# Lubrication

# Lubrication Basics

*Technology of Reducing Friction, Heat and Wear Through The Introduction of a Lubricant Between Surfaces in Relative Motion.*

# Lubricant Functions

- ***Primary Functions:***
  - *Reduce Friction Between Surfaces*
  - *Carry Away Heat (Approximately 95% of Lubricant is Used to Cool Surfaces)*
  - *Reduce Wear By Separating or Protecting Surfaces*
  - *Transmit Power (Hydraulic)*
  - *Insulate (Electrical Transformers)*

## *Lubricant Functions, cont.*

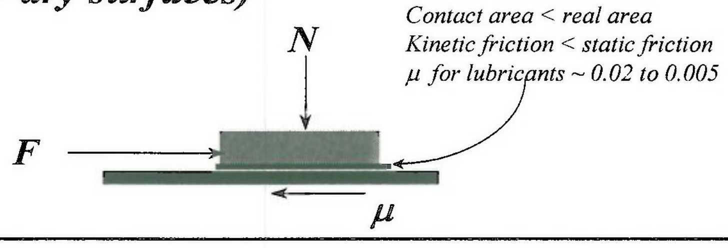
- ***Secondary Functions:***
  - ***Protect Surfaces From Oxidation & Corrosion***
  - ***Suspend & Carry Away Contaminants***
  - ***Form a Seal (Greases)***

## *Friction*

- ***Resistance to Relative Motion***
- ***Proportional to Load***

$$F = \mu N$$

- ***Avg Coefficient of Static Friction = 0.25 (0.17 dry surfaces)***



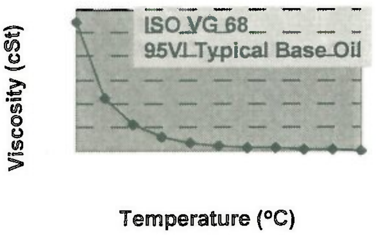
# Standard Lubricant Tests

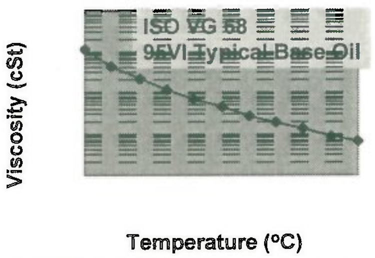
# What Is Viscosity?

- *A Measure of a Fluids Internal Resistance to Flow - Shear Stress / Shear Rate*
- *Must Be Measured at One Standard Temperature for Comparison*
- *Given in Centistokes (Kinematic) or Centipoise (Absolute)*
- *Is Highly Temperature & Pressure Dependent*

# *Variation in Viscosity With Temperature*

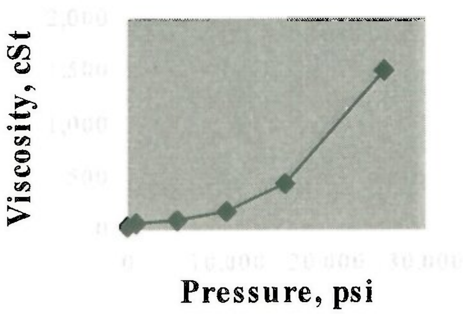
- ***Viscosity Decreases Exponentially With Increasing Temperature***
- ***At Very Low Temperature Becomes Solid***
- ***Inaccurate Measurement If > 0.2% Moisture In Lubricant (2000 ppm)***



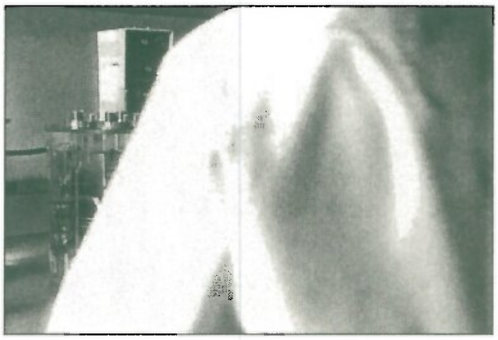




# *Variation in Viscosity With Pressure*

***Tests Conducted on a plain mineral oil. Viscosity rises exponentially with increasing pressure. With pressures approaching 100,000 psi, lubricant acts almost as a solid. Surfaces deform elasto- plastically.***



# *What Is Viscosity?*



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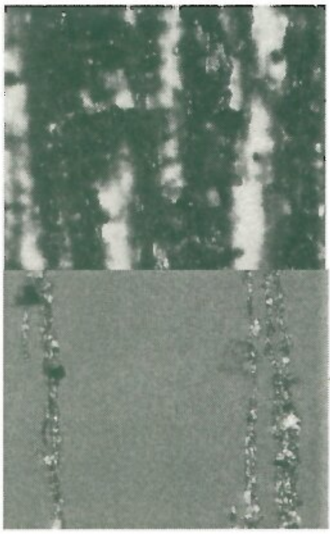
# *Low viscosity*

- ***Allows increased amount of boundary lubrication resulting in higher wear rates***
- ***Boundary lubrication is strongly implied through identification of black oxide particles***
- ***Greater friction requires more power***



NO BOUND LUBRICATION

# High Viscosity

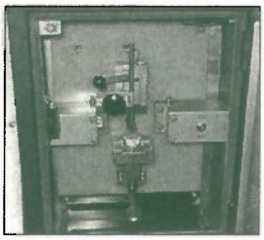
- ***Strong indicator of lubricant oxidation***
- ***Can be caused by lubricant mixing***
- ***Too high viscosity can result in lubrication starvation and boundary lubrication at startup, producing excessive wear***
- ***Increases rate of oil degradation due to higher temperatures created by greater friction***
- ***Excessive increases in viscosity require significantly more power to operate equipment, a sometimes costly condition***

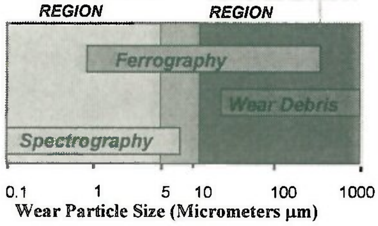
+ up to 8μ particles

# Emission/Absorption Spectroscopy

- ***Strengths***
  - ***Fast Test***
  - ***Comprehensive List of Elements***
- ***Weaknesses***
  - ***Particle Transport Problems; Particle Size Limitations***
  - ***Constant Need for Calibration***

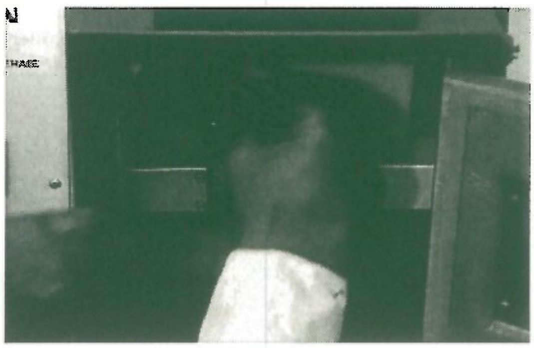
# Particle Transport






- ***All methods are inefficient in transporting large particles from the reservoir to the excitation area***
- ***Acid Digestion or Rotrode methods can alleviate some of this problem, but increases the testing time and costs significantly***

# Elemental Analysis



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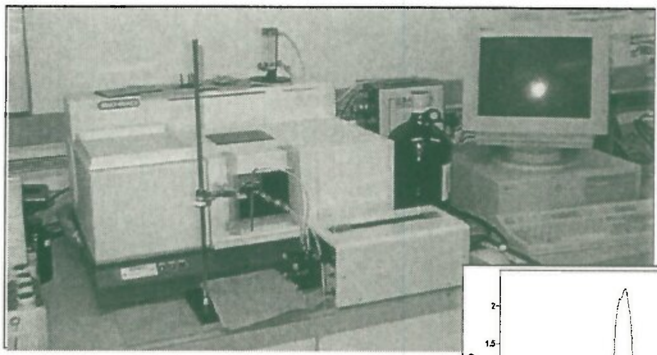
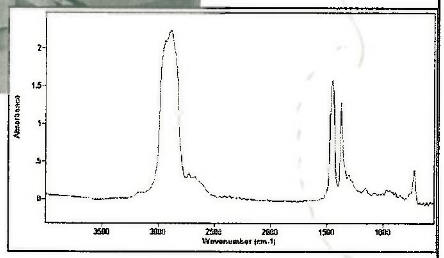
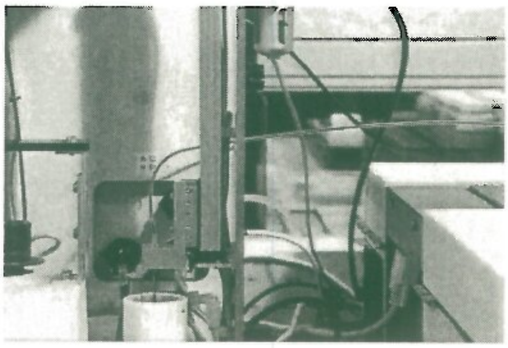
# FTIR Spectroscopy






***Measures absorbance properties of chemical bonds in the lubricant sample***

# FTIR Spectroscopy



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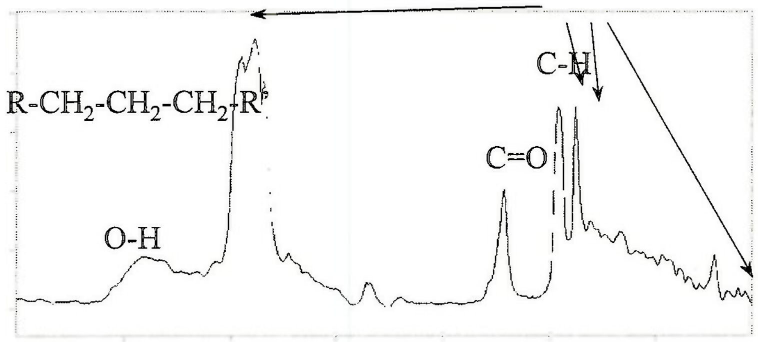
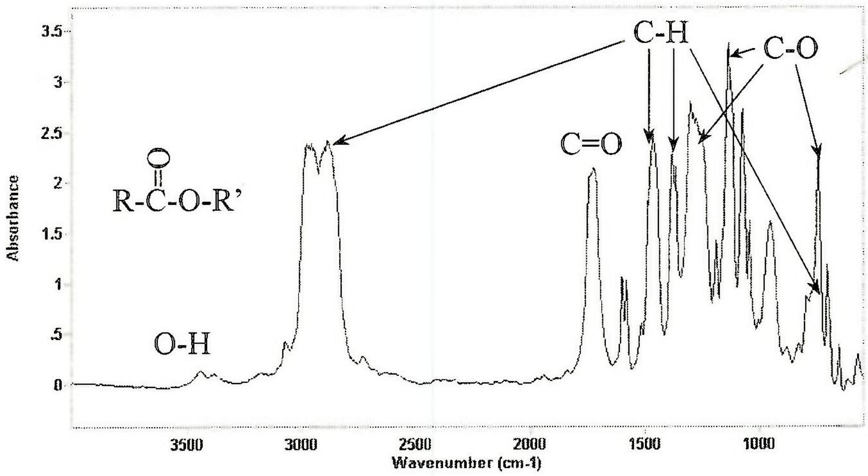
## FTIR Spectroscopy




Mineral Oil

## FTIR Spectroscopy

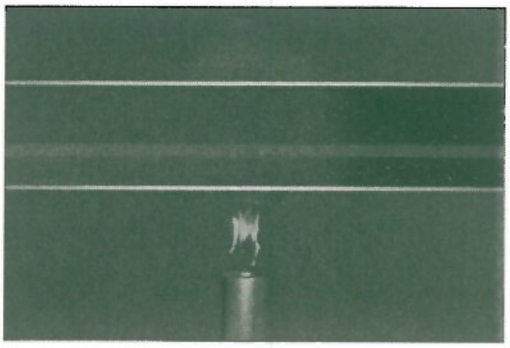



Organic Ester

## *Oxidation*

- ***Increases lubricant viscosity***
- ***Increases rate of wear***
- ***Increases rate of corrosion and pitting on wear surfaces***
- ***Nitrates and Sulfates similar in generation and effect***
- ***Rate of oxidation degradation increases as temperature increases*** each 80°C → DOUBLE

## *Oxidation*



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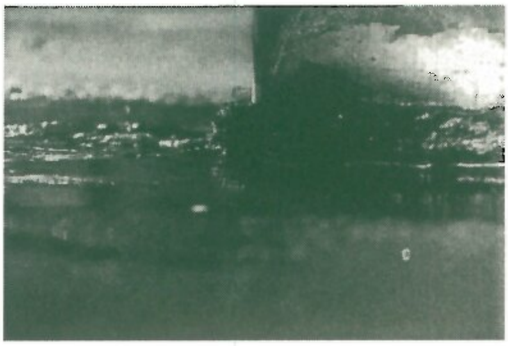
## *Water Contamination*

- *Affects viscosity*
- *Increases oxidation and formation of acids*
- *Reduces bearing life dramatically*
- *Will not demulsify from some lubricants*
- *Causes internal rust of case and components*

## *Water Contamination*



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# Particle Counter

- ***Quantitative results***
- ***Sensitive to water and gas contamination***
- ***Only useful for clean running systems***
  - ***Contaminant debris not generally expected***
  - ***Turbines and Hydraulics***

Infrared particle counter. Provides trend that can indicate increases in abnormal wear.

# Particle Count Test Results

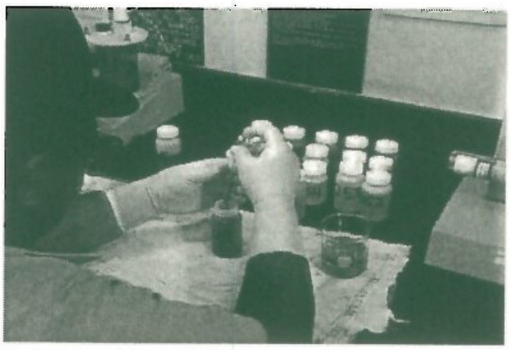
This shows a typical print out from a particle counter displaying results by number of particles in any one group.

Hiac/Royco
05/02/97 13:46:58 Counter 1
Sample ID: 44397
Sample ID:
Elapsed time: 00:00:11.62
Run 1 Counts/1.00 mL:

| Chan: | Size: | Cuml: | Diff: |
|---|---|---|---|
| 1 | 5.00 | 2546.6 | 1880.1 |
| 2 | 10.00 | 666.50 | 334.10 |
| 3 | 15.00 | 332.40 | 146.70 |
| 4 | 20.00 | 185.70 | 87.000 |
| 5 | 25.00 | 98.700 | 72.000 |
| 6 | 40.00 | 26.700 | 12.900 |
| 7 | 50.00 | 13.800 | 12.500 |
| 8 | 100.00 | 1.300 | 1.300 |

ISO Code: 19/16

# Particle Count



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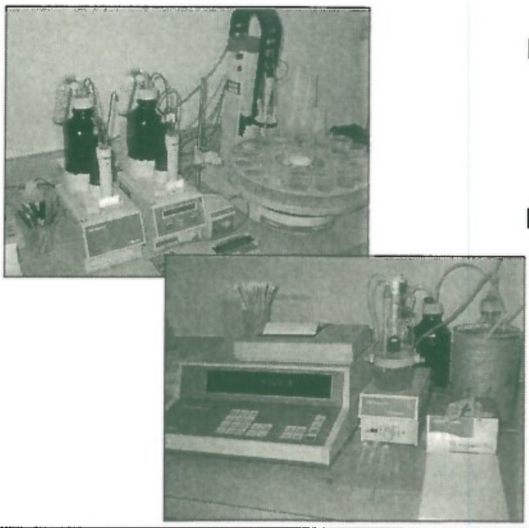
# Titration

- *TAN looking for acidity changes*
  - *In this application, more likely to find oxidation products*
  - *Acid contaminant likely only through process contamination*
  - *Causes corrosive wear debris and general increases in the wear rate*

## Titration

- TBN looking for alkalinity
  - Overbase additive applications most likely (Large Diesel Engines)
  - Absence of additive (low TBN) will cause increases in rates of wear, corrosion, and solid combustion product generation
  - Process contamination possible, but not observed

## Running Titrators



- Time consuming tests- take about 10-15 minutes to get end-point
- Run Water by Karl Fischer when upper water limit is less than 500 ppm; takes an average of 10 minutes to get end-point

## Running Titrators

Courtesy of Coastal Training

## Observations

- ***Large particles in sample***
  - *Ferrography loses sensitivity to particles over 300 microns in width*
  - *Likely to settle in sample bottle*
  - *Particles over 80 microns easily visible to naked eye*
- ***Shake sample before opening***
  - *Releases gas entrained in the lubricant*

## Observations

- *Crackle Test*
  - *Hot Plate set at 115-125C*
  - *Sensitive to between 200 and 1000 ppm depending on oil viscosity and additives*

## Typical Fluid Viscosities

- *Viscosities Measured at 70 Degrees F*

| | |
|---|---|
| – Honey | 1,500 cP |
| – SAE 50 Motor Oil | 800 cP |
| – SAE 30 Motor Oil | 300 cP |
| – SAE 10 Motor Oil | 70 cP |
| – Water | 1 cP |
| – Air | 0.018 cP |

## Lubricant Properties

- Viscosity
  - Can Be Modified With Viscosity Index Improvers
- Oxidation Resistance
  - Heat/Air Causes Acids; Darkening of Oil
  - Rate Doubles Every 18°F Rise
- Flash & Fire Point
- Pour Point

## Lubricant Properties, cont.

- Foaming Resistance
- Demulsibility - Ability of Oil to Separate From Water
- Aniline Point - Relative Solvency
  - Desired Range 190°F - 220°F
  - < 190°F Seals Swell
  - > 220°F Seals Shrink

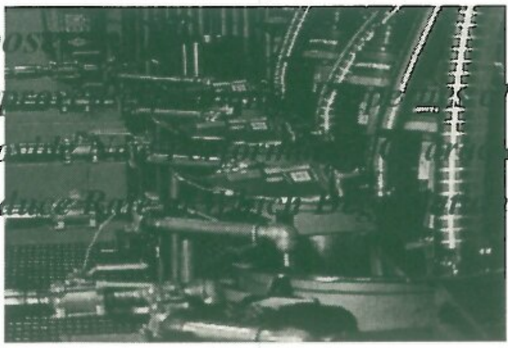
# Additives

■ Purp

– Im f Base Oil

– Pr eristics

– Re Takes Place



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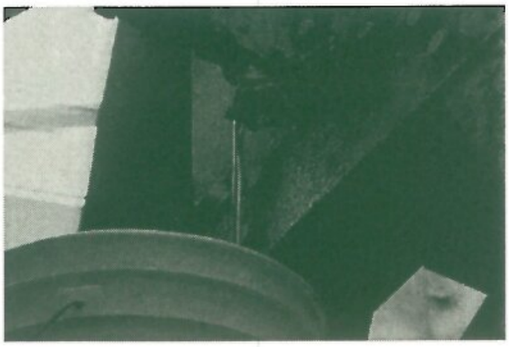
# Additives



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## *Common Additives*

- *Oxidation Inhibitor*
- *Corrosion Inhibitor*
- *Antiwear Improver*
- *Detergent*
- *Dispersant*
- *Alkaline Reserve*
- *Rust Inhibitor*
- *Pour Point Depressant*
- *VI Improver*
- *Extreme Pressure*
- *Antifoam Agent*
- *Tackiness Agent*
- *Emulsifier*
- *Thickening Agent*
- *Water Repellent*
- *Metal Deactivator*
- *Odor Masking Agent*
- *Biocide*

## *Lubricant Types*

- *Fluid*
  - *Hydraulic / Spindle*
    - » *Mineral Oil, R&O, AW/R&O, Food*
  - *Turbine - Normal, Clay Contacted*
  - *Engine - Single Grade, Multigrade*
  - *Gear - AW, EP, Borate*
  - *Transmission - Automatic, Manual, Coupling*
  - *Emulsions & Process Oils*

## Lubricant Types

- *Semi-Fluid (Grease)*
  - *Thickener + Lubricant*
    - » *Lithium, Lithium Complex, Aluminum Complex, Calcium, Barium, Polyurea, Etc.*
    - » *Solid Additives - Clay, Graphite, Lead, Molydisulfide*
  - *Extreme Pressure (EP), Non-EP*
  - *Be Aware of Incompatibilities of Thickeners*

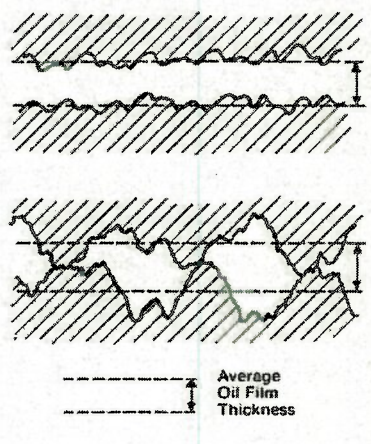
## Synthetic vs Mineral Base Oils

- *Extreme Temperature Operating Conditions*
- *Better Resistance to Chemical Contamination*
- *Special Molecular Properties*
- *Better Oxidation Stability*
- *Higher Price* — 4-6 times more/mineral oil

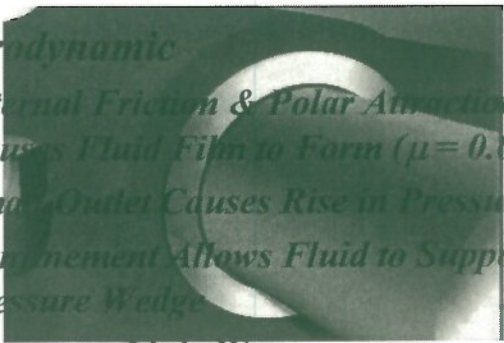
# Lubrication Films

- Thick Film - Full Separation of Surfaces
  - Hydrodynamic Lubrication
  - Elastohydrodynamic Lubrication
  - Hydrostatic Lubrication
- Thin Film - Some Surface Contact
  - Boundary Lubrication
- Solid Film - Low Shear Strength Solid Bonded to Surfaces

# Lubricant Film Thickness



# *Lubrication Films*



- **Hydrodynamic**
  - *Internal Friction & Polar Attraction to Metal Causes Fluid Film to Form ($\mu = 0.0005 - 0.02$)*
  - *Small Outlet Causes Rise in Pressure*
  - *Confinement Allows Fluid to Support Load, Pressure Wedge*
  - *Generates Little Wear*
  - *Surfaces Totally Separated*

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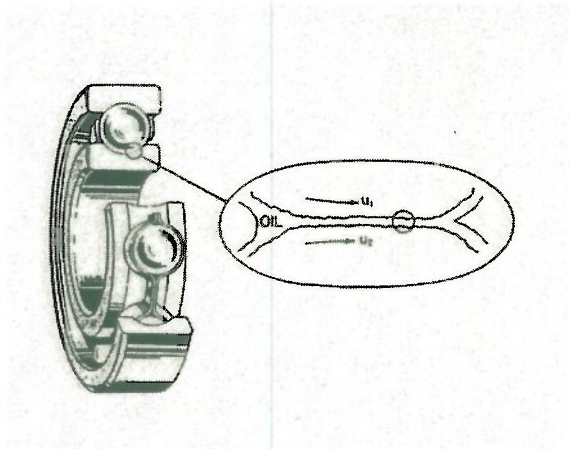
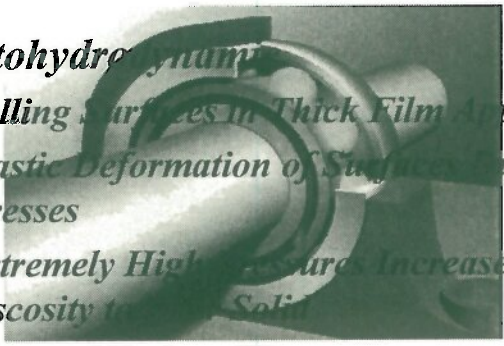
# *Hydrodynamic Lubrication*



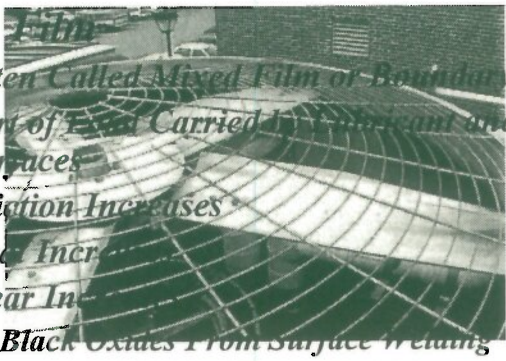
## Lubrication Films



- **Elastohydrodynamic**
  - Rolling Surfaces in Thick Film Applications
  - Elastic Deformation of Surfaces Due to High Stresses
  - Extremely High Pressures Increase Lubricant Viscosity to Near Solid
  - Cause of Fatigue Wear

Courtesy of Coastal Training

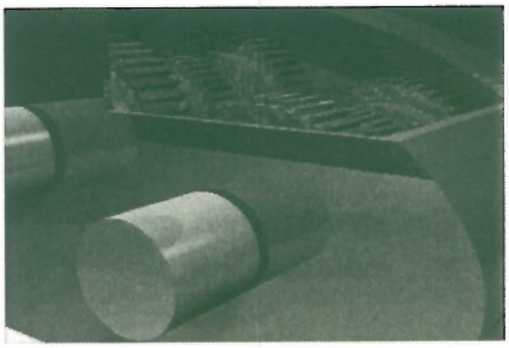
## Lubrication Films



- **Thin Film**
  - Often Called Mixed Film or Boundary Lubrication
  - Part of Load Carried by Lubricant and Part by Surfaces
  - Friction Increases
  - Heat Increases
  - Wear Increases
    - » Black Oxides From Surface Welding
    - » Beta Red Oxides From High Heat Generation

Courtesy of Coastal Training

# *Lubrication Films*



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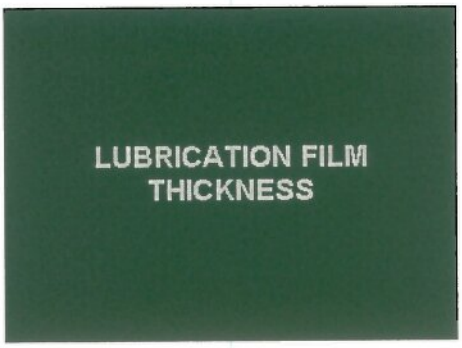
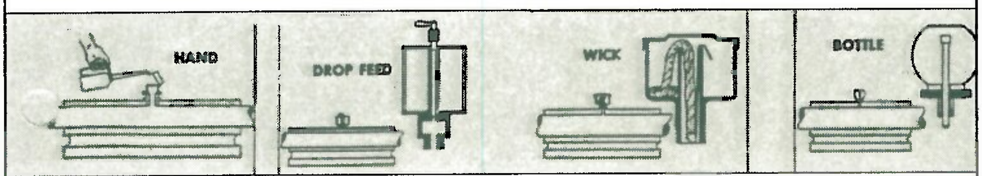
# *Lubrication Films*



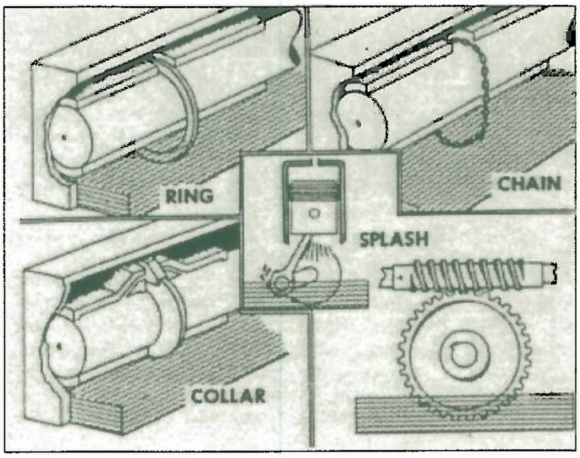
# Other Methods of Lubrication

- Brush
- Drip
- Splash/Bath
- Spray
- Slinger Ring

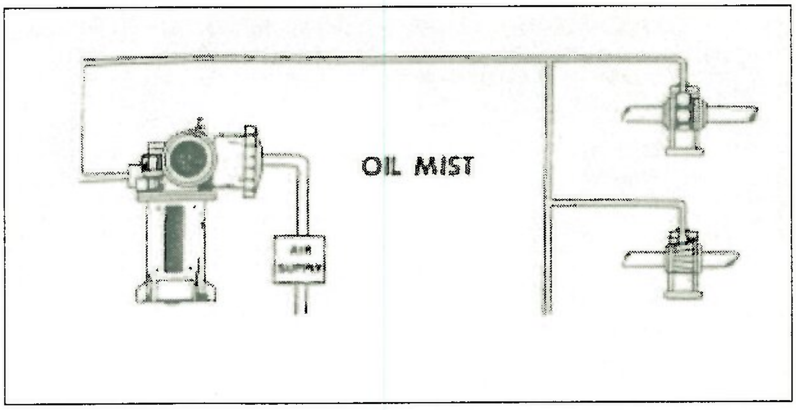
# Once Through Lubrication



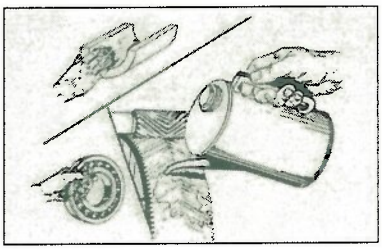
# Reservoir Lubrication

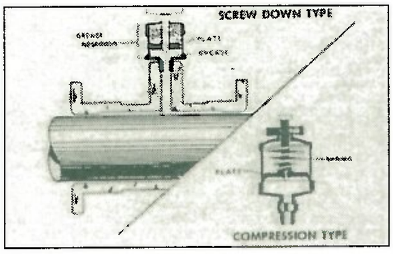



# Oil Mist System

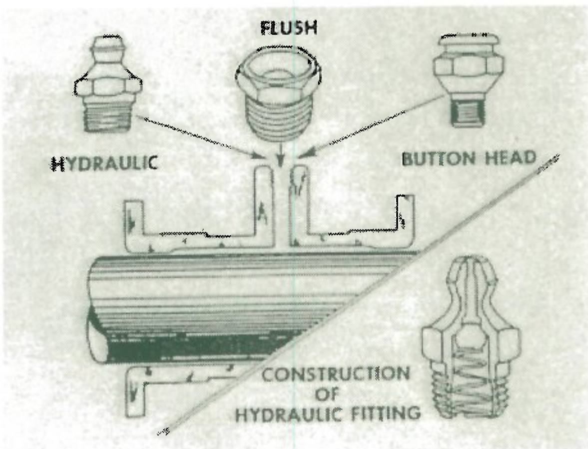


# Grease Lubrication

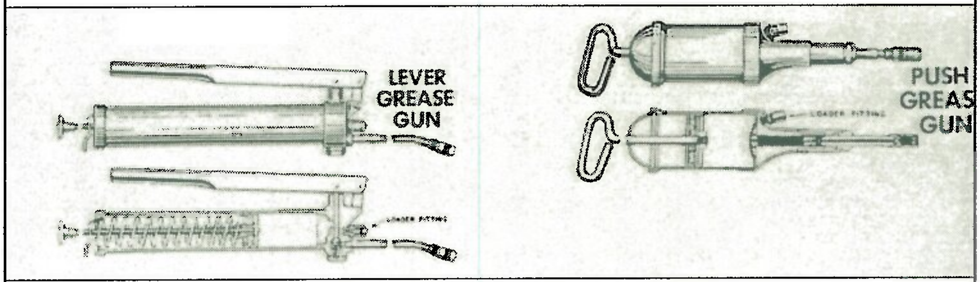





# Grease Fittings



## Grease Gun

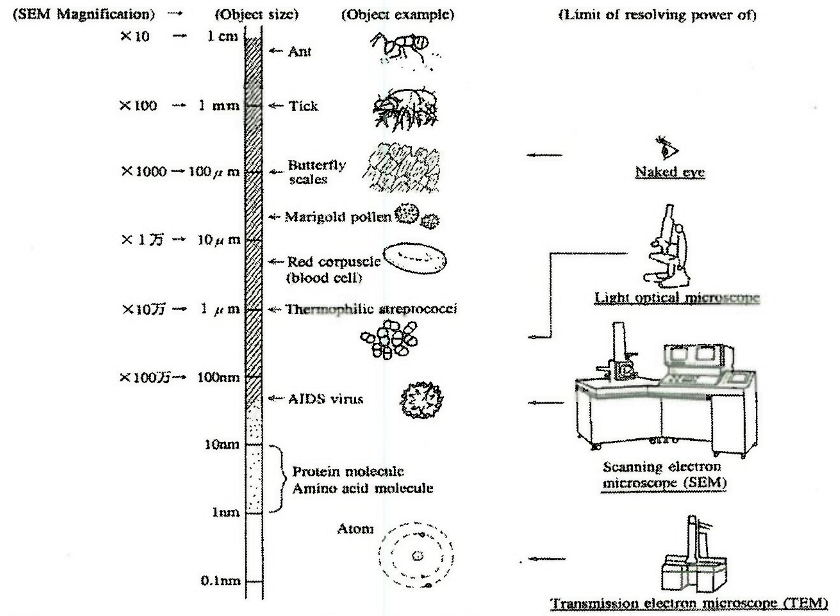



[MAICRON]

## What is a Micron?

- 1-Millionth of a Meter
- 39.37 Or 40 μ-inches (Millionth of an Inch)
- Smallest Particle Observable: 40 microns or 1,600 μ-inches
- Human Hair Diameter: ~ 80 microns or 3,200 μ-inches
- Normal Wear Particle: 5-10 microns or 200 - 400 μ-inches (0.5-2 microns Thick)

## How small is small?




# *What Does Particle Size Denote?*

- ***In analytical Ferrography, reported particle size indicates the maximum dimension measureable in three dimensions - length, width, thickness***
- ***Particles are flat & have length-to-thickness aspect ratios generally > 5 to 30***
- ***A 50 μm particle may have a thickness of only 2 μm; therefore represents surface wear incremental depth of 2 μm***

# Filtration

# Filter Media Types

## Surface Media

Straight through flow path. Contamination is captures on the surface which faces the flow. Generally made of woven wire. The pore size is the largest hard spherical particle that will pass through under specific conditions. Smaller particles may be captures as contamination builds-up. Long and thin particles may flow through, since their end size is small.

# *Filter Media Types*

### Depth Media

In depth media the fluid must pass through the filter in indirect paths. Particles are trapped in a maze of openings throughout the filter media. This type of filter can have a very high capture rate at small particle sizes.

# *Filter Media Types*

Two Main Types:
Cellulose and Fiberglass

| General Comparison Of Filter Media | | | | | |
|---|---|---|---|---|---|
| Media Material | Capture Efficiency | Dirt Holding Capacity | Differential Pressure | Life in a System | Initial Cost |
| Fiberglass | High | High | Moderate | High | Moderate |
| Cellulose (paper) | Moderate | Moderate | High | Moderate | Low |
| Wire Mesh | Low | Low | Low | Moderate | High |

# Filter Beta Ratio & Efficiency

$$B_x = \frac{\text{\# of particles upstream}}{\text{\# of particles downstream}}$$

"x" is at a specific particle size

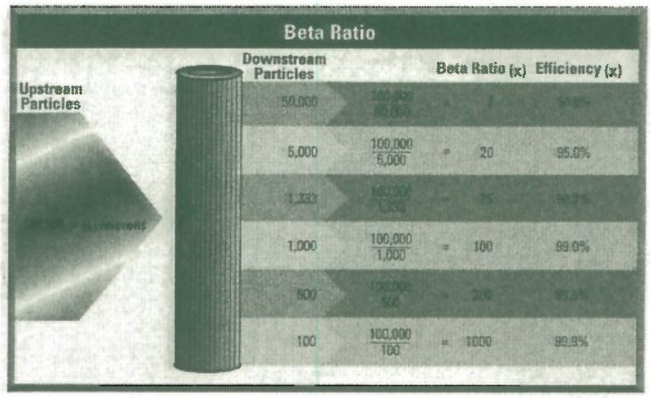
$$B_{10} = \frac{50{,}000}{10{,}000} = 5$$

$$\text{Efficiency}_x = \left(1 - \frac{1}{\text{Beta}}\right) 100$$

$$\text{Efficiency}_{10} = \left(1 - \frac{1}{5}\right) 100$$

$$= 80\%$$

# Filter Efficiency



# *Filter Selection*

P = Full flow pressure filter (equals one filtration placement)

R = Full flow return filter (equals one filtration placement)

O = Off-line (flow rate 10% of reservoir volume equals .5 of a filtration placement)

* Number of filtration placements in system, more placements are the option of the specifier.

**Lubrication Systems**

| Component Type | Suggested Cleanliness Code | Media Efficiency Betax >200 | Number of Filter Placements* | Minimum Filter Placements |
|---|---|---|---|---|
| Ball Bearings | 15/13/11 | 2 | 1.5 | P or R, & O |
| | | 2 | 1 | P or R |
| Roller Bearings | 16/14/12 | 5 | 2 | P & R |
| | | 2 | 0.5 | 0 |
| Journal Bearings<br>Gear Boxes | 17/15/13 | 5 | 1.5 | P or R, & O |
| | | 10 | 2.5 | P, R & O |

# *Filter Selection*

**Hydraulic Systems**

| Component Type | System Pressure | Suggested Cleanliness Code | Media Efficiency Betax >200 | Number of Filter Placements | Minimum Filter Placements |
|---|---|---|---|---|---|
| Servo Valves | <1000 | 16/14/12 | 2 | 1 | P |
| | | | 5 | 2 | P & R |
| | 1000-3000 | 15/13/11 | 2 | 1.5 | P & O |
| | >3000 | 15/12/10 | 2 | 2 | P & R |
| Proportional Valves | <1000 | 17/15/13 | 2 | 1 | P |
| | | | 5 | 1.5 | P & O |
| | | | 10 | 2.5 | P, R & O |
| | 1000-3000 | 17/14/12 | 2 | 1 | P |
| | | | 5 | 2 | P & R |
| | >3000 | 16/14/11 | 2 | 1.5 | P & O |
| | | | 5 | 2.5 | P, R & O |
| Variable Volume Pumps | <1000 | 18/16/14 | 5 | 1 | P or R |
| | | | 10 | 2 | P & R |
| | 1000-3000 | 17/16/14 | 2 | 0.5 | O |
| | | | 5 | 1.5 | P or R, & O |
| | | | 10 | 2.5 | P, R & O |
| | >3000 | 17/15/13 | 2 | 1 | P or R |
| | | | 5 | 2 | P & R |
| Vane Pumps<br>Fixed Piston Pumps<br>Cartridge Valves | <1000 | 19/17/15 | 5 | 0.5 | O |
| | | | 10 | 1.5 | P or R, & O |
| | 1000-3000 | 18/17/14 | 5 | 1 | P or R |
| | | | 10 | 2 | P & R |
| | >3000 | 18/16/13 | 5 | 1.5 | P or R, & O |
| | | | 10 | 2.5 | P, R & O |
| Gear Pumps<br>Flow Controls<br>Cylinders | <1000 | 20/18/15 | 10 | 1 | P or R |
| | | | 20 | 2.5 | P, R & O |
| | 1000-3000 | 19/17/15 | 10 | 1.5 | P or R, & O |
| | >3000 | 19/17/14 | 5 | 0.5 | O |
| | | | 10 | 1.5 | P or R, & O |

PREDICTOIL

# Sampling Techniques

**An Analytical Report, No Matter How**

**Brilliantly Written, Is Worse Than**

**Meaningless If the Samples Taken Are Not**

**Representative of the System Being Monitored.**

**(i.e. Garbage in, Garbage Out)**

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# Sampling/Monitoring Goals

- *Find Problem Early Enough to Mitigate*
- *Root Cause Analysis to Eliminate Source*
- *Verify Symptoms Found by Other Methods*
- *Predict Service Life to Plan Downtime*
- *Increase or Maintain Plant Uptime*

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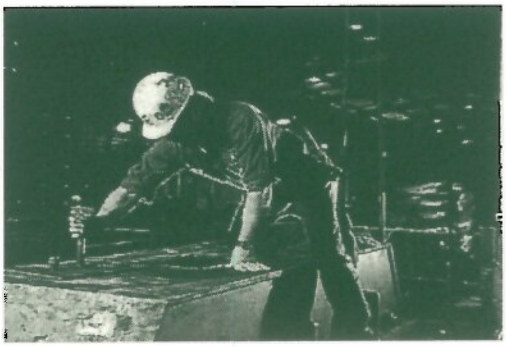
# Sampling Frequency



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# Component Elements

- All Rotating Machinery Have:
  - Lubricant (Fluid, Grease, Emulsion)
  - Support Bearings (Rolling Element, Plain)
  - Gears (Optional)
  - Sliding Surfaces
  - Seals

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## Wear Condition Monitoring

- Use Lubricant to Capture Information On:
  - External Contamination
  - Internal Contamination
  - Rubbing & Abrasive Wear
  - Fatigue Wear
  - Lubricant Degradation
  - Erosion/Cavitation/Corrosion

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## Sampling Point Selection

- Objective is to Get Representative Sample of Solid Phase in Fluid Phase
- The Ideal Location
  - Sample Tap in Return Line of Last Lubricated Component; or,
  - Sample Valve in Case 1/3 Distance From Bottom; or,
  - In Circulating Portion of Reservoir, at Entry End, Near Midheight of Reservoir.

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## Sampling Point Selection

- Know Lube System & Path
- Estimate Pumping Rate
- Locate Filters
- Find Return Line After Last Lubricated Component
- Use Sampling Valves
- Sample While Running, If Possible

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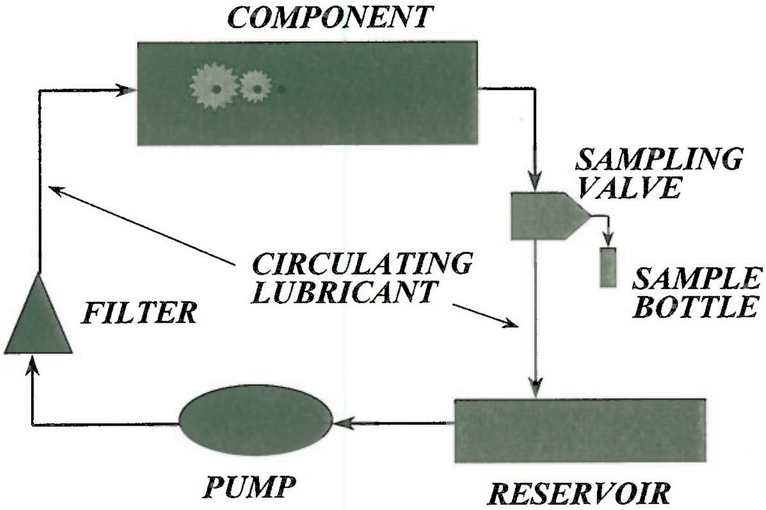
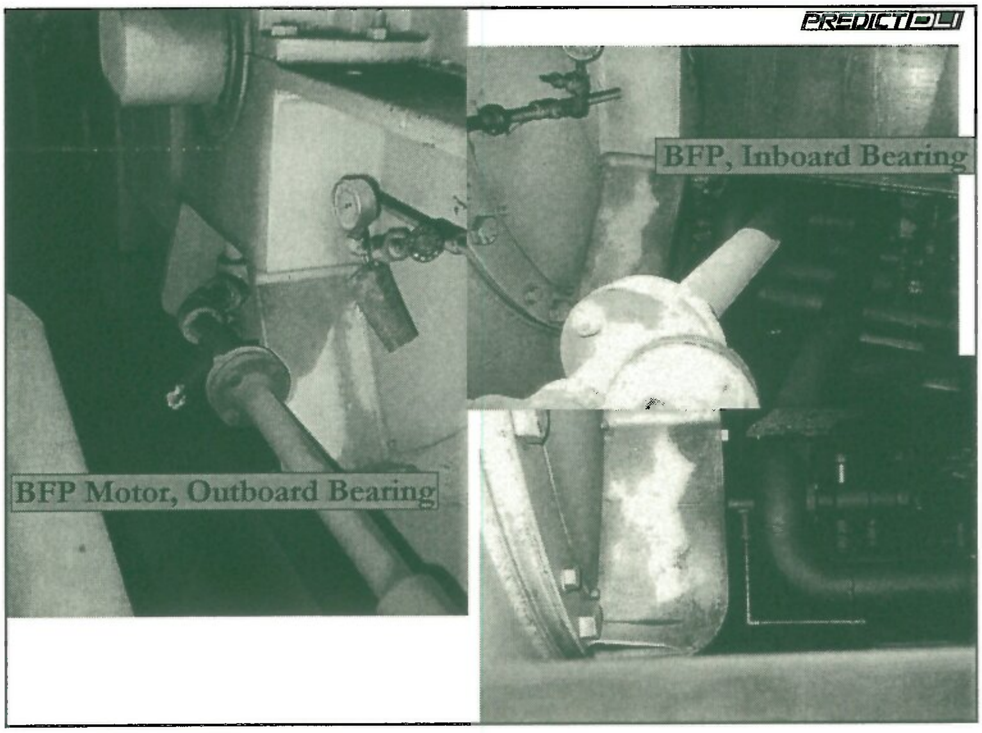
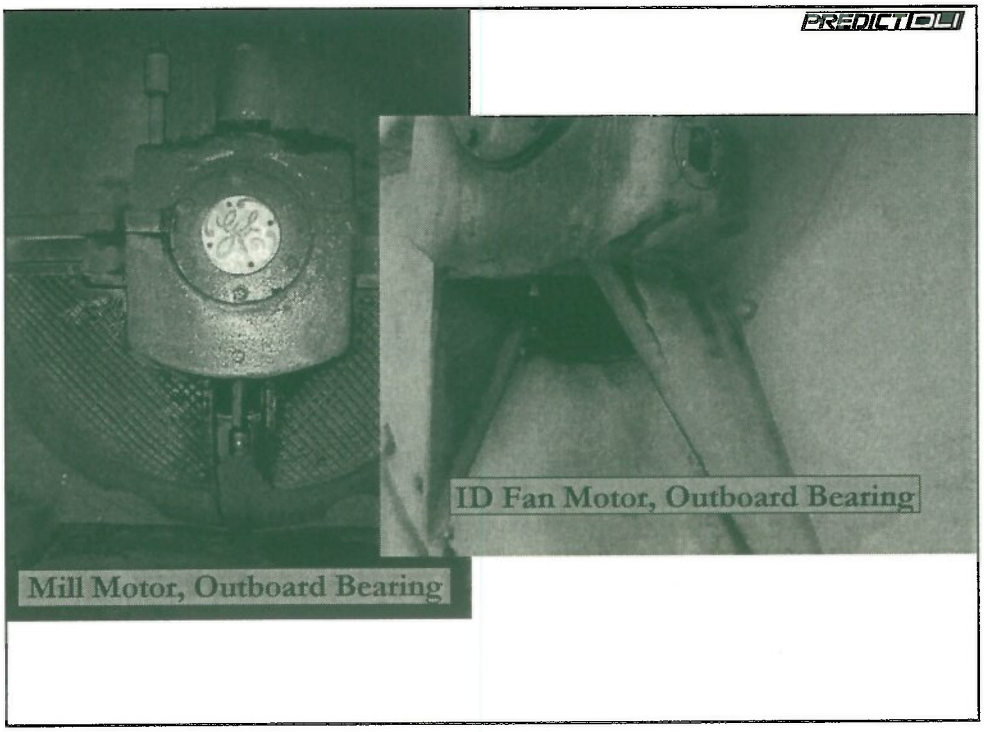
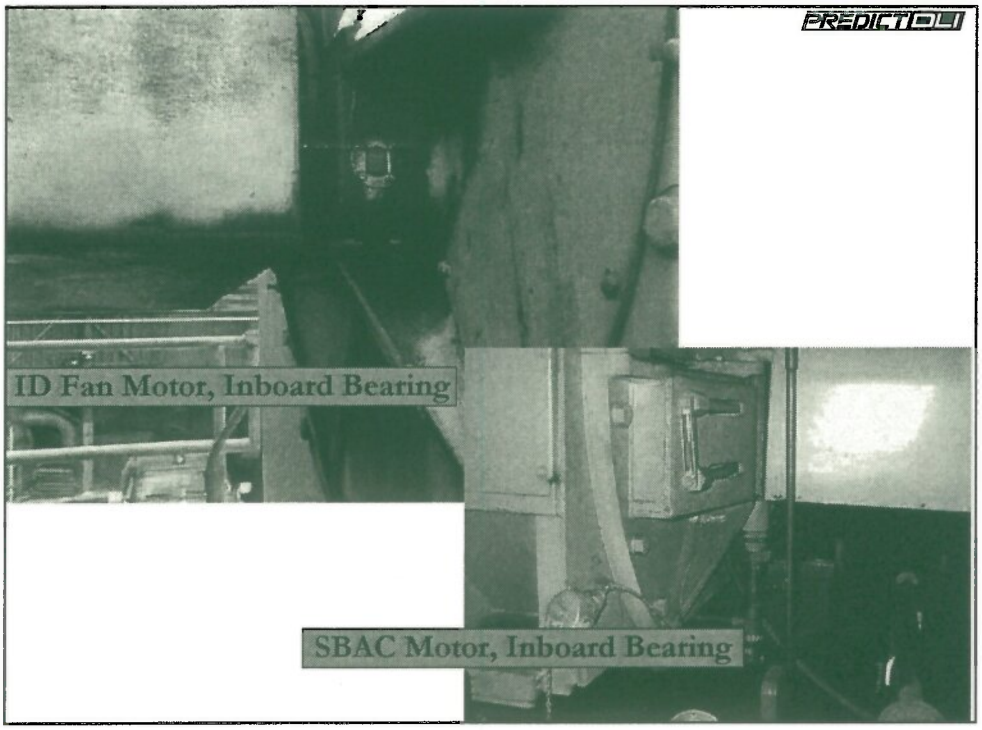
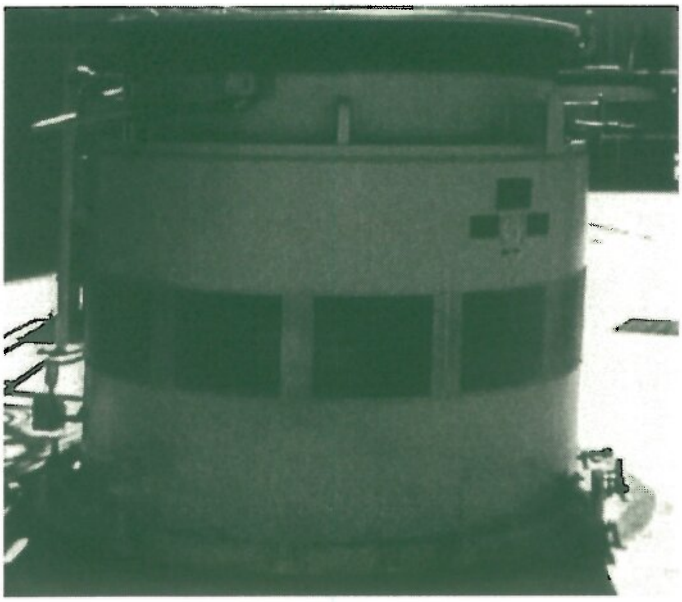
## Sampling Point Selection



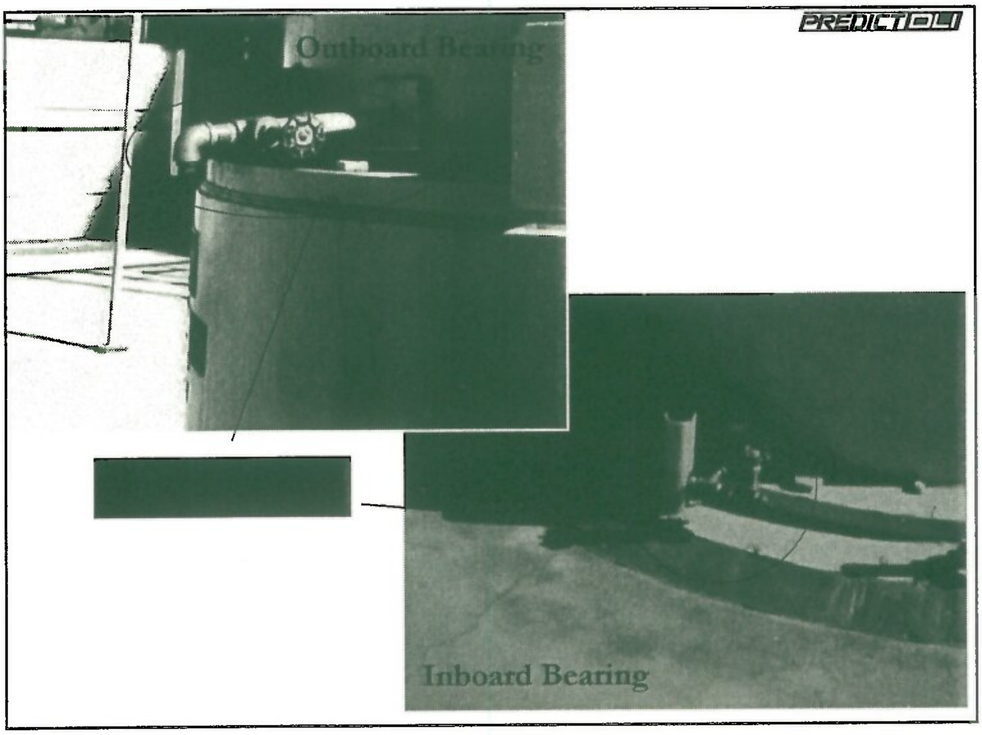

BFP, Inboard Bearing
BFP Motor, Outboard Bearing


ID Fan Motor, Outboard Bearing
Mill Motor, Outboard Bearing



Circulating Water Pump

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# *Factors Affecting Particle Concentration*

- *Load and Speed*
- *Filtration Efficiency*
- *Lubricant Film Thickness*
- *Environmental Contamination*
- *Reservoir Capacity*
- *Operating Cycles - Continuous, Interrupted, Reversing*

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# Particle Loss Mechanisms

- Filtration
- Settling
- Adhesion
- Pulverizing
- Magnetic Separation

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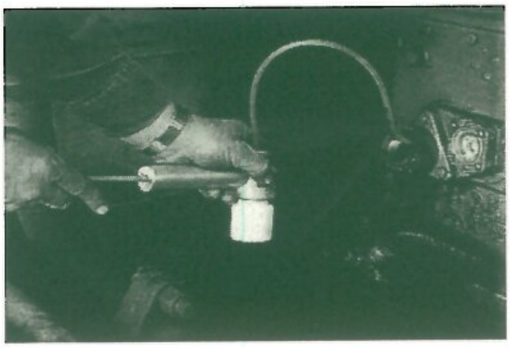
# Taking a Sample



Courtesy of Coastal Training

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## Taking a Sample

- ***From Valves in Return Line***
  - ***Place Valve as Close to Pipe as Possible***
  - ***Use as Small Diameter Pipe as Possible***
  - ***Calculate Dead Volume & Flush 2X Amount Into Waste Can***
  - ***Clean Valve Spigot Before Taking Sample***
  - ***Take Sample Before Closing Valve & Fill Bottle Only 3/4 Full***
  - ***Send Out Same Day -- Don't Wait!*** → CAN LOSE INFO.

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## Taking A Sample

- ***Using a Vacuum Sampling Pump***
  - ***Objective is to Sample From Same Spot Each Time***
  - ***Tape Tubing to Wire or Rod to Ensure Same Location***
  - ***Tape Ends of Tubing Closed When Not Used***
  - ***Don't Push to Bottom or Let Curl to Top***
  - ***Don't Pull Lubricant Into Suction Mechanism***
  - ***Properly Dispose of Tubing After Each Sample***

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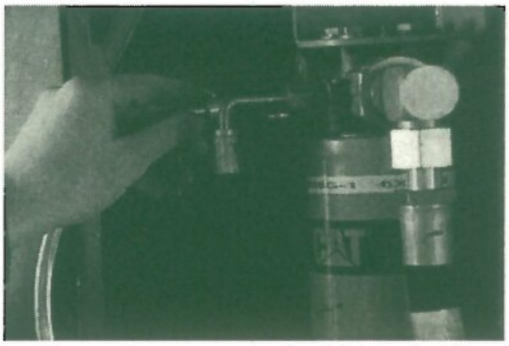
## Sampling Cautions

- DO NOT
  - Sample More Than 15 Minutes After Shut-Down
  - Sample Downstream of Filter
  - Sample in "Dead" Areas of System
  - Sample From Top or Bottom of Reservoir

PREDICTOLI

## Taking a Sample



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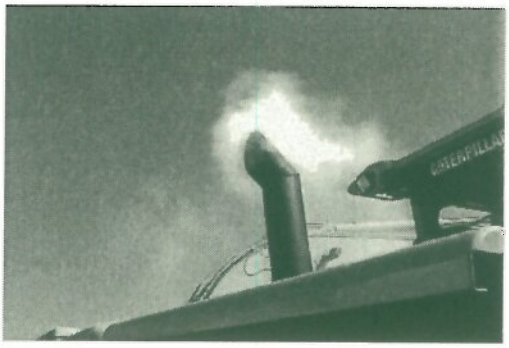
# Taking a Sample



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# Taking a Sample

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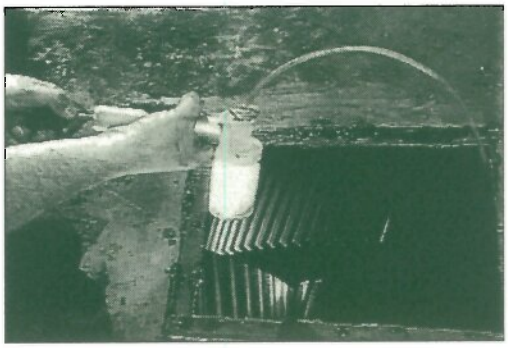
# Taking a Sample

Courtesy of Coastal Training

# Sampling Habits

- *Label Sample Point Locations*
- *Mark Sample Bottles Prior to Sampling*
- *Clean Surfaces Prior to Sampling*
- *Drain Stagnant Oil From Valve*
- *Use New, Clean, Plastic Bottles*
- *Use New Sample Tubing*
- *Ship Samples Immediately*

# Sampling Habits



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**Technical Bulletin**

# Lubricant Sampling Techniques for Wear Particle Analysis

Wear Particle analysis is a method of detecting abnormal wear trends in lubricated, rotating machinery. Its effectiveness depends on proper sampling techniques. Valid samples must contain a representative selection of wear particles.

Since wear particles and contaminants in a lubricating system are seldom uniformly distributed, proper sample taking is critical. Considerations for sampling are addressed in this document. Familiarity with these considerations is essential for accurate application of Wear Particle Analysis and include:

- Life of a particle
- Sampling from pipes
- Sampling from tanks
- Effects of in-line filters
- Grease samples
- Sampling frequency
- Sample bottles and caps
- Sampling accessories
- Training

**Life of a Particle**

To establish the operating conditions and health of machines by Wear Particle Analysis, it is essential that the lubricant sample contain a representative selection of particles. Since particulate matter exists as a separate phase in the fluid, it cannot be assumed that a uniform distribution exists throughout the lubricant. Consequently, careful attention must be paid to the method of sample extraction.

During normal operation of lubrication and hydraulic systems, wear particle concentration achieves an equilibrium level for each set of operating parameters. Since wear debris is continually generated in any operating mechanical system, the achievement of an equilibrium level implies that particles are removed from the fluid at the same rate they are generated.

Factors which influence the operating time to equilibrium are:

- Filtration: i.e., the average number of times a particle of a given size and composition passes through the filter.
- Oil pumping cycle rate: Pumping rate expressed in volume per unit time, divided in the volume of lubricant in the system.
- Dispersive qualities of the lubricant: A fluid may contain detergent additives, which will prevent agglomeration of particles and discourage surface adhesion.
- Physical traps: Particles may settle out or adhere to the surfaces semi-permanently. Examples include: the bottom of sumps, oil tanks, etc.

To obtain a representative sample of lubricant for Wear Particle Analysis, these guidelines should be followed:

- Samples should be taken from a single location in a system. Since large particles are so important in Wear Particle Analysis, every effort should be made to take a sample before an in-line filter.
- Samples should be taken during normal operating conditions.
- If samples cannot be taken while the machine is in operation, sample no more that 15 minutes after shutdown.

A further consideration is the effect of an oil change. Since a complete lubricant change removes the majority of particles from the system, the operational period needed to return to normal equilibrium must be considered (this rarely exceeds 24 hours). Each machine has a characteristic time it returns to equilibrium. Large particles will regain their equilibrium level sooner than small particles.

**Sampling from Pipes**
Dynamic sampling during operation yields the most representative sample. For best results, the sample should be taken before filtering from a pipe that carries oil scavenged from the wearing parts.

The sample must represent the complete system, i.e., the scavenged oil must pass through all wearing parts. If the pipe is large and the flow velocity is low, sampling from the bottom of the pipe should be avoided.

Sample valves should always be flushed before taking a sample.

**Sampling from Tanks**
There are two principle sources of error in oil tank sampling, both related to the natural tendency of the particles to settle:

1. If the sample is removed from the bottom of a tank, a high particulate volume may be obtained as a result of sedimentation.
2. If a sample is taken from the reservoir too long after machine shutdown (more than 15 minutes), a low particulate volume may be obtained due to settling of debris.

The following are recommendations for sampling tanks:

- It is preferable to remove a sample while the system is operating. If this is not possible, the sample should be obtained within 15 minutes after machine shutdown.
- If the system contains a permanently installed sampling line, it should be flushed prior to sample removal. The dead volume of oil in the sample line should be estimated and approximately twice that volume extracted before the actual sample is taken.
- Sample from the center of the tank or halfway through the fluid level. Maintain sufficient clearance above the sludge line.
- If a standpipe is used for sampling, it should be designed so that the particles will not settle directly into the pipe.
- The user should make a sampling rod to retrieve samples from a tank. The polyethylene tune is attached to the rod and the rod inserted through an opening in the tank. The rod should be designed with a "stand-off" feature to prevent the end of the tune from touching the sides and the bottom of the tank.

*Predict Technologies Division*
*9555 Rockside Road • Cleveland, Ohio • 44125*
*800-543-8786 • 216-642-3223 • Fax: 216-642-3223*

*DLI Engineering Division*
*253 Winslow Way West • Bainbridge Island • WA 98110*
*206-842-7656 • Fax: 206-842-7667*

**Effects of In-Line Filters**
Filters change the particle population in two ways. First, they lower the number of particles in the oil. Second, filters remove large particles more effectively than small ones, so that the number of larger particles is reduced. Consequently, samples should be taken upstream of a filter to ensure the most representative sample of a system.

**Grease Samples**
Taking grease samples poses a special problem since greases do not circulate like oils. Wear particles will concentrate in certain areas depending on bearing design. Consult your PREDICT Technologies Sales Representative about the appropriate sampling techniques for the bearings you want to monitor.

**Sampling Frequency**
Sampling frequency is determined by the nature of the machine, its use and how important early warnings is to the user. Failures can result from operation beyond the machine's design specifications or from effects of the operating environment.

Experience has shown that taking a monthly sample ensures that the onset of abnormal wear is detected in time to minimize the consequences. Longer intervals increase the possibility of undetected progressive failure.

**Sample Bottles and Caps**
PREDICT Technologies provides bottles and caps to ensure the integrity of Wear Particle Analysis.

**Sampling Accessories**
The following accessories are available for taking samples.

Sample Pump
The manual suction pump draws an oil sample from a sump. Contamination is eliminated because the oil comes in contact with a disposable plastic tube.

Polyethylene Tube
One-quarter-inch or five-sixteenth-inch OD tubing is used with the sampling pump. Provided in reels of 500 ft. or 100 ft., the tubing is cut in the field to suit the application and to avoid contamination. The used section of tubing is discarded after each sample is taken.

**Training**
A one hour lecture on the contents of this document, followed by on-site demonstrations and discussions, should adequately train an operator or technician in proper sampling techniques.

January, 1997

# Addendum to Lubricant Sampling Techniques Technical Bulletin

Many customers ask for specific drawings, blueprints, or other means of identifying exactly where oil sampling ports should be placed on components. Unfortunately, no drawings exist that I know of for equipment; instead there are rules that, if followed, will result in the placement of sampling valves in the most representative location. The great variety of gearcases, bearing stands, couplings, turbines, compressors, etc., makes even generic drawings difficult to generate. Those most familiar with the inner workings of the component are best suited to select and place sampling ports or sampling locations. Therefore, the following points are re-emphasized for those wanting to select sample valve or port locations:

1. Remember, all samples should be taken from a point closest to the exit point of the last lubricated element prior to returning to the sump or reservoir. This helps to ensure that the sample is representative of the on-going wear condition and circulating contaminates.
2. If a sampling valve is used, generally in a low or non-pressurized system, make the connection as short as possible. Make sure the valve is installed where the lubricant is in turbulent motion and representative of the total fluid volume. If the valve is installed in a return pipe having significant flow rate (velocity), an extension of the valve assembly into the pipe (with the upstream side cut down) may be necessary to ensure trapping a representative population of large particles. Prior to taking the sample, the line must be flushed of stagnant oil. Estimate the volume of stagnant oil and let at least twice that volume pass into a waste container before taking the lab sample.
3. If it is unsafe to take a sample while the unit is running, shut down the unit and take the sample within 15 minutes. Settling occurs much faster in warm or hot oils; therefore, make sure you are not sampling off the top of the sump or reservoir. The sampling point should be in the middle 2/3's of the reservoir or sump.
4. If a sample pump (sample thief) is used, there is significant difficulty in getting repeatable samples from one month to the next. Therefore, care is required in getting the sample. Make sure you are not sampling from a 'dead' or stagnant portion and, if possible, attach the tubing to a wire or rod and mark the depth at which you take the sample. Each sampling period, sample from the same location.

Be aware that your goal is to get a sample representative of the circulating contamination, wear, moisture and gases. The mechanic responsible for the equipment knows and understands the component best and, becoming familiar with the sampling goals, is the best consultant on where to install a sampling valve. Most equipment require some modification to ensure effective sampling points; therefore, it is best to consult the people most knowledgeable of the equipment.