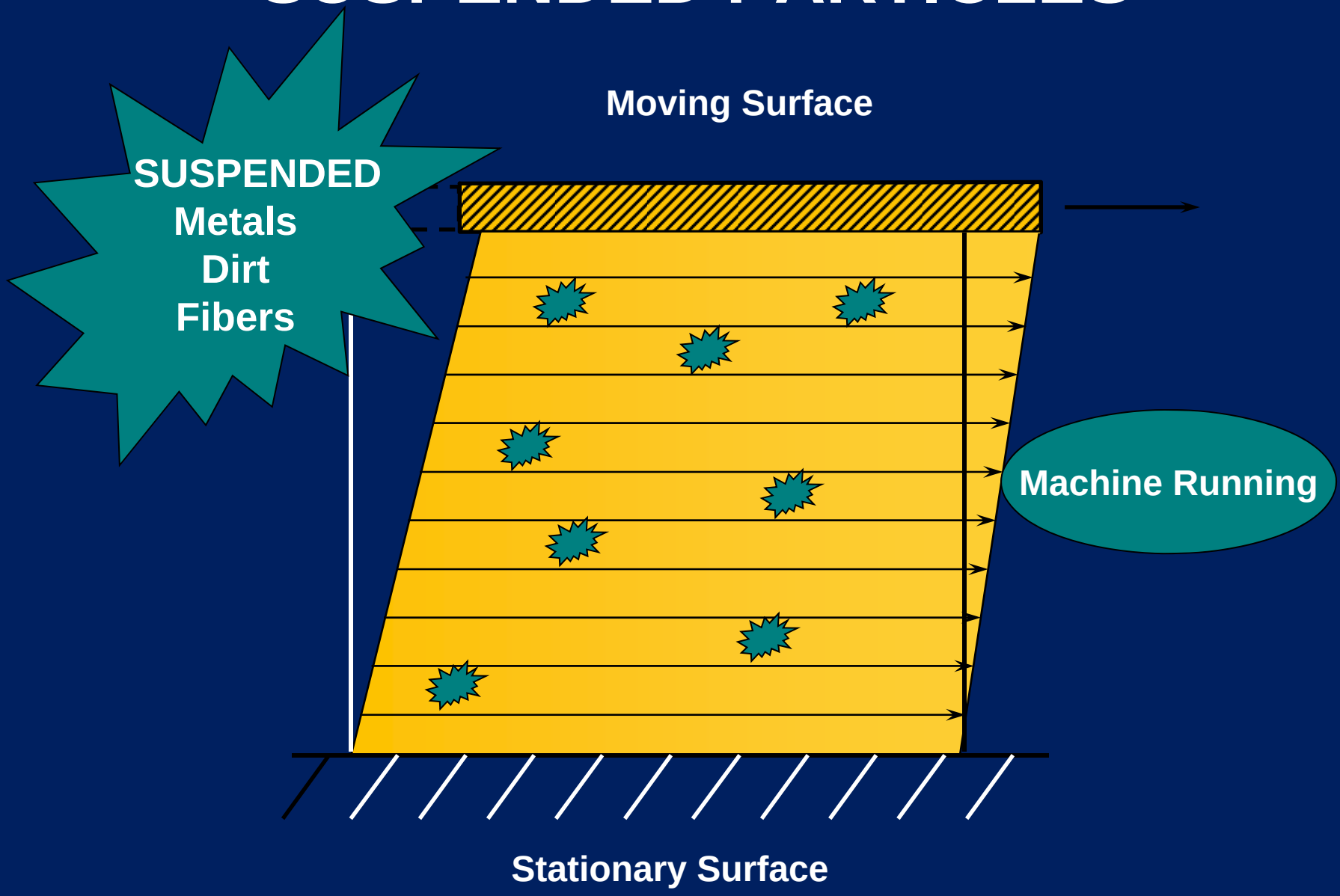


Drain port of gear case

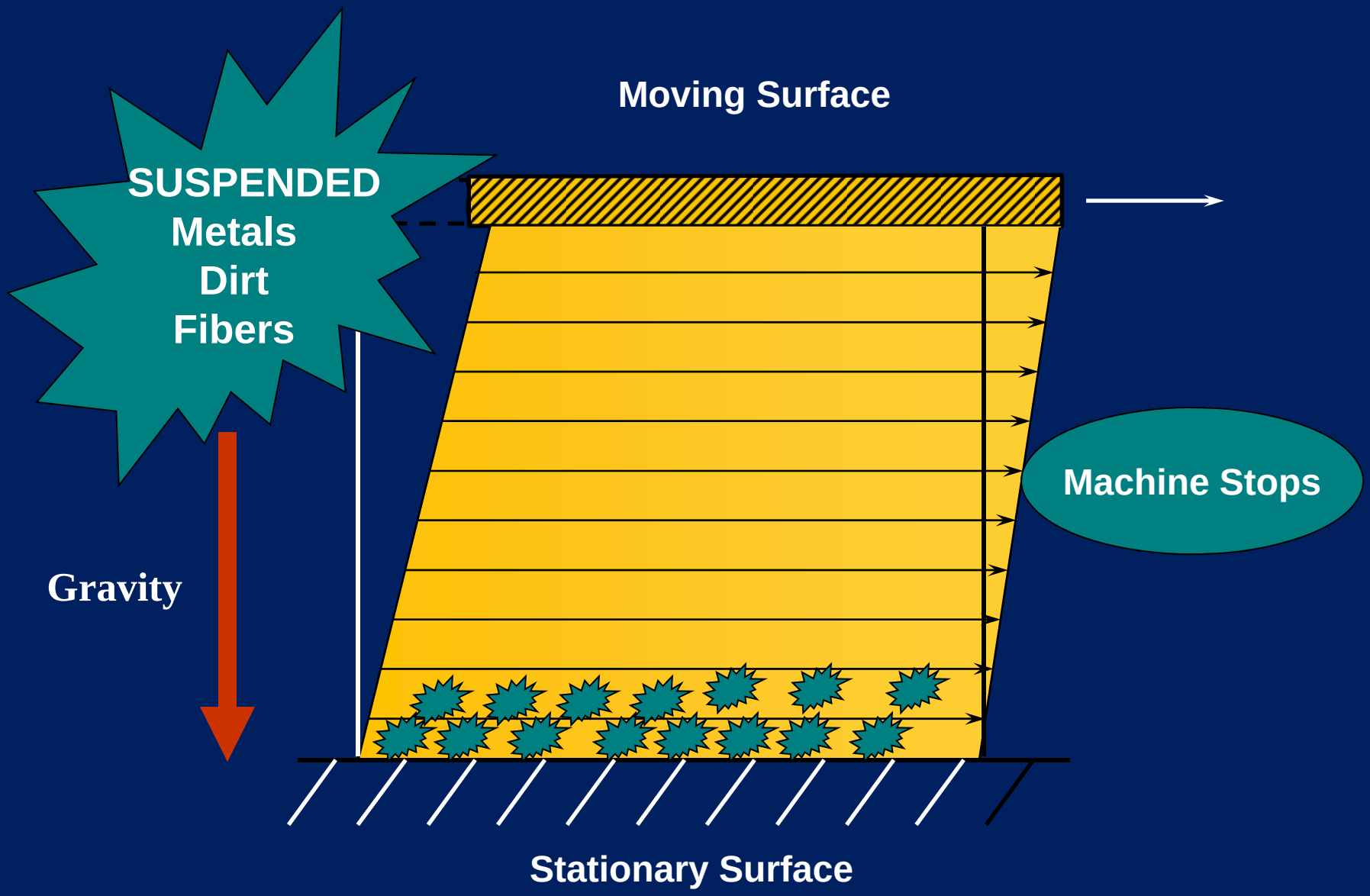
GEARBOX OTHER SAMPLING OPTIONS



SUSPENDED PARTICLES

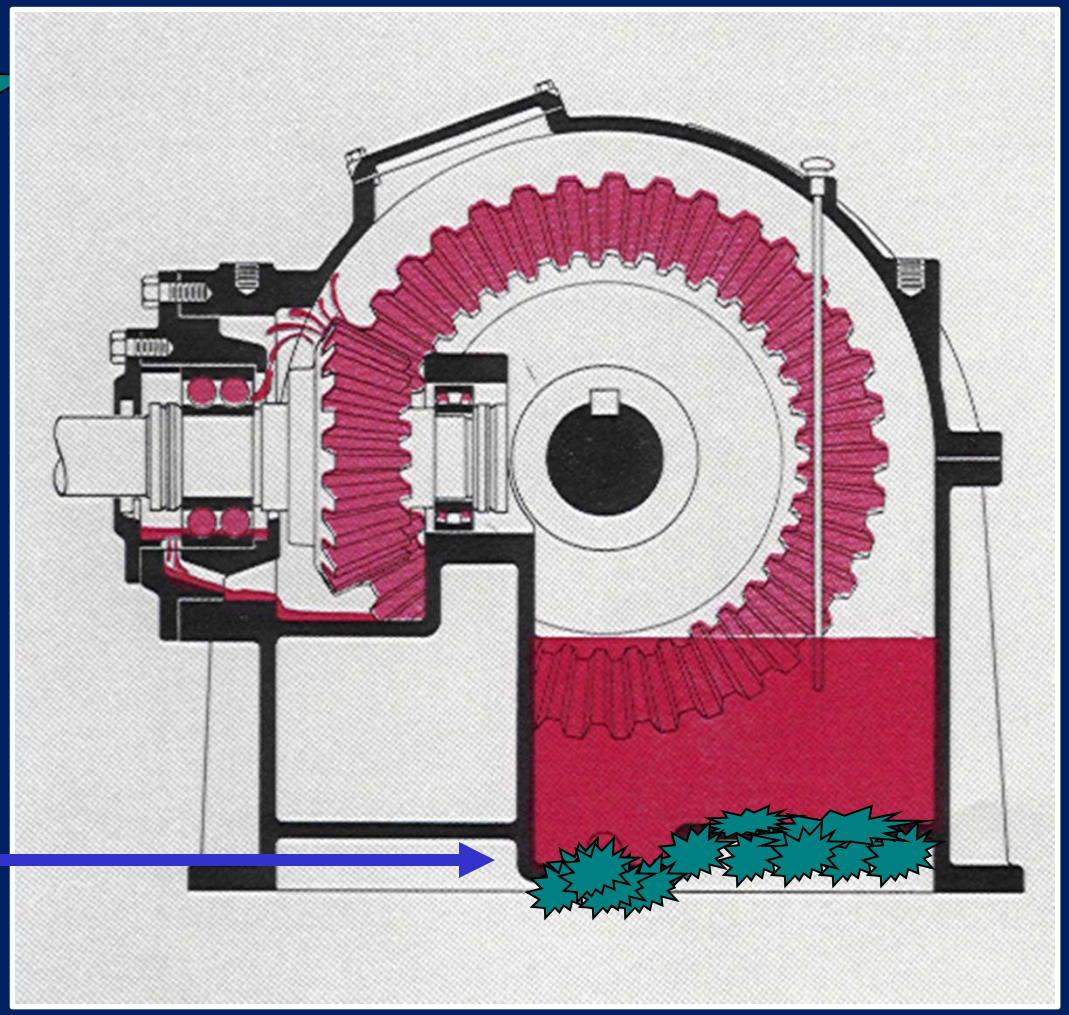


CIRCULATION STOPS



SETTLING

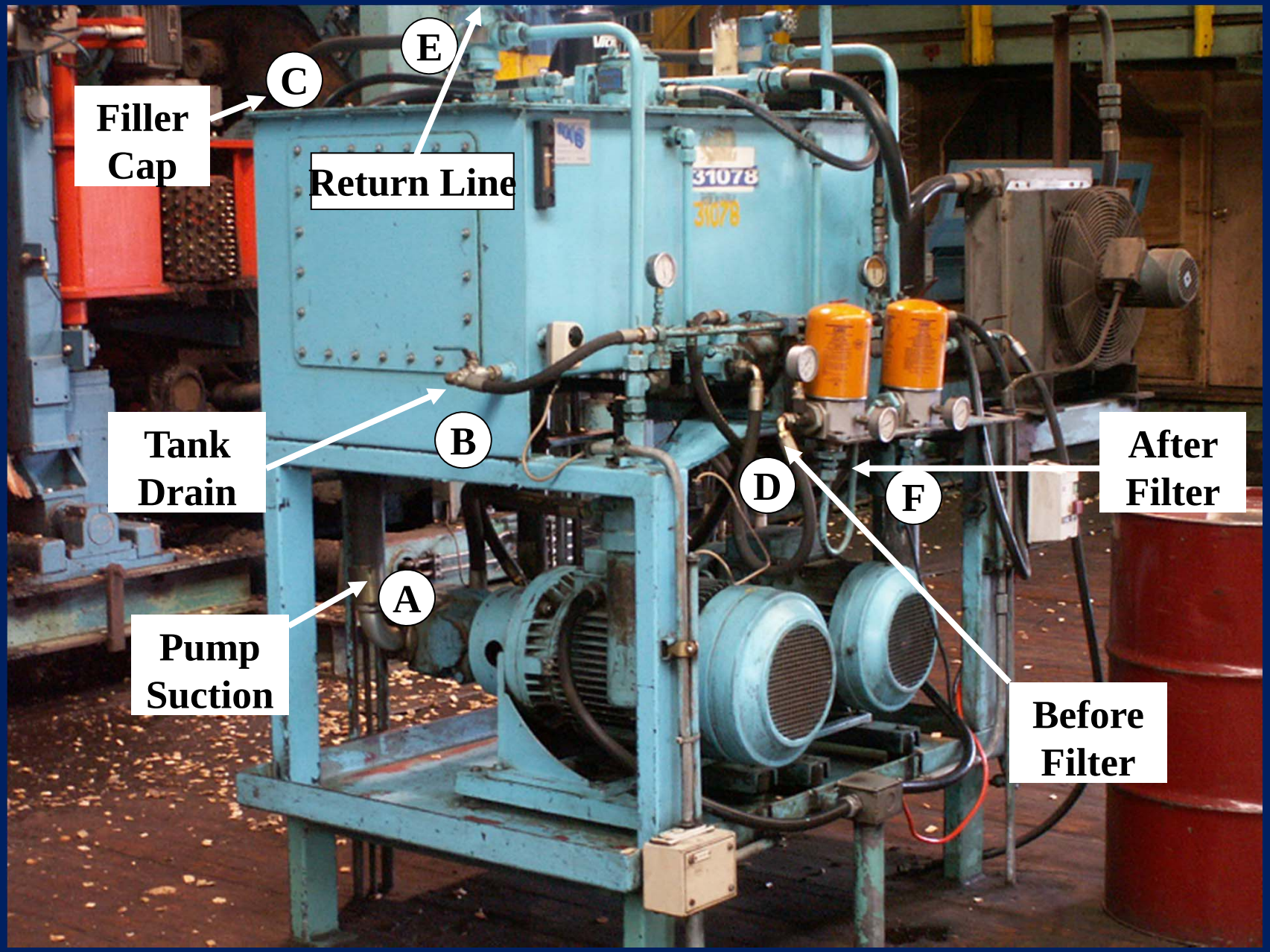
SUSPENDED Particles Turn To GUNK



SAMPLING CAUTIONS

- Using a Drop Tube:
  - Insert Tube to Center Sump Level or the Length of the Dipstick
  - Do Not Jam the Tube Against Sump Bottom (Into Sludge & Deposits)
- Using a Drain Port:
  - Allow Sufficient Flow to Remove Bottom Sediment & Water.
- Drain at least 25-50% before taking sample

Courtesy: ALS



BOTTLE TYPES

Polyethylene – Opaque Plastic

PET Plastic – Clear Transparent Plastic

Which one is the best?

Clean < 100 particles > 10 microns per ml.

Super-clean < 10 Particles > 10 microns per ml.

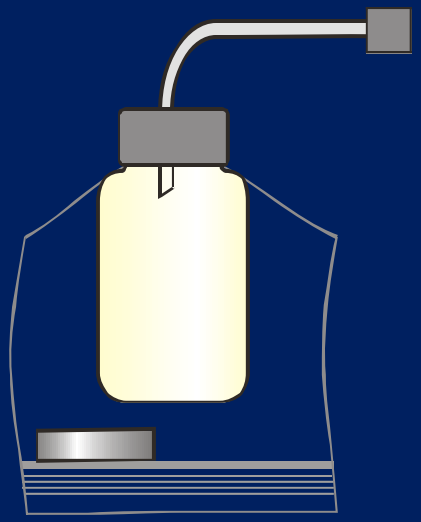
Ultra-clean < 1 Particles > 10 microns per ml. Visual inspection made easy

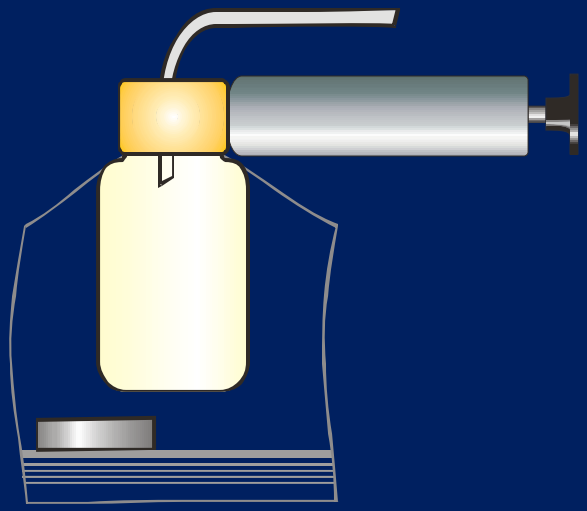
Difficult to make visual observations in frosted bottle

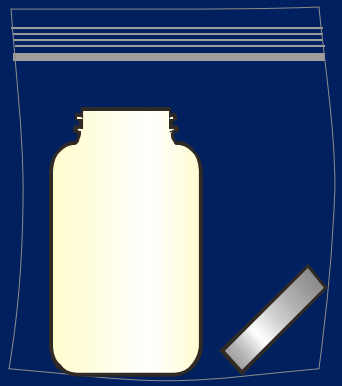
Courtesy:Slater Trico

CLEAN SAMPLING

1. In clean-air environment, place capped bottle into a clean zip-lock bag and seal.
2. Place individual bags into a large zip-lock bag with vacuum pump.
3. Just prior to sampling, remove cap without opening bag.
4. Thread bottle onto vacuum pump without opening bag.
5. After sampling, place cap tightly onto bottle without opening bag.
6. Remove bottle from bag.







LINE FLUSHING REQUIREMENTS

Recommended flushing volume = 5 to 10 x sample line volume

Volume = $\pi r^2 \times l$ 4 oz sample bottle = ~ 5.4 in^3

General rule of thumb:

1/4 in. SS tubing = 3/4 bottle / ft of sample line

3/8 in. SS tubing = 1bottle / ft of sample line

1/2 in. SS tubing = 2 bottles / ft of sample line

Double flush volume for carbon steel piping.

PERFORM VISUAL ASSESSMENT

- Screen for Visible Problems:
  - Abnormal color or cloudiness
  - Visible Free Water
  - Visible Metals or Debris
- Note Atypical Conditions on Sample Form
- Act Upon Corrections Immediately

SAMPLE INTERVALS

- Initial Baseline Samples:
  - High Priority Equipment First
  - Develop Action & Follow-up Plan
- Add Subsequent Equipment
- Adjust Intervals as Appropriate:
  - Reduce Abnormal or Problem Systems
  - Extend Normal or Less Active Systems

SAMPLING GUIDELINES

Machine Type	Normal Use	Intermittent Use
Diesel Engines	Two weeks, 250 Hrs	Monthly
Natural Gas Engines	Monthly, 500 Hrs	Quarterly
Gas Turbines	Monthly, 750 Hrs	Quarterly
Steam Turbines	Monthly, 750 Hrs	Quarterly
Air, Gas Compressors	Monthly, 750 Hrs	Quarterly
Refrigeration Compressors	Start, Mid & End of Season	Start, Mid & End of Season
Gears, Bearings	Monthly,750 Hrs	Quarterly
Hydraulics	Monthly,750 Hrs	Quarterly

Factors involved in determining sampling frequency

- Criticality of equipment
- Severity of the operation environment
- Oil drain intervals
- Amount of make-up oil
- Whether operation is continuous or intermittent

ASSIGNING SAMPLE INTERVALS

- Criteria:
  - Operating Priority of Equipment
  - OEM Recommendations or Requirements
  - Environmental Influences (dust, water, etc.)
  - Current PM, Lube & Filter Schedules
  - Current or Historical Problems of Specific or Like Equipment
  - Specific Goals of Program Objectives

WHAT IS THE PROBLEM?

Iron	Chromium	Nickel	Aluminum	Copper	Lead	Tin	Cadmium	Silver	Vanadium	Silicon	Sodium	Potassium	Titanium	Molybdenum	Antimony	Manganese	Lithium	Boron	Magnesium	Calcium	Barium	Phosphorous	Zinc
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	0	6	2
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	3	2
42	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	1	0	0	0	909	1
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	5	0	38	1
3	0	0	0	0	1	0	0	0	0	2	0	2	0	0	0	0	1	0	0	5	0	38	2

Sample Information							Contaminants			Fluid Properties					
Date Sampled	Date Received	Lube Time	Unit Time	Lube Change	Lube Added	Filter Change	Fuel Dilution % Vol	Soot % Vol	Water % Vol	Viscosity 40°C cSt	Viscosity 100°C cSt	Acid Number mg KOH/g	Base Number mg KOH/g	Oxidation abs/cm	Nitration abs/0.1 mm
06-Jan-2011	11-Jan-2011			Unk		Unk			<.1 - FTIR	156		0.04		3	6
10-Jan-2012	12-Jan-2012			No		No			<.1 - FTIR	161		0.08		1	5
26-Mar-2012	29-Mar-2012			No		No			<.1 - FTIR	157		0.08		2	7
05-Jul-2012	09-Jul-2012			No		No			<.1 - FTIR	949		0.42		3	4
05-Oct-2012	09-Oct-2012			No		No			<.1 - FTIR	152		0.01		2	3
27-Dec-2012	03-Jan-2013			No		No			<.1 - FTIR	172		0.19		2	2

TEST PACKAGES BY EQUIPMENT TYPE

RECOMMENDED TEST PACKAGES

Recommended For
Most Industrial Circulating Oil Systems
Such as Turbines, Bearing Reservoirs, Paper Machine Oils, Rotary Compressors, Pumps & Motors

- Spectrometals
- Viscosity @ 40°C
- Water (Karl Fischer)
- Acid Number
- Particle Count with ISO Rating

RECOMMENDED HYDRAULIC FLUID OIL ANALYSIS PROGRAM

- Spectrometals
- Viscosity @ 40°C
- Water (Karl Fischer)
- Acid Number
- Particle Count with ISO Rating

RECOMMENDED GEAR OIL ANALYSIS PROGRAM

- Spectrometals
- Viscosity @ 40°C
- Water (Karl Fischer)
- Acid Number
- Direct Read Ferrography/Particle Quantifier or, Particle Count if filtered

RECOMMENDED FOR NATURAL GAS ENGINES

- Spectrometals
- Viscosity @ 100° C
- Water (Crackle)
- FTIR
- Acid Number
- Base Number (optional)

RECOMMENDED HEAVY DUTY ENGINE OIL ANALYSIS PROGRAM

- Spectrometals
- Viscosity @ 100° C
- Water (Crackle)
- Fuel Soot
- Fuel Dilution
- BN - Base number (for extended drains)
- Acid Number (Optional)