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LUBRICATION FUNDAMENTALS

A Suncor Energy business

LUBRICATION FUNDAMENTALS

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- **Functions of a Lubricant**
- Lubricating Oil Properties
- Base Oils
- Lubricating Oil Films
- Oil Additives

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LUBRICATION INDUSTRY

API	American Petroleum Institute
ASTM	American Society for Testing Materials
SAE	Society of Automotive Engineers
NLGI	National Lubricating Grease Institute
STLE	Society of Tribologists & Lubrication Engineers
AGMA	American Gear Manufacturers Association
ISO	International Organization for Standardization

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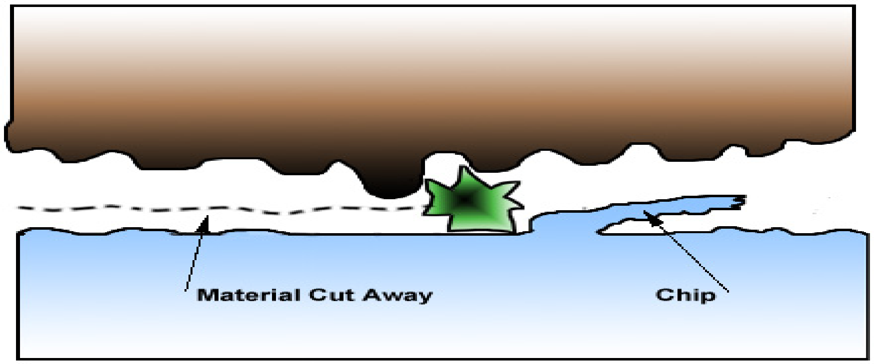
TRIBOLOGY

- Is the science and technology dealing with the **design**, **lubrication**, **friction**, and **wear** of interacting surfaces in relative motion



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FUNCTIONS OF A LUBRICANT

- Reduce Friction
- Minimize Wear (Keep Moving Surfaces Apart)
- Cool Parts (Carry Away Heat)
- Prevent Corrosion
- Disperse Combustion Products (e.g., Soot)
- Act as a Sealant
- Transmit Power

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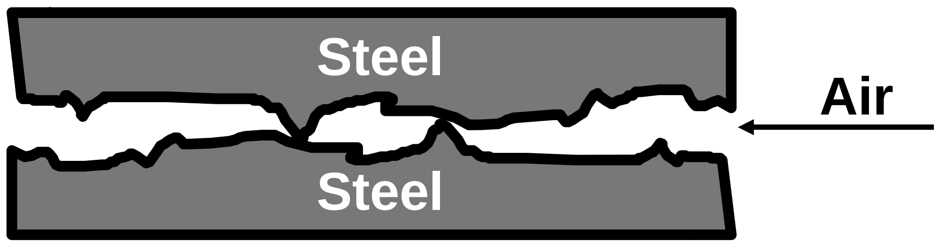
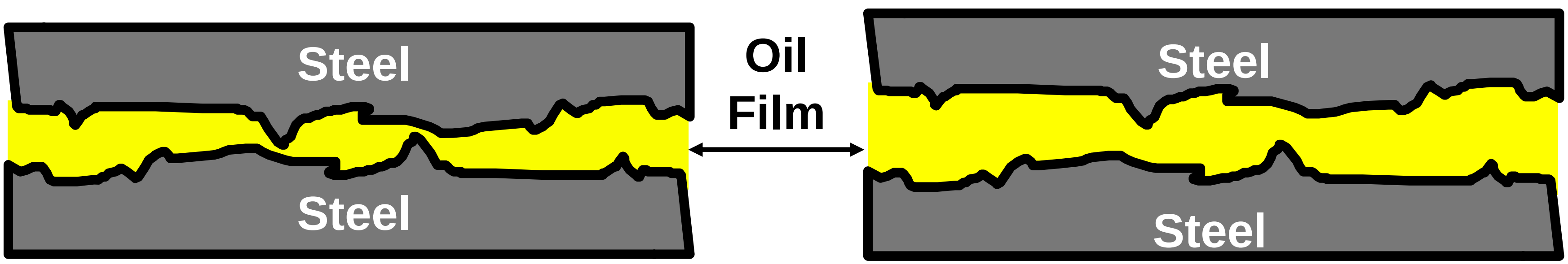
WHY LUBRICATE?

- Lubrication is key when sliding (area) contact is present.
- Lubricants are used to reduce friction and wear by preventing metal to metal contact.



No Lubricant: High Friction



Thin Film (Boundary) Lubrication: Moderate Friction

Full Film (Hydrodynamic) Lubrication: Low Friction

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LUBRICATION FUNDAMENTALS

- Functions of a Lubricant
- **Lubricating Oil Properties**
- Base Oils
- Lubricating Oil Films
- Oil Additives

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LUBRICATING OIL PROPERTIES

- Viscosity
- Viscosity Index
- Density / Specific Gravity
- Flash Point
- Fire Point
- Pour Point
- Cloud Point

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LUBRICATING OIL PROPERTIES

- What is the most important characteristic of a lubricating oil?

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LUBRICATING OIL PROPERTIES

- What is the most important characteristic of a lubricating oil?

1. Viscosity

2. Viscosity

3. Viscosity

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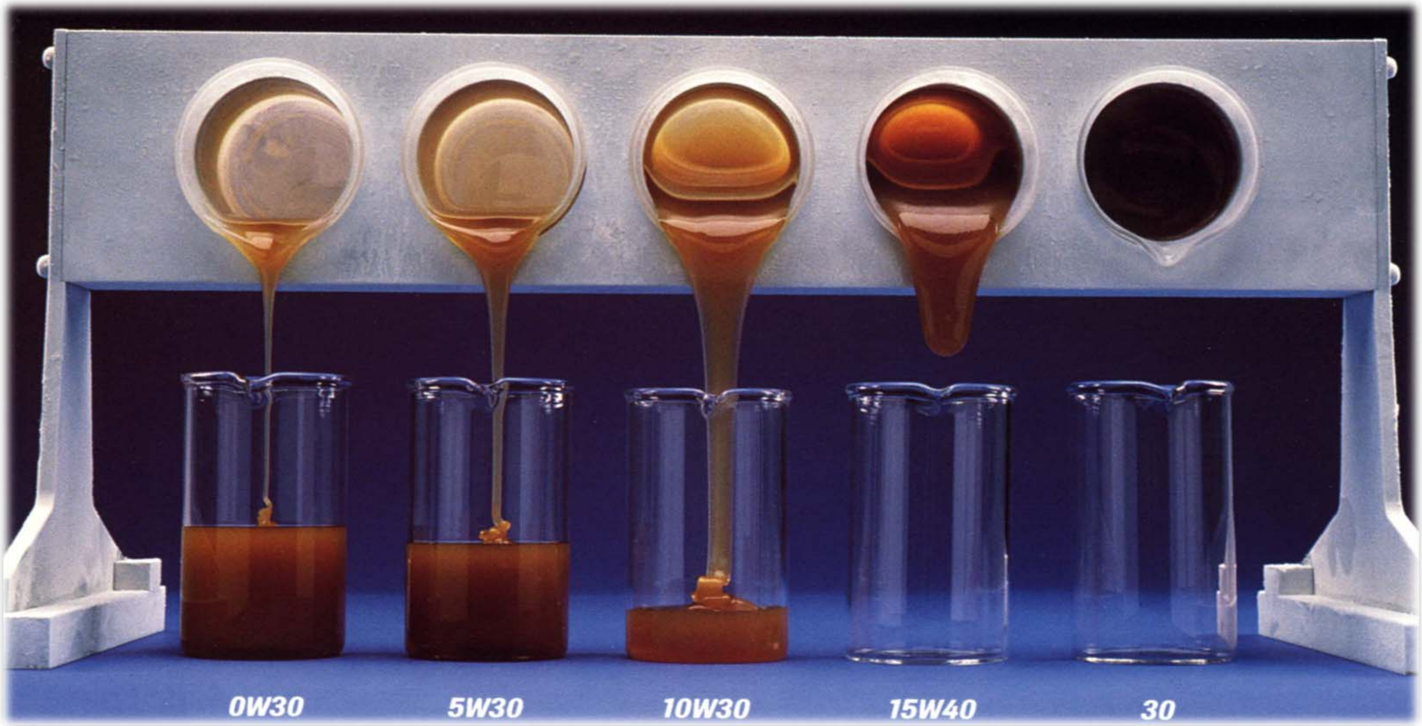
VISCOSITY

- Measurement of the oil's internal resistance to motion



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VISCOSITY

- Measure of resistance to flow at a given temperature (Typically 40ºC & 100ºC)
    - Viscosity changes inversely with temperature
        - * i.e., As temperature increases, oil becomes thinner
    - Change in Viscosity is NOT linear

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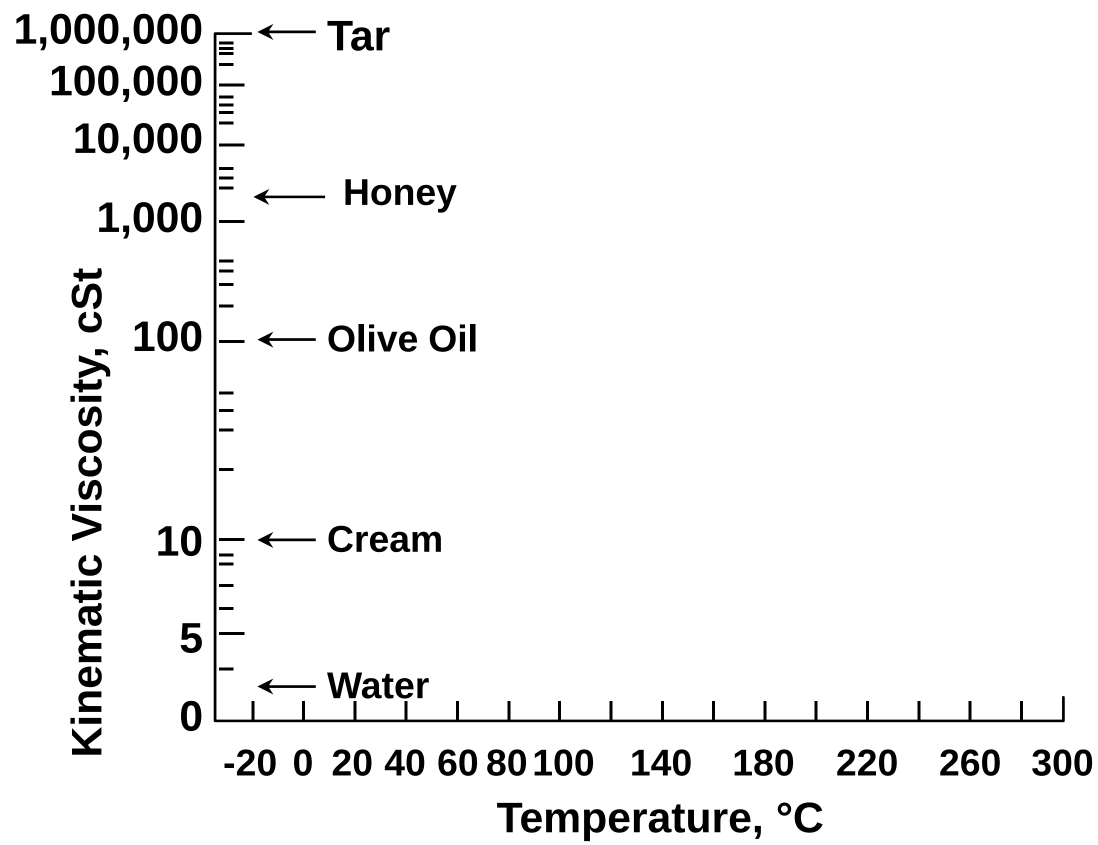
VISCOSITY AND TEMPERATURE

- Lubricant Viscosity Decreases Dramatically With Increasing Temperature
(Log-Log Relationship)

- Viscosity Index (V.I.) is a Measure of the "Viscosity-Temperature Relationship" for an Oil

- Multigrade Oils Have Higher V.I.'s Than Single Grades - Viscosity Changes Less With Temperature



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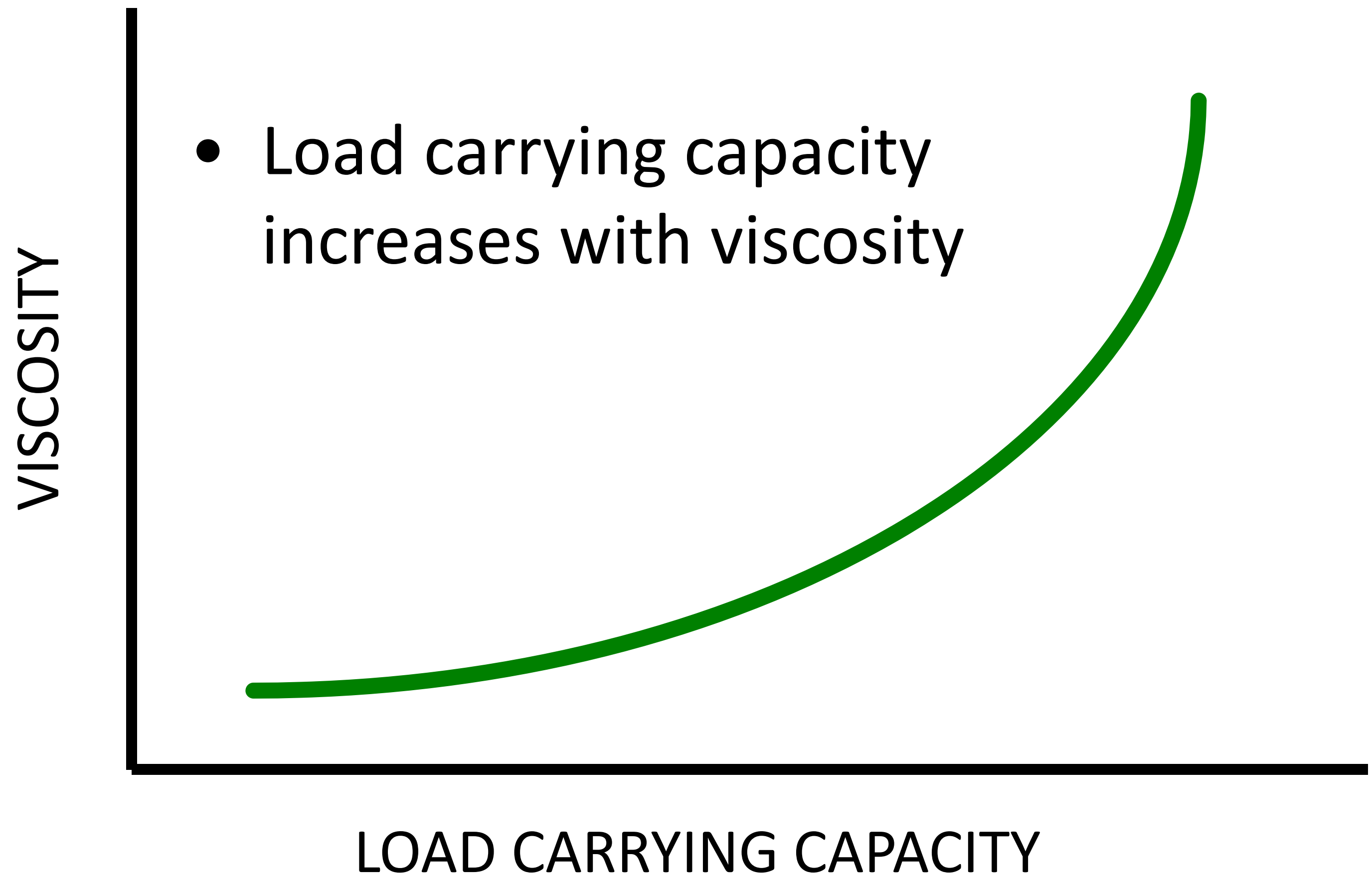
VISCOSITY

- Load carrying capacity increases with viscosity



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VISCOSITY EXAMPLE

- Using the viscosity chart paper provided, determine the viscosity of the following product at 70^{o}C
  - 32 cSt @ 40^{o}C
  - 6.5 cSt @100^{o}C

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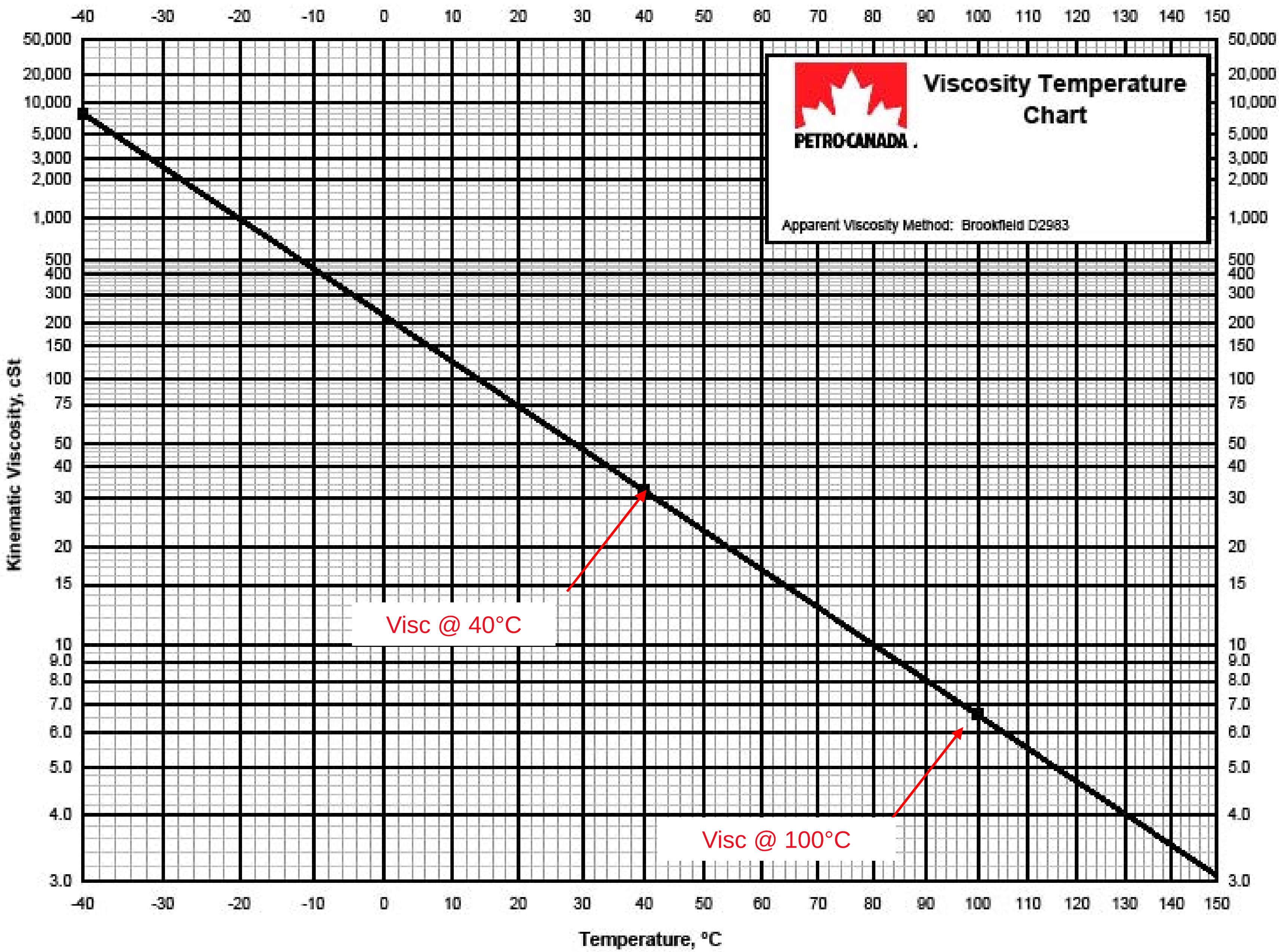

Petro-Canda Lubricants Viscosity Temperature Chart

VISCOSITY MEASUREMENT

- Viscosity Systems (most common)
  - Kinematic (cSt) (metric)
    - American (SUS / SSU)
  - Absolute (cP)

    * Low temperature

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KINEMATIC VISCOSITY

- Measure of fluid's resistance to flow due to gravity
- Derived from the time taken for a lubricant to travel through a capillary tube
- Measurement – Stoke (St)

  $= 1\ cm^2$ / second
- **Typically reported as centistoke – (cSt)**

  $= 1\ mm^2$ / second

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ISO VISCOSITY SYSTEM

ISO Viscosity Grade	Mid point @40ºc (cSt)	Minimum (cSt)	Maximum (cSt)
2	2.2	1.98	2.42
3	3.2	2.88	3.52
5	4.6	4.14	5.06
7	6.8	6.12	7.48
10	10	9.0	11.0
15	15	13.5	16.5
22	22	19.8	24.2
32	32	28.8	35.2
46	46	41.4	50.6
68	68	61.2	74.8
100	100	90	110
150	150	135	165
220	220	198	242
320	320	288	352
460	460	414	506
680	680	612	748
1000	1000	900	1100
1500	1500	1350	1650

ISO SYSTEM
+/- 10%

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AGMA VISCOSITY SYSTEM

Equivalent ISO Grade	Viscosity Range (cSt @40ºC)	AGMA R&O #	AGMA EP #	AGMA Synthetic #
32	28.8 – 35.2	0		0 S
46	41.4 – 50.6	1		1 S
68	61.2 – 74.8	2	2 EP	2 S
100	90 – 110	3	3 EP	3 S
150	135 – 165	4	4 EP	4 S
220	198 – 242	5	5 EP	5 S
320	288 – 352	6	6 EP	6 S
460	414 – 506	7, 7 Comp	7 EP	7 S
680	612 – 748	8, 8 Comp	8 EP	8 S
1000	900 – 1100	8A, 8A Comp	8A EP	
1500	1350 – 1650	9	9 EP	9 S
	2880 – 3520	10	10 EP	10 S
	4140 – 5060	11	11 EP	11 S
	6120 – 7480	12	12 EP	12 S
	190 – 220 (100ºC)	13	13 EP	13 S

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SAE J300 (1999) VISCOSITY CLASSIFICATION

SAE Viscosity Grade	Low Temperature Cranking Viscosity, Max (cP @ ºC)	Low Temperature Pumping Viscosity, Max (cP @ ºC)	Kinematic Viscosity @ 100ºC, Min (cSt)	Kinematic Viscosity @ 100ºC, Max (cSt)	High Shear Rate Absolute Viscosity @ 150ºC, Max (cP)
0W	6200 at -35	60 000 at -40	3.8	-	-
5W	6600 at -30	60 000 at -35	3.8	-	-
10W	7000 at -25	60 000 at -30	4.1	-	-
15W	7000 at -20	60 000 at -25	5.6	-	-
20W	9500 at -15	60 000 at -20	5.6	-	-
25W	13000 at -10	60 000 at -15	9.3	-	-
20	-	-	5.6	<9.3	2.6
30	-	-	9.3	<12.5	2.9
40[1]	-	-	12.5	<16.3	2.9
40[2]	-	-	12.5	<16.3	3.7
50	-	-	16.3	<21.9	3.7
60	-	-	21.9	<26.1	3.7

[1] 0W-40, 5W-40 and 10W-40 grades   [2] 15W-40, 20W-40 and 25W-40 grades

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LUBRICANT PROPERTIES: VISCOSITY INDEX (VI)

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- **Viscosity** is a measurement of resistance to flow at **one** temperature.
- **Viscosity Index (VI)** is a measurement of the rate of change of viscosity over a **range** of temperatures. In simple terms: it measures how fast the oil thickens up as it gets colder or how fast it thins out as it gets hotter.
- **With Most lubricants, the higher the VI the better**

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LUBRICANT PROPERTIES: VISCOSITY INDEX (VI)

- The **Viscosity Index** is calculated from viscosities at 40°C and 100°C

- **High VI** is a term which means that the oil is usable over a wider temperature range.

- **VHVI** = Very High Viscosity Index

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TYPICAL VI OF DIFFERENT BASE STOCKS

- **Base Stocks** are the refined oils (derived from crude oil) which are blended together with additives to produce a finished lubricant. They are described in a separate section.
- Traditional **solvent refined** paraffinic base stocks have VIs in the range **85 to 95**. Process improvements such as "hydrofinishing" can improve the VI to **over 100**.
- Our **HydroTreated** base stocks have Viscosity Indices in the range **90-110**.
- Our **Hydro-cracked** iso-dewaxed base stocks are **over 120 VI .**

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VISCOSITY INDEX

PETRO-CANADA

- **V**iscosity **I**ndex is an **inherent property of the base oil** used to blend a lubricant.
- **VI can be improved** significantly by blending soluble additives called VI Improvers into the oil.
- These additives are long polymer molecules which uncoil at high temperatures to increase viscosity, while at low temperatures they form tight "balls" which no longer contribute much to viscosity.
- One caution : **VI improvers do not last for ever** in a blend. They can be chopped up or "sheared down" by constant mechanical motion in the oil.

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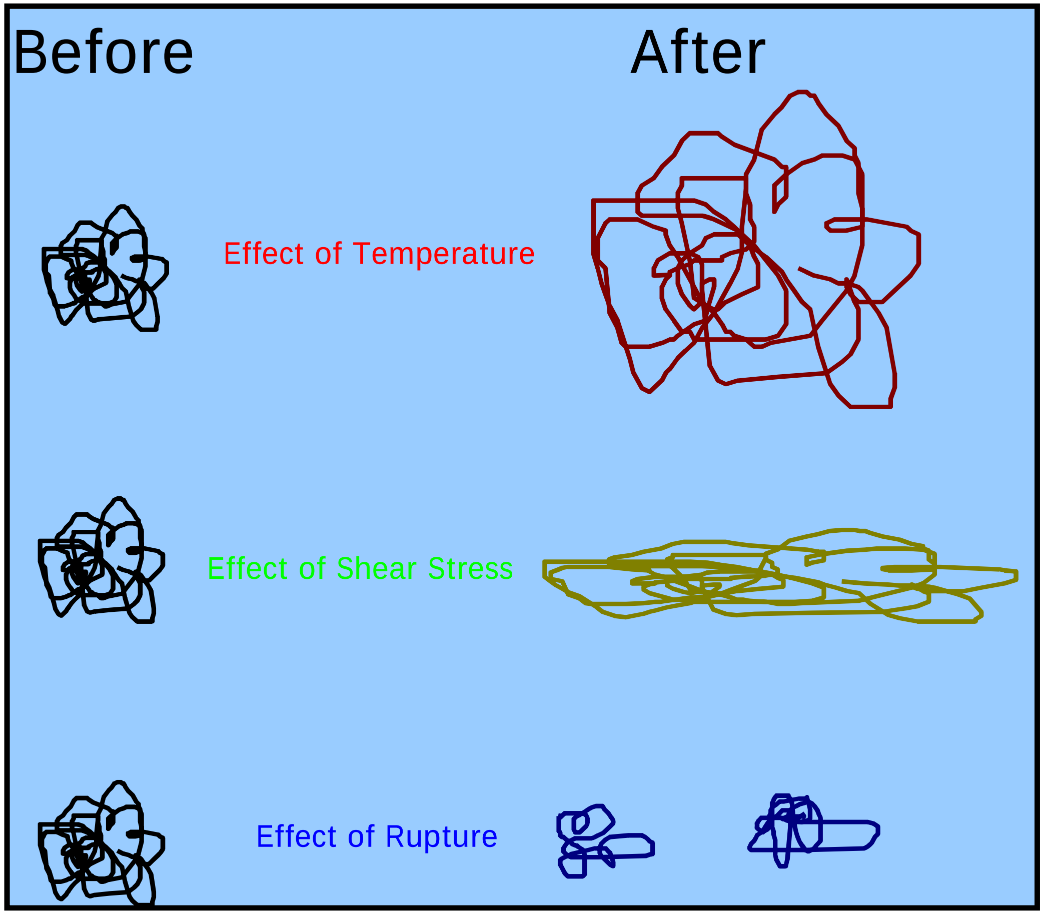
HOW A VI IMPROVER WORKS

Large "string-like" molecules that expand (unwind) at higher temperatures, thereby preventing the oil from thinning out too rapidly.

Under “Shear Stress”(e.g. going through small orifices in hydraulic valves, or squeezed by piston rings on cylinder walls) the VI improver can be ruptured and lose its effectiveness.



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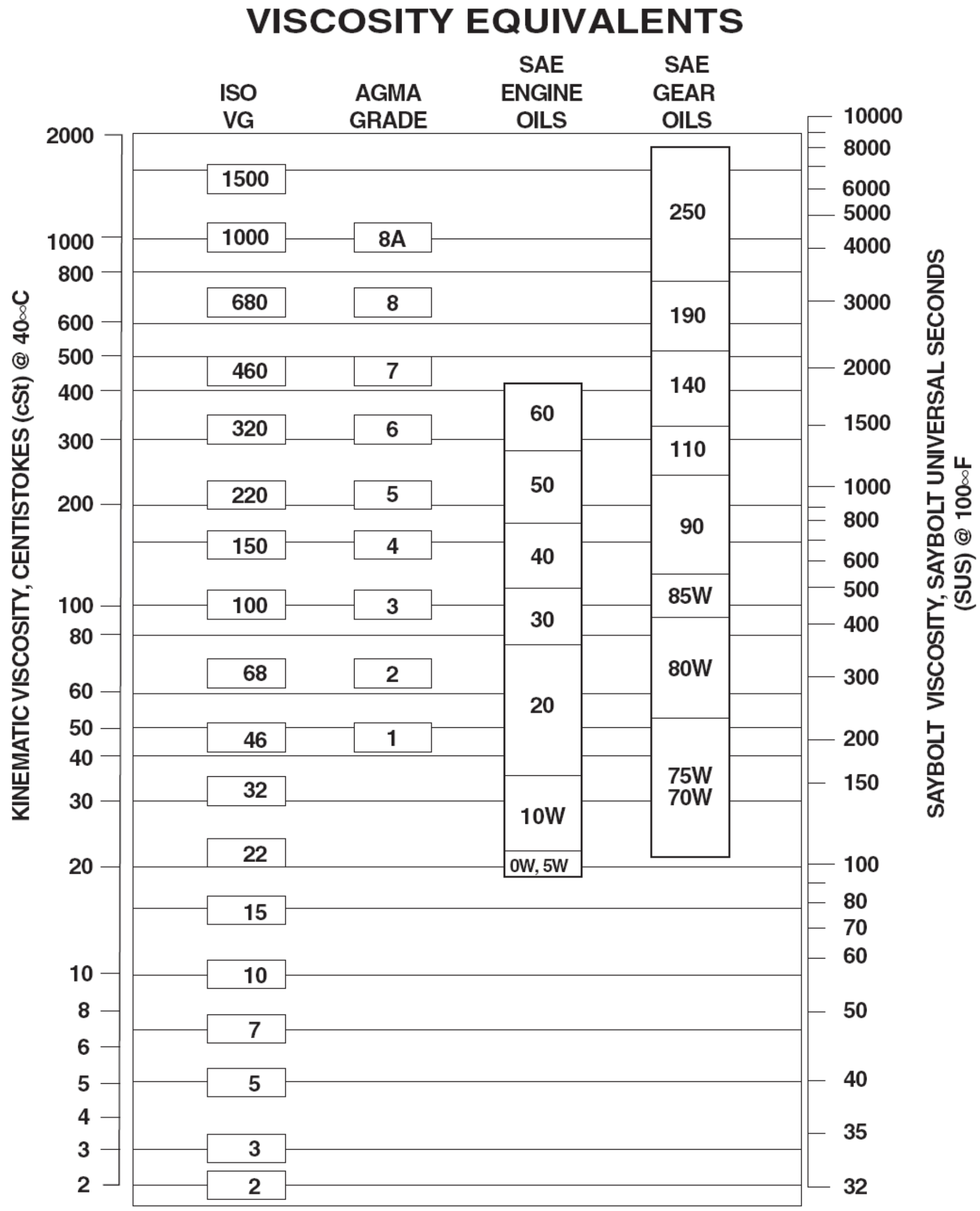
VISCOSITY COMPARISON CHART

NOTE:

- Read across horizontally.
- Assumes 96 VI single grade oils.
- Equivalence is in terms of viscosity at 40°C only.
- Viscosity limits are approximate: For precise data, consult ISO, AGMA and
- SAE specifications.
- W grades are represented only in terms of approximate 40°C viscosity.
- For low temperature limits, consult SAE specifications.



VISCOSITY – RULES OF THUMB

Minimum Viscosities

Centistokes (At Operating Temperature)

33	For gear lubrication.
30	For a gear pump.
21	Spherical roller bearings.
13	Other rolling element bearings.
13	Hydraulic systems to prevent excessive pump wear and slippage.
13	Plain bearings.
4	Minimum viscosity to support a dynamic load.

OPTIMUM VISCOSITIES

The optimum viscosity is the ideal allowable at the operating temperature.

Centistokes

25	Hydraulic systems
30	Plain Bearings
40	Spur & Helical Gears (e.g. ISO-VG 150 @ 60°C)
75	Worm Gears (e.g. 460 @ 75°C)

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LUBRICATION FUNDAMENTALS

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- Lubricating Oil Properties
- **Base Oils**
- Lubricating Oil Films
- Oil Additives

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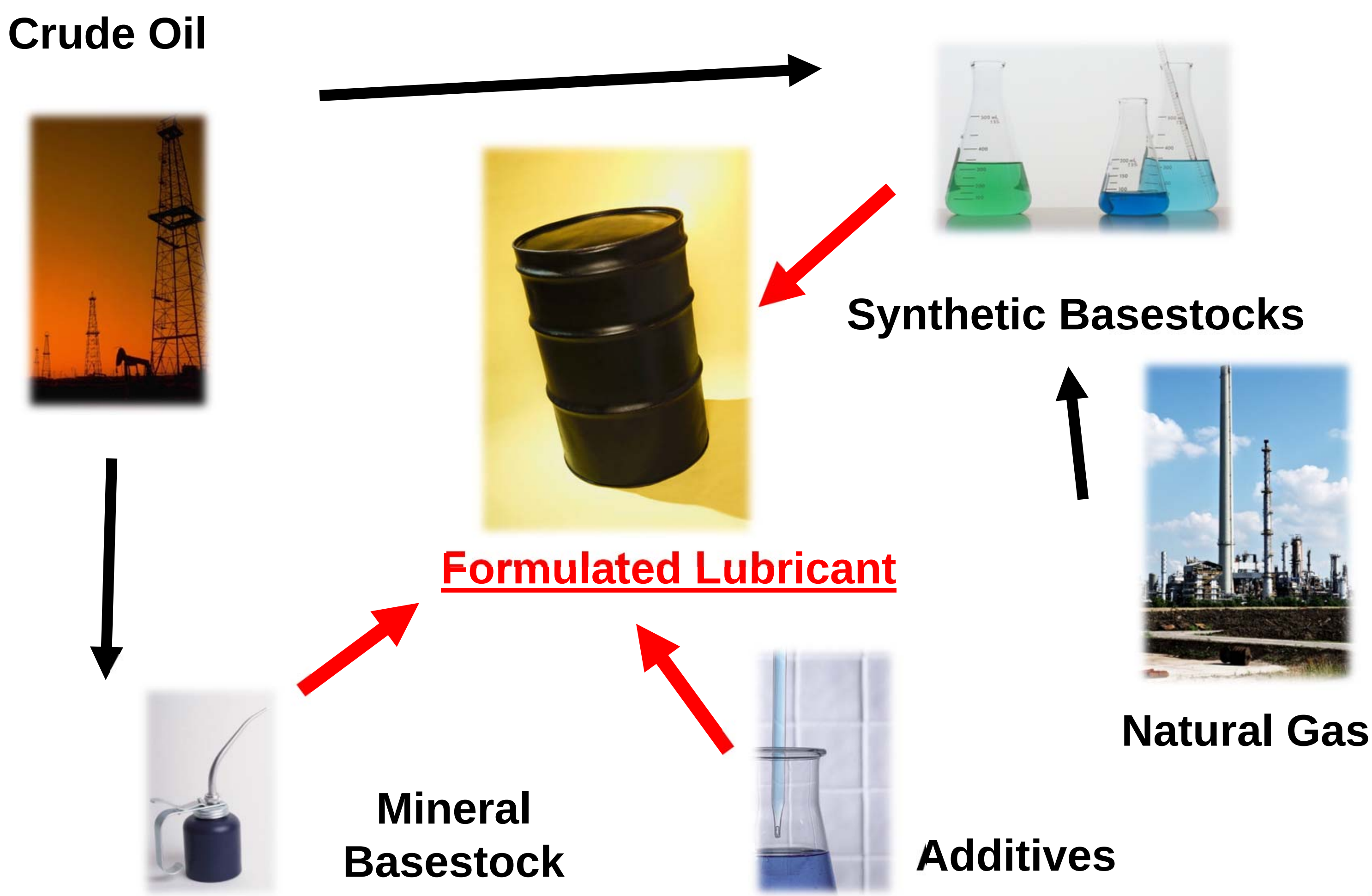
LUBRICATING OILS



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LUBE BASE OILS - API CLASSIFICATION

Base Oil Characteristics				
API Group	**Sulphur wt %**	**Saturates wt %**	**Viscosity Index**	**Manufacturing Method**
I	>0.03	<90	80-119	Solvent Refined
II	<0.03	>90	80-119	Hydroprocessed
III	<0.03	>90	120+	Severely Hydroprocessed
IV	Polyalphaolefins (PAO)			Oligomerization
V	Other Base Oils			Various

Viscosity Index is for base oil only – not final blended product.

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HYDROTREATED VS. SOLVENT REFINED

BENEFITS

- May use poor quality crude
- Lower operating costs
- Typically have higher VI's
- Improved oxidation resistance
- Improved high temperature stability

DISADVANTAGES

- Higher capital costs
- Requires hydrogen supply
- High pressure units - skilled technicians
- Different additive package

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DEFINITIONS

- **MINERAL-BASED**
  – A distillate (physical separation) of petroleum
- **“SYNTHETIC”**
  – Oil derived from chemical manipulation resulting in significant modification from original source
- **BIOBASED**
  – Formulated with renewable and biodegradable base stocks. It’s worth noting that some definitions only consider biodegradability.

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ANALOGY

- Crude oil is extracted from ground
- Group I oil is made from solvent distillation
- Group II and III oils are made using high pressure hydrogen
- Group IV oils are made by chemically selecting a modifying molecule sizes

- Cow is milked
- Milk and cream are separated by gravity only
- Milk is separated by centrifuge and then pasteurized with high temperatures
- Butter is made by forcing tiny fat molecules into larger grouping

*Fluid Life Corp.

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SYNTHETIC OILS

- Polyalphaolefin (PAO)
- Diesters
- Polyglycols
- Phosphate Esters
- Polyol Esters
- Silicones

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BASE OILS COMPARATIVE CHARACTERISTICS

	Mineral Oil	Polyalpha-olefin	Diester	Polyol Ester	Poly-glycol	Phosphate Ester	Silicone Oil
Viscosity Temperature	F	G	G	G	VG	P	E
Low Temperature	P	G	G	G	G	F	G
Oxidation Stability	F	VG	G	E	G	F	G
Compatible with Mineral Oil	E	E	G	F	P	P	P
Low Volatility	F	E	E	E	G	G	G
Anti-Rust	E	E	F	F	G	F	G
Additive Solubility	E	G	VG	VG	F	G	P
Seal Swell	E	E	F	F	G	F	E

P - Poor F - Fair G – Good VG - Very Good E - Excellent

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LUBRICATION FUNDAMENTALS

- Functions of a Lubricant
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- **Lubricating Oil Films**
- Oil Additives

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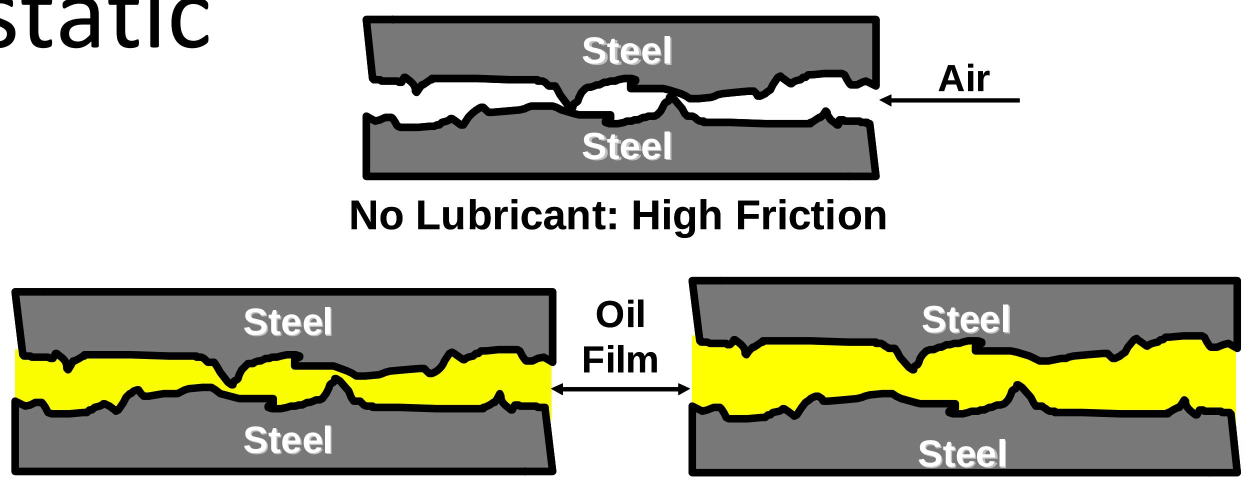
LUBRICATING OIL FILMS

- Hydrodynamic
- Elastohydrodynamic (EHD)
- Boundary
- Hydrostatic



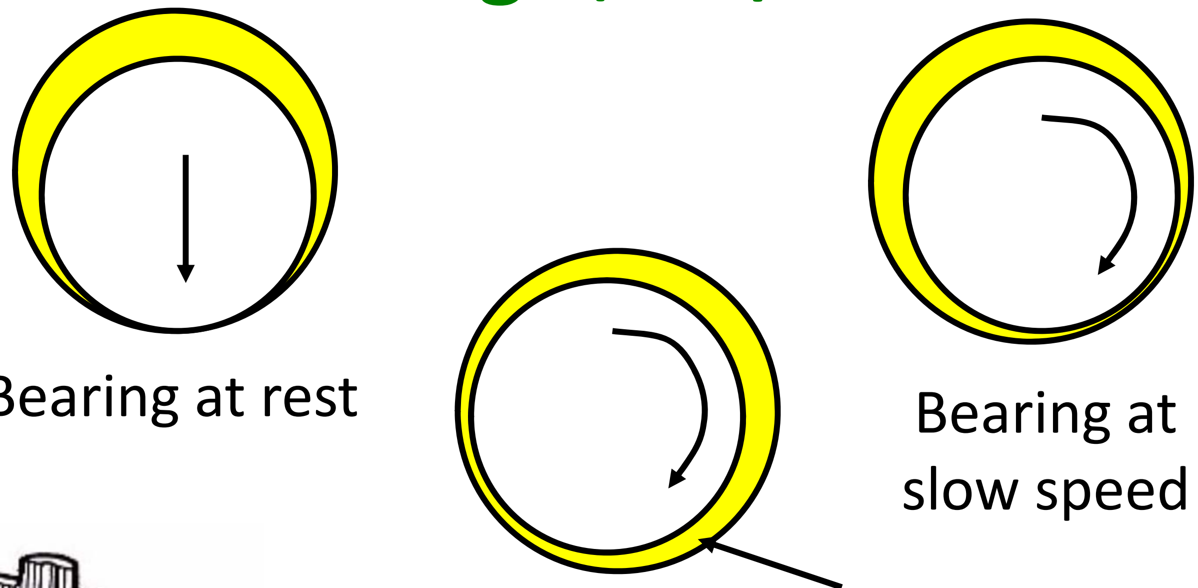
No Lubricant: High Friction

Thin Film (Boundary)
Lubrication: Moderate Friction

Full Film (Hydrodynamic)
Lubrication: Low Friction

HYDRODYNAMIC LUBRICATION

Journal Bearings (Compaction SK-09002)

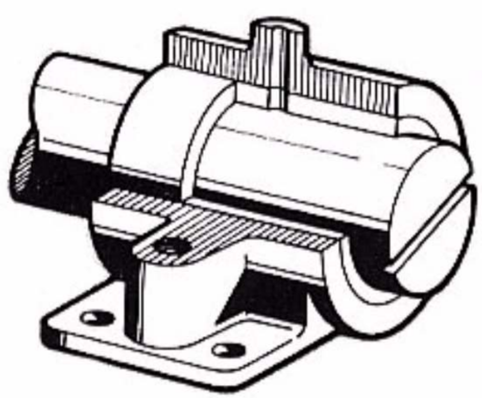


Bearing at rest

Bearing at slow speed

Bearing at high speed

Oil wedge produces pressure, high viscosity, and full film hydrodynamic lubrication



Plain bearing

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LUBRICATION FUNDAMENTALS

- Functions of a Lubricant
- Lubricating Oil Properties
- Base Oils
- Lubricating Oil Films
- **Oil Additives**

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ADDITIVES

- General purposes
- Different additives
    - Specific purpose
    - How they work

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WHY ADDITIVES?

- TO **PROTECT** THE METAL **SURFACES**
- TO **IMPROVE** LUBRICANT **PERFORMANCE**
- TO **EXTEND** LUBRICANT SERVICE **LIFE**

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ADDITIVES

SURFACE PROTECT

Rust inhibitor

Corrosion inhibitor

Anti-wear

Extreme pressure

Dispersant

Detergent

Tackifier

LUBE ENHANCER

Anti-oxidant

Anti-foamant

Pour Point depressant

Vi improver

Friction modifier

Emulsifier

De-emulsifier

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OXIDATION INHIBITOR

- **WHAT IT DOES**
  – Prevents varnish, sludge & acid pre-cursors from forming
- **HOW IT WORKS**
  – Reacts more readily with O_2 than does oil

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OXIDATION INHIBITOR

- It will be used up
- Every 10^{o}C increase in temperature results in oxidation being 2* faster

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OXIDATION INHIBITOR

- Oxidation is significantly **accelerated** by:
  - Catalysts – such as metals, dust, water
  - Oxygen – from high rates of air entrainment
  - High temperature

Temperature °C	Hours	Days
80	10000	416
90	5000	208
100	2500	104
110	1250	52
120	625	26
130	313	13

Example Only – Not real data

Every 10°C rise in sump temperature over 80°C decreases the life of the oil by one half

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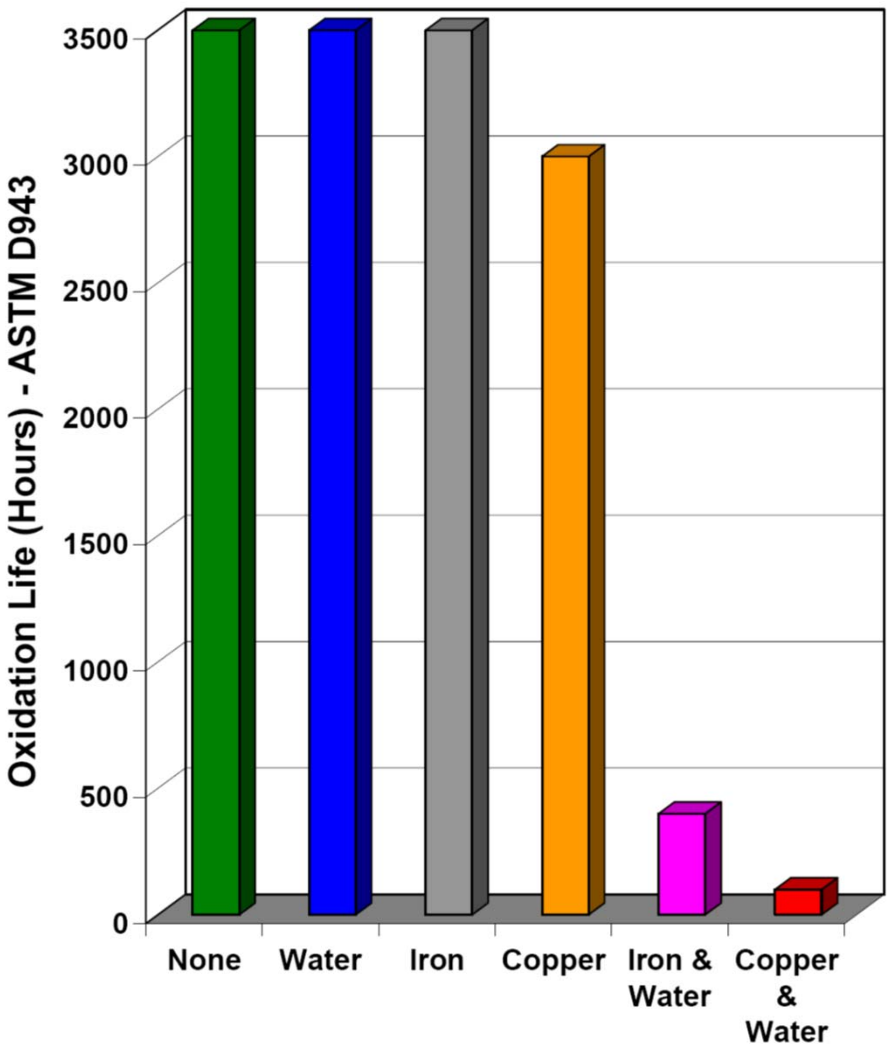
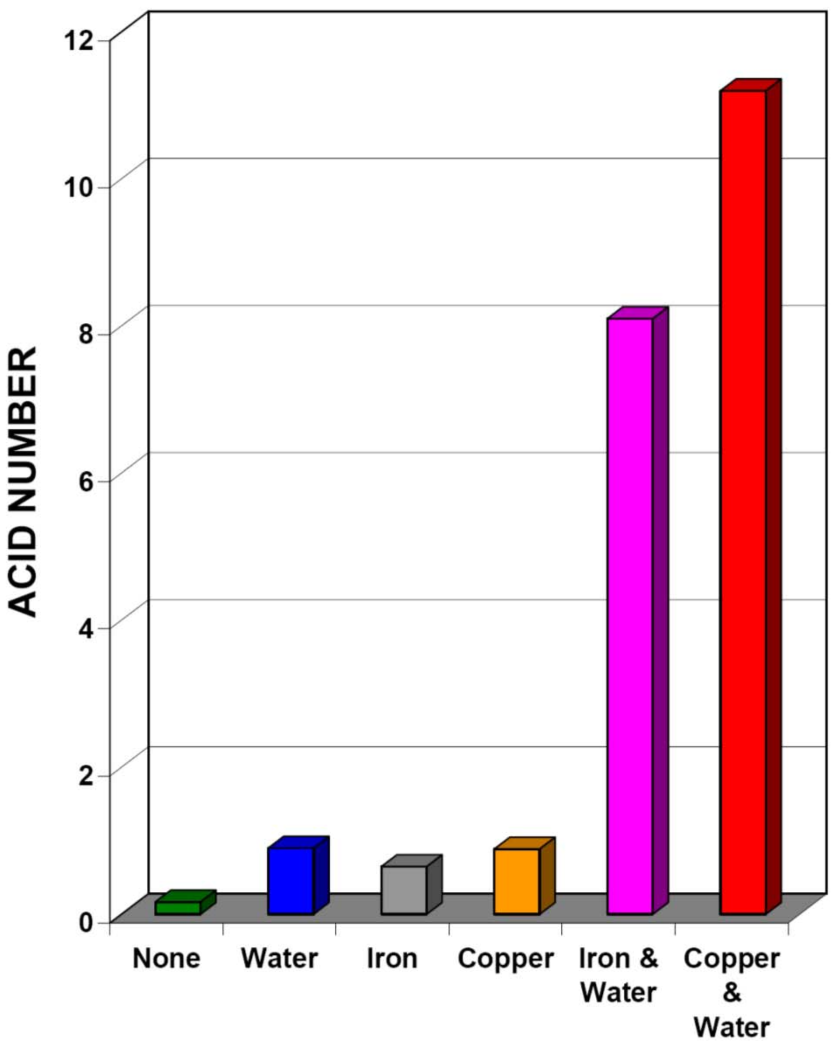
WATER + CATALYST ON OXIDATION LIFE

150 SSU @100°F Turbine Oil

(32 cSt @ 37.8°C)

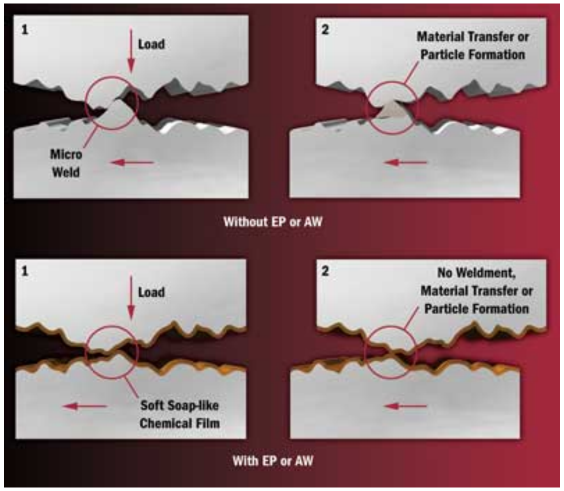




Ref: Volume XXIII – Proceedings of National Conference on Fluid Power, 1969, Weinschelbaum, M.

ANTI-WEAR (AW)

- **WHAT IT DOES**
  - Minimizes wear caused by metal-to-metal contact
- **HOW IT WORKS**
  - Forms chemical film on surface
  - Film rubs off



ANTI-WEAR (AW)

- Typically Zn / P material (ZDDP)
- Sensitive to ‘long term’ water contamination
  - Will result in a reddish deposit
- Will be consumed
  - Not trackable in standard oil analysis because cannot destroy Zn or P
- Needs bare metal surface

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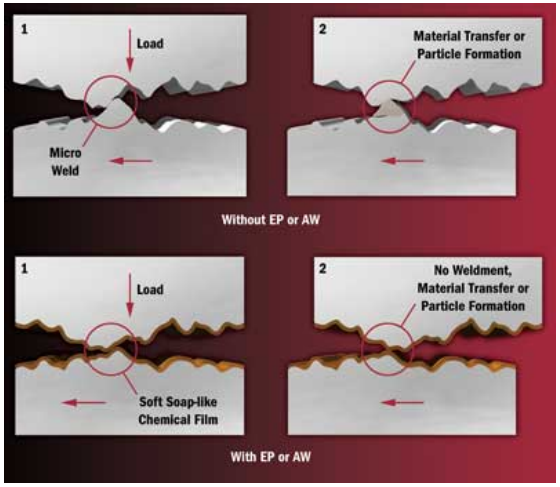
EXTREME PRESSURE (EP)

- **WHAT IT DOES**
  - Prevents welding & excessive wear under shock loading / high vibration
- **HOW IT WORKS**
  - Heat at point of shock load causes formation of new compound
  - Compound wears off



EXTREME PRESSURE

- Typically S – P material
  - Sulphur is reactive to yellow metals, especially above 75°C
- Will be consumed
- In the presence of water and heat can form S & P acids
- Needs bare metal surface

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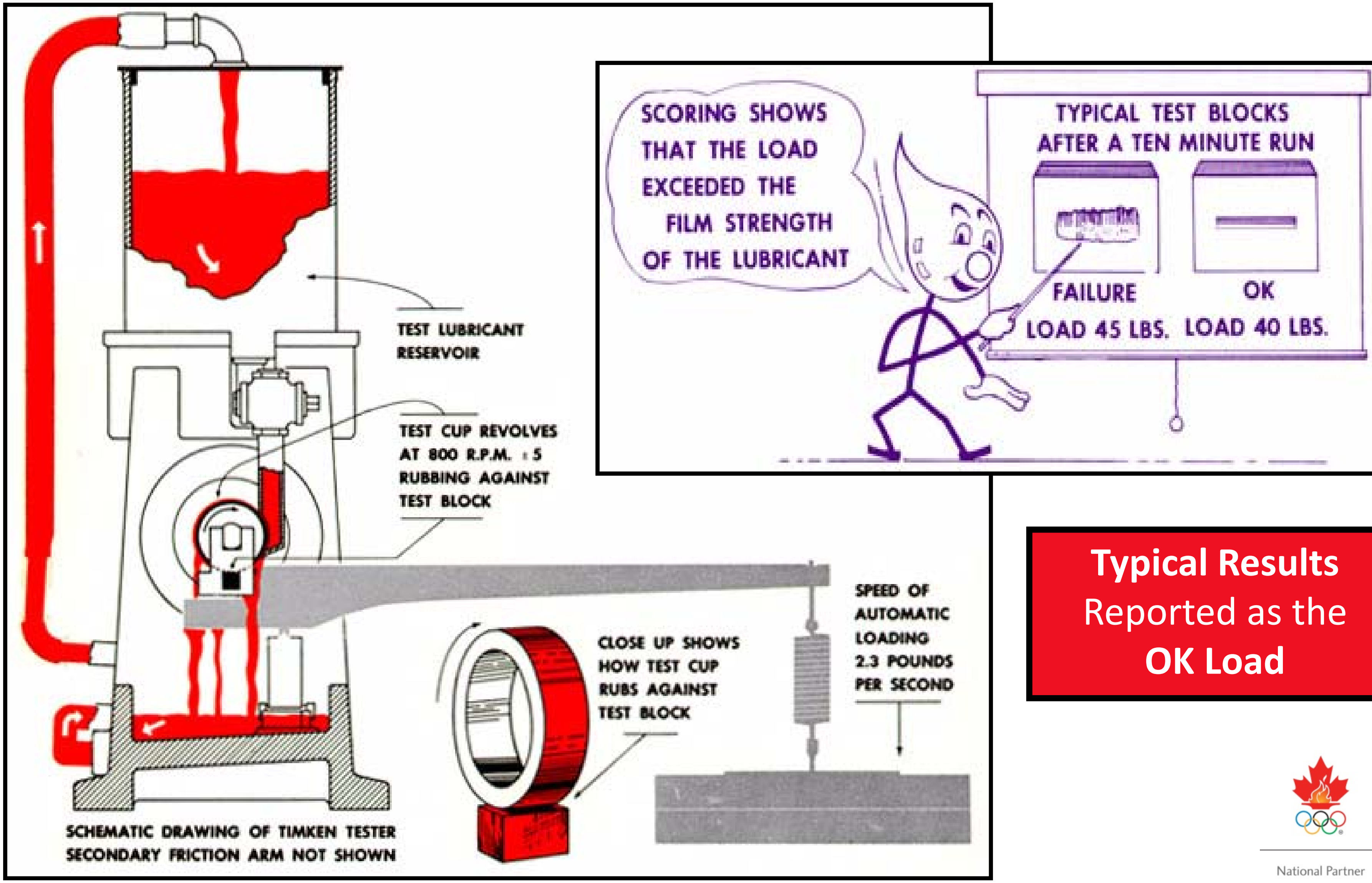
TIMKEN EP TEST



Typical Results
Reported as the
OK Load

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4 BALL EP TEST

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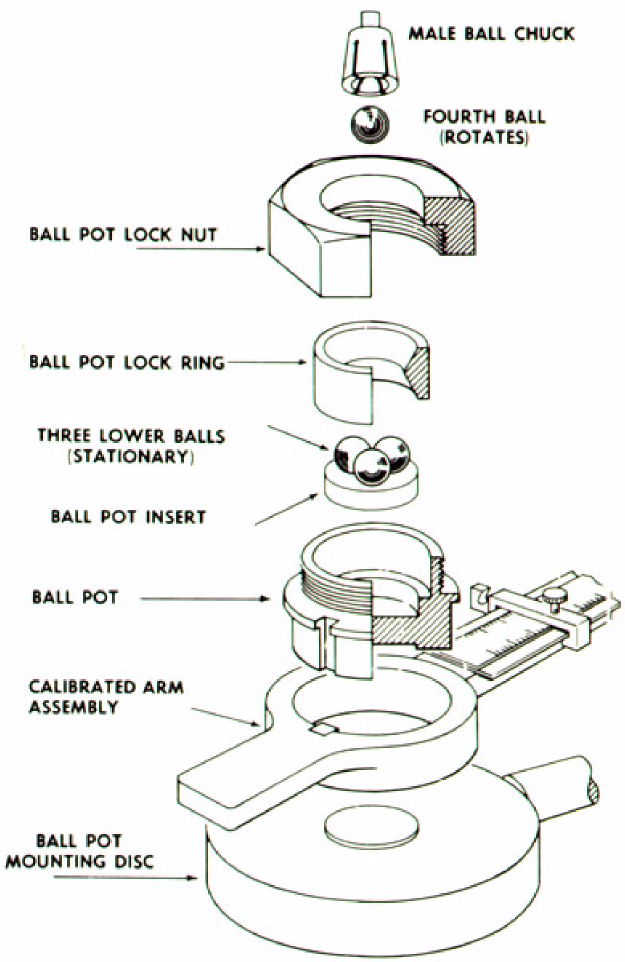
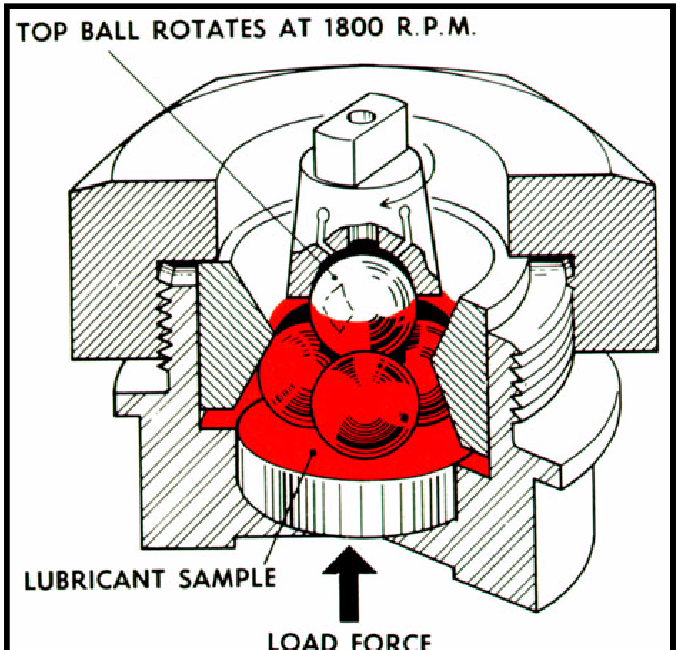
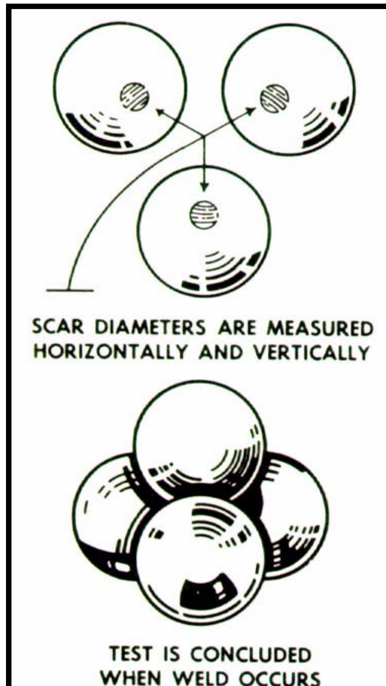
WHY THE TEST?

To evaluate the EP characteristic of lubricants by a load scar curve and weld point.







Typical Results

Weld Point

LWI – Load wear index

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VISCOSITY INDEX (VI) IMPROVER

- **WHAT IT DOES**
  - Reduces rate of change of viscosity with temperature
- **HOW IT WORKS**
  - Additive acts as ‘thickener’ with increasing temperature

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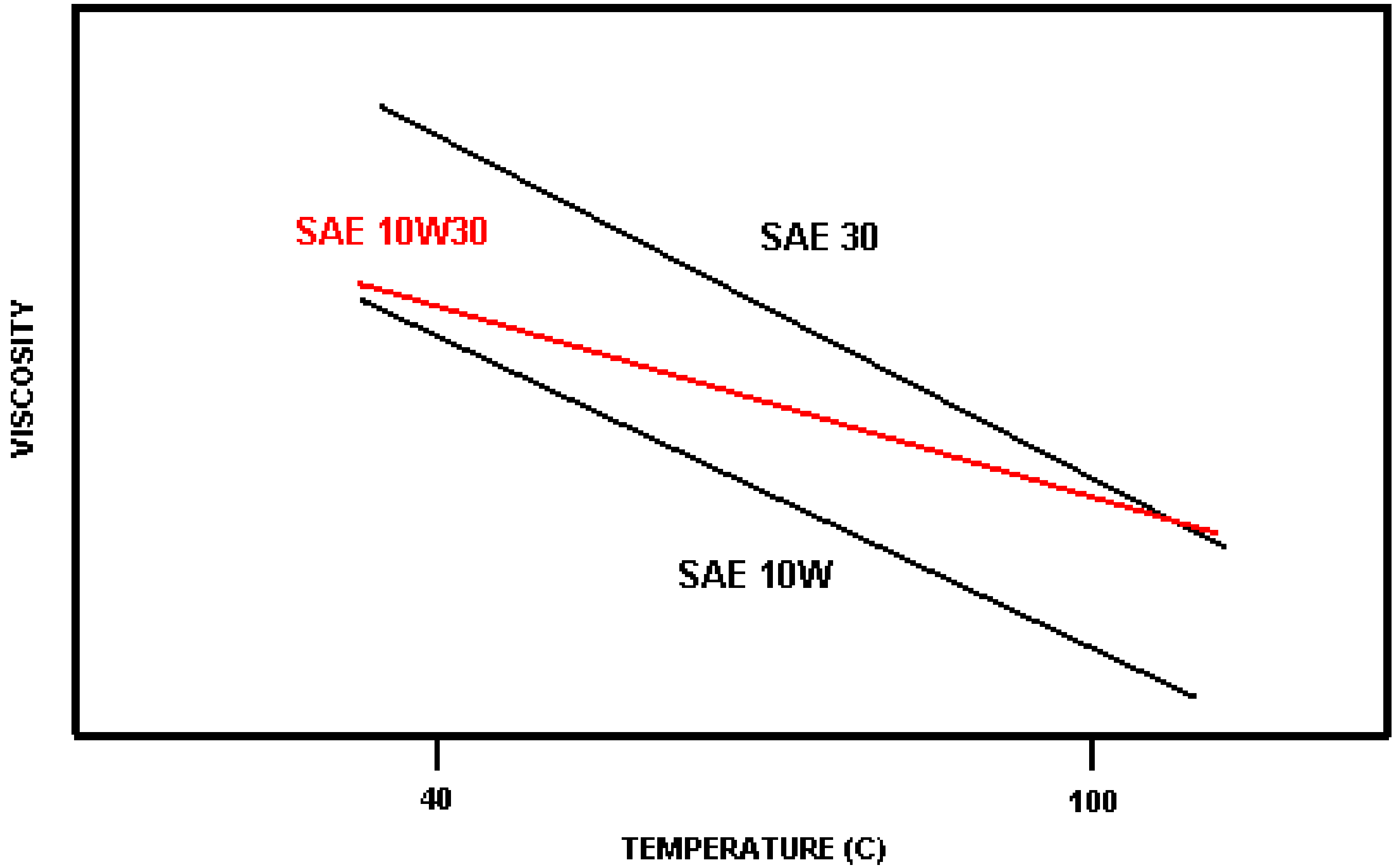
VI IMPROVER



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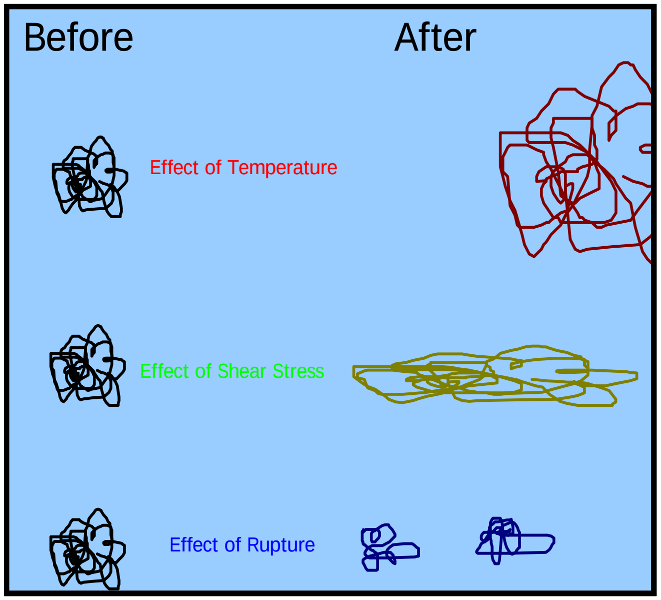
VI IMPROVER

- Can be permanently sheared down under certain high load / high shear operations
  - May or may not be an issue
- Filtration at 1 m may impact this additive



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DISPERSANT

- **WHAT IT DOES**
  - Keeps oxidation particles in suspension in oil
- **HOW IT WORKS**
  - Combines with small particles to prevent formation of large particles

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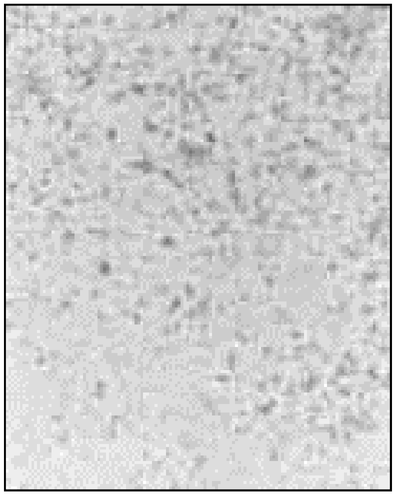
DISPERSANT

- Non-metallic co-component with detergent
- Will be consumed
- Not generally used in industrial oils



Soot Dispersed - Low Viscosity Increase

Soot Agglomerates - High Viscosity Increase

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DETERGENT

- **WHAT IT DOES**
  - Prevents oxidation particles from forming sludge, varnish or gum
- **HOW IT WORKS**
  - Reacts with metal surfaces to minimize space for oxidation particles

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DETERGENT

- Typically metallic additive   (Ca / B / Mg)
- Will be consumed
- Not typically found in industrial oils
- Needs bare metal surface

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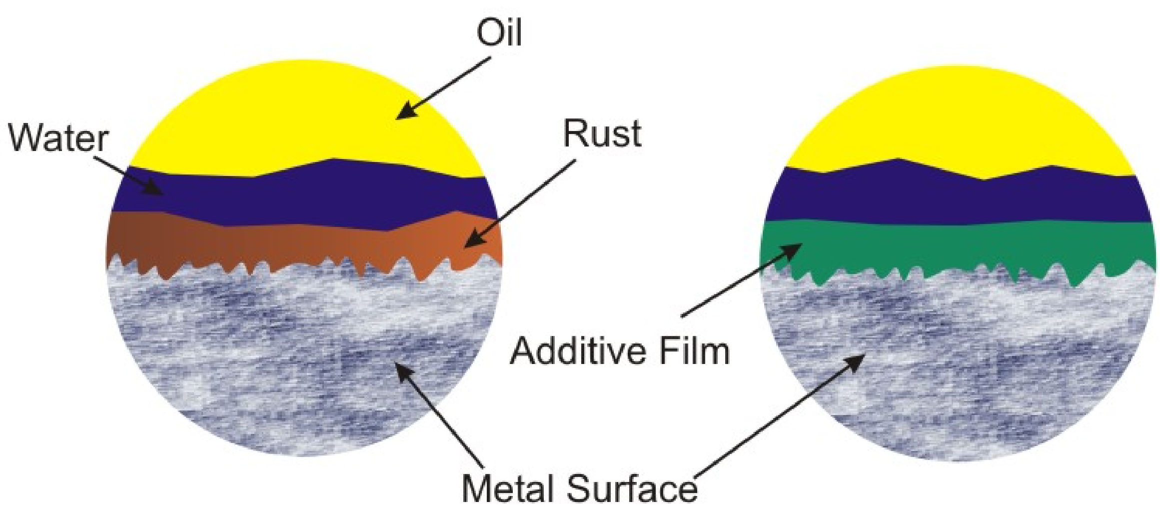
RUST & CORROSION INHIBITORS

- Protects iron and steel parts from attack by acidic contaminants and water
- Forms a protective film on metal
  - – delicate balance, can interfere with other surface active additives



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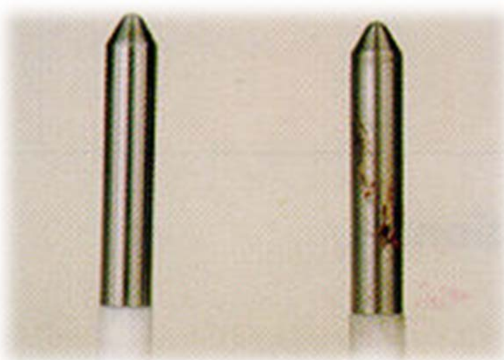
RUST & CORROSION INHIBITORS

Rust Test

- ASTM D665
  - 60°C
  - 24 hours
  - Distilled or Synthetic sea water
  - Pass or Fail



Copper Corrosion

- Evaluates the extent of discolouration or tarnishing of a copper strip immersed in the lubricant
  - ASTM D130
  - 2 Hours @ 100°C
  - Alphanumeric (1a..4c)

ANTI-FOAM AGENTS

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- **WHAT IT DOES**
  - Very important part of lubricant formulation
  - Helps foam to dissipate more rapidly.
  - Large silicon molecules dispersed in the oil.
- **HOW IT WORKS**
  - Promotes combination of small bubbles into large bubbles which break up more easily.
  - Changes surface tension of oil
  - Very low concentrations are required
- **ASTM D892**
  - Three tests, Sequence I, II, III
  - Report the volume of foam (ml) after 5 minute blowing period and 10 minute rest period at each test sequence. (i.e. 10/0)

Sequence I	24°C
Sequence II	93.5°C
Sequence III[1]	24°C

1. On same oil after Sequence II test.

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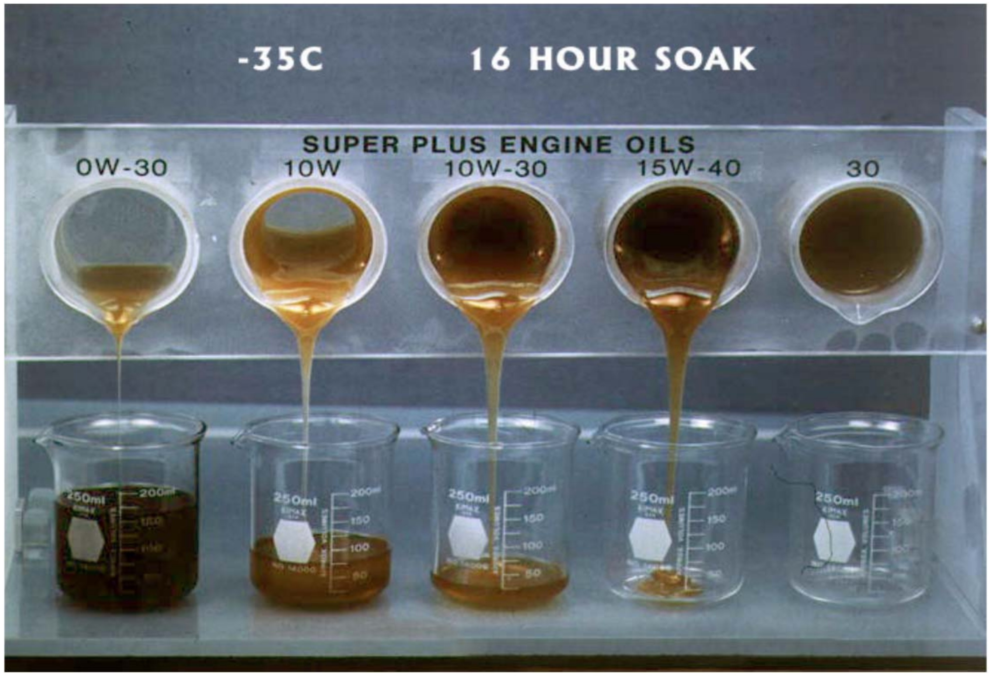
POUR/CLOUD POINT DEPRESSANTS

- Inhibit the formation of large wax crystals
- Enhances the lower operability temperature of the oil
- High molecular weight polymers



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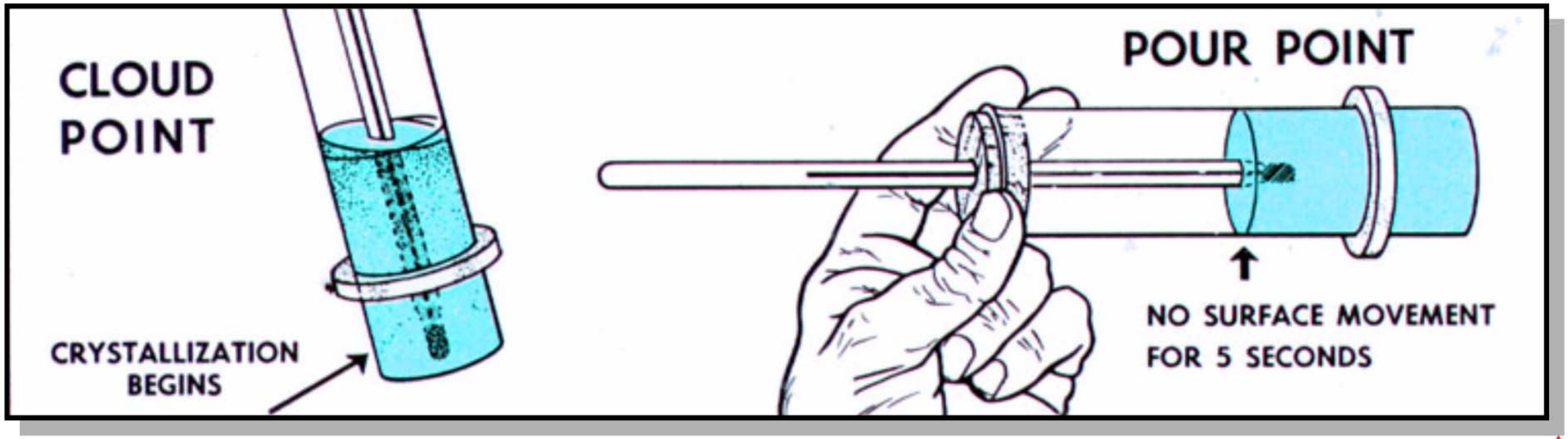
POUR/CLOUD POINT DEPRESSANTS

- Temperature at which no movement is observed for 5 seconds
- Wax comes out of solution in small crystals as the oil nears pour point. Small crystals form a gel that keeps the oil from moving.



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FRICTION MODIFIERS

- Increase oil film strength
- Long chain molecules
- Polar end adsorbs to metal surface
- Effective at low temperatures and mild sliding conditions
- Fatty acid or fatty oil derivatives
- Ash containing compounds such as Molybdenum Disulphide (MoS_2), graphite, Teflon (PTFE), are also called Friction Modifiers
- Sometimes called anti-seize or solid lubricants

Commonly found in Engine Oils to improve fuel economy.

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DEMULSIFIER ADDITIVES

- Added to oils in improve the ability of water to shed from the oil.
- Desirable for :
  - paper machines
  - hydraulics
  - turbines
  - gears
- Additives that are added to the oil for other reasons often attract water (i.e. detergents).

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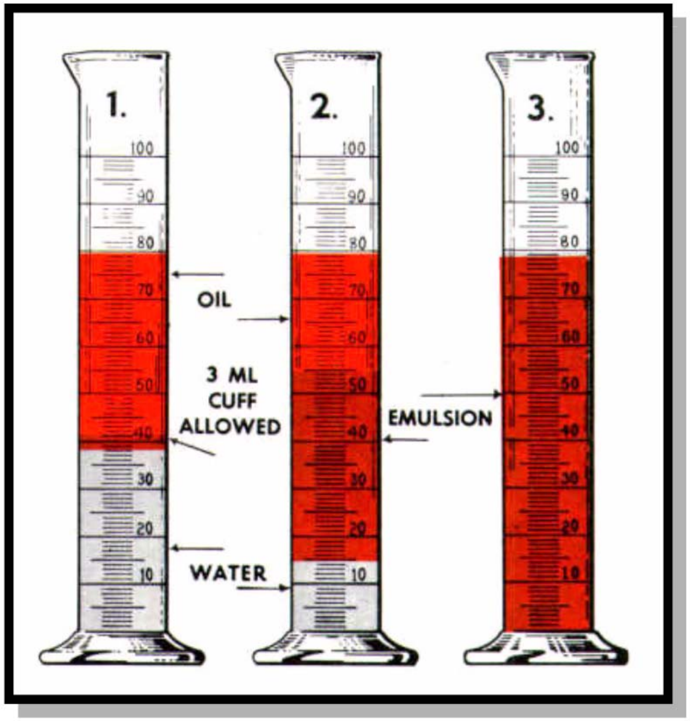
DEMULSIBILITY TESTS

- Determines the ability of the oil to shed water.
  - ASTM D1401, D2711 (should be used for oils containing EP additives)

Reported as:

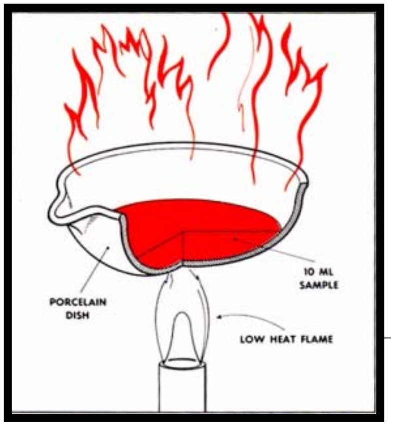
Oil/Water/Emulsion (minutes)

38-4-38 (20)



SULPHATED ASH

- Determines the non-combustible residue in a lubricating oil (ASTM D874)
- Sometimes used as an indication of the amount of detergent in a new oil
- Metallic additive components – Calcium, Magnesium, Zinc
- New specs are limiting the ash content
- Primary function of the sulfated ash is to minimize valve wear (recession) in NGEO



USE OF ADDITIVES

ADDITIVE	Engine Oils	ATF	General R&O Oil	AW Hydraulic	Industrial Gear Oil	Automotive Gear Oil	Grease
Detergents	✓	✓					
Dispersants	✓	✓					
Anti-Oxidants	✓	✓	✓	✓	✓	✓	✓
Rust Inhibitors	✓	✓	✓	✓	✓	✓	✓
Anti-Wear	✓	✓		✓	✓	✓	✓
E.P. Agents					✓	✓	✓
VI Improvers	✓	✓		HVI	Some	Some	
Pour Point Depressants	✓	✓	✓	✓	✓	✓	
Anti-Foam	✓	✓	✓	✓	✓	✓	
Dyes		✓					✓
Friction Modifiers	✓	✓					

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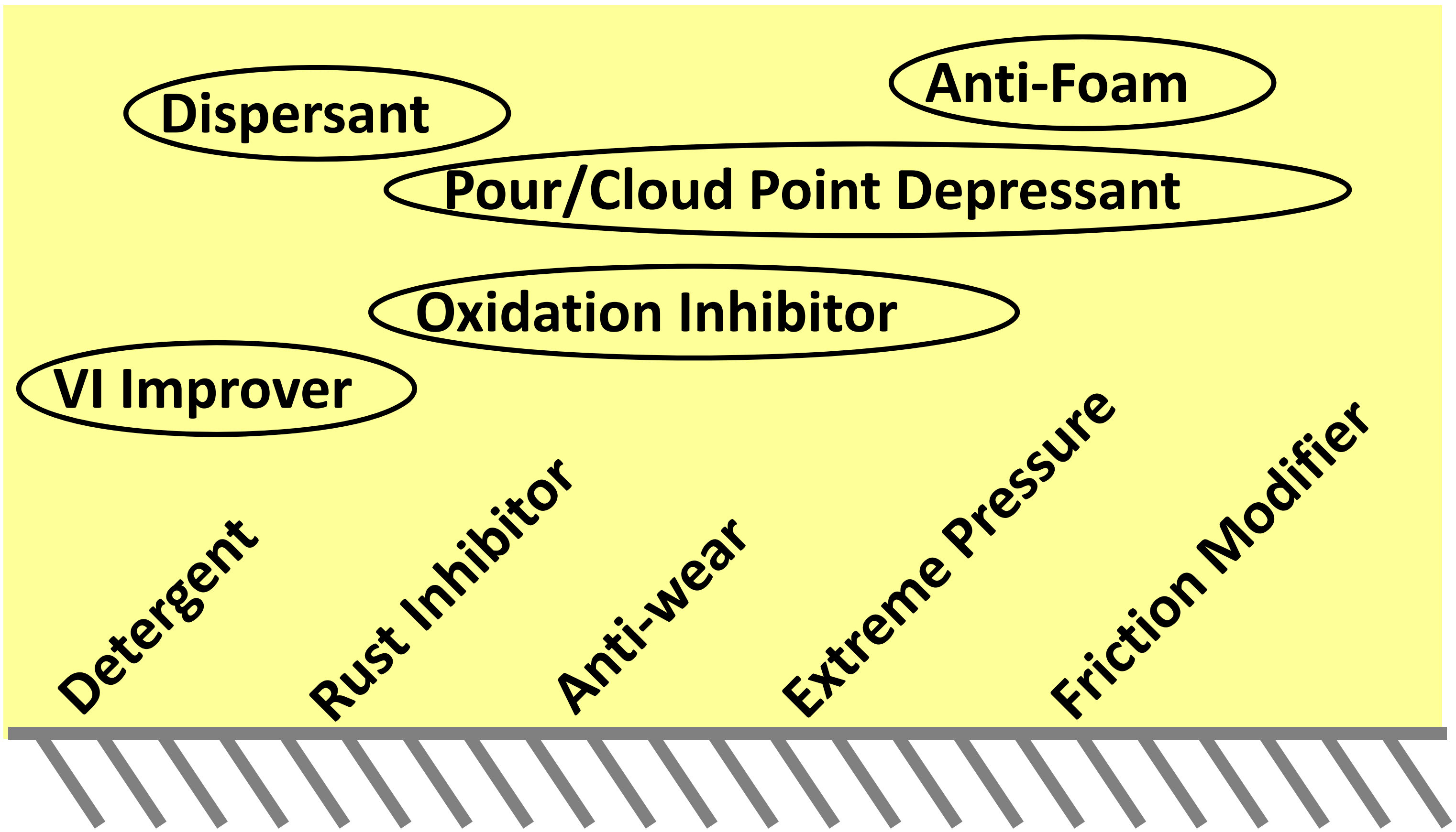
ADDITIVES AT WORK



Some additives work in the oil, some work on the metal surface –

VERY DELICATE BALANCE

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CLEANLINESS AND CONTAMINATION CONTROL

National Partner

AGENDA

- INTRODUCTION
- CONTAMINATION SOURCES
  - Internal
    - Corrosion
    - Wear Debris
  - Ingress
    - Airborne Contaminants
    - Moisture
    - Dirty Oil
  - Wrong Lubricant
- ISO PARTICLE COUNT SYSTEM
- PREVENTION
  - Storage
    - Lube Rooms, Dispensing
  - Handling and Distribution

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CLEANLINESS AND CONTAMINATION CONTROL

- **Contamination is the greatest single cause of lubricant degradation and malfunction leading to abnormal wear and failure of equipment components.**

- Because
  - Contamination sources are everywhere
  - It causes wear and surface degradation
  - It causes the lubricant to malfunction
  - It costs you money!

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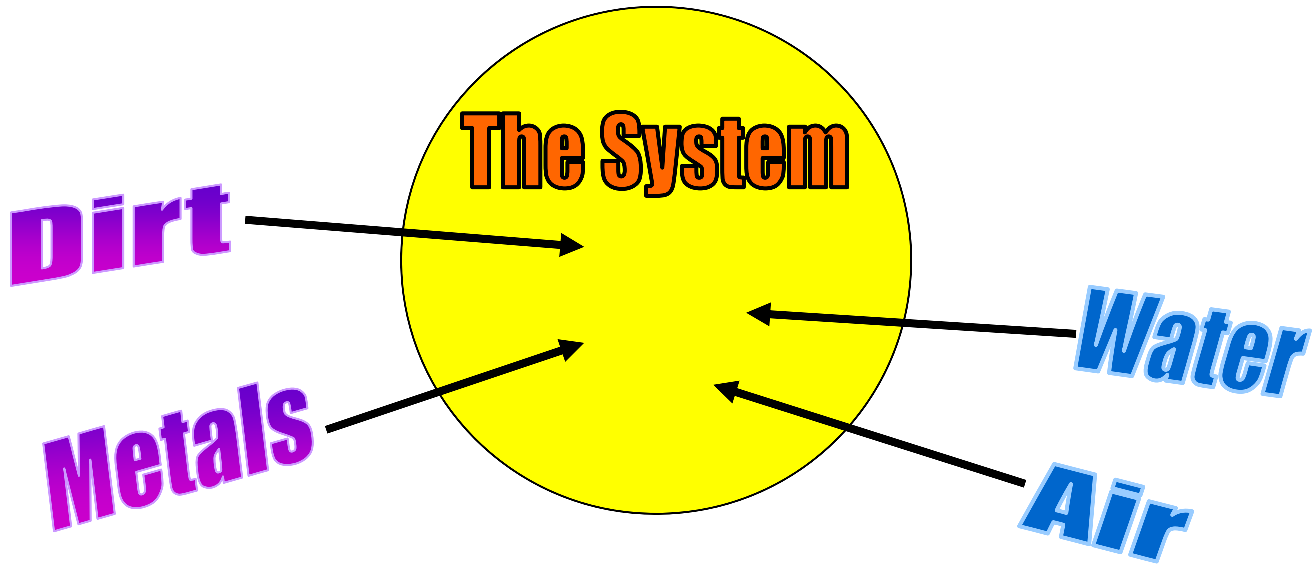
WHAT IS CONTAMINATION?



Anything in a fluid that does not belong is a <u>CONTAMINANT</u>.

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SOURCES OF CONTAMINATION

PETRO-CANADA

- Built in contamination
- Generated contaminants
- External ingression
- Maintenance introduced contaminants

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SOURCES (CONT'D)

Built in contaminants from components:

- Cylinders, fluids, hoses, hydraulic motors, lines and pipes, pumps, reservoirs, valves, etc.

- **Generated contaminants:**
  - Assembly of system
  - Break-in of system
  - Operation of system
  - Fluid breakdown

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SOURCES (CONT'D)

External ingression

- Reservoir breathing
- Cylinder rod seals
- Bearing seals

Contaminants introduced during maintenance

- Disassembly/assembly
- Makeup oil

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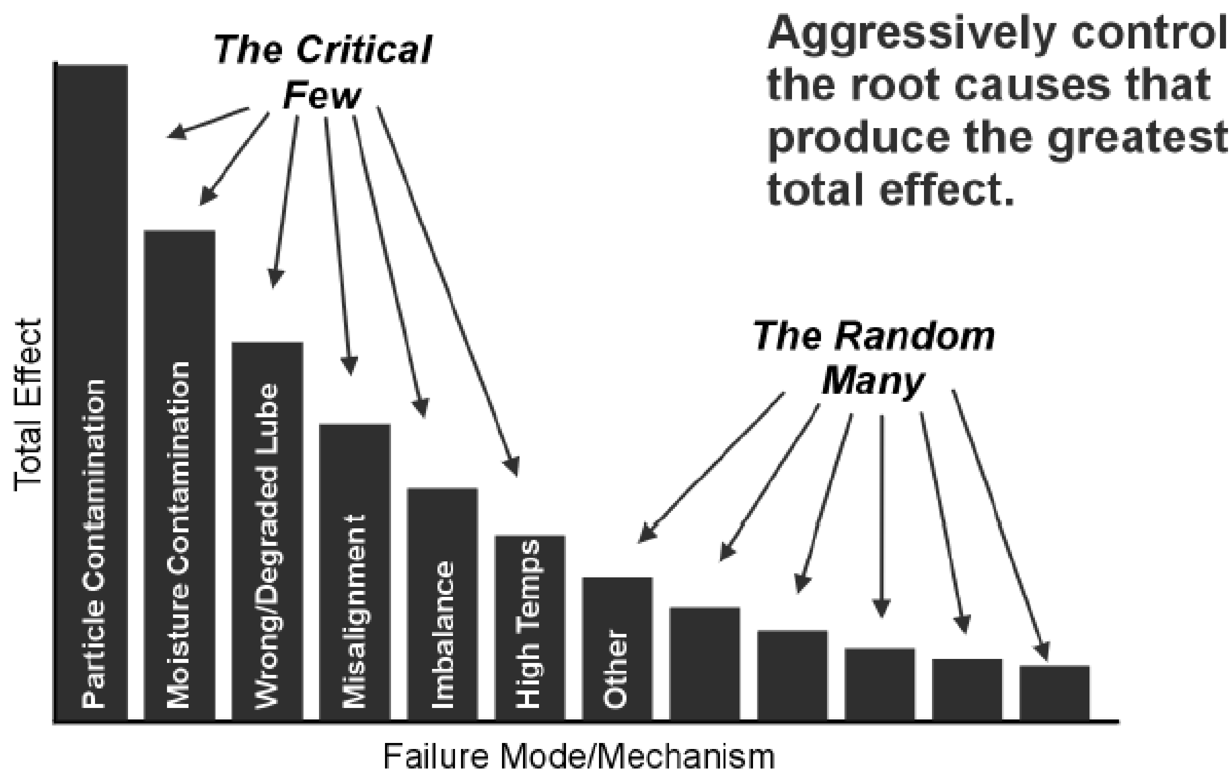
OIL CONTAMINATION

PARETO PRINCIPLE



80/20 RULE

80% of consequences come from 20% of causes.

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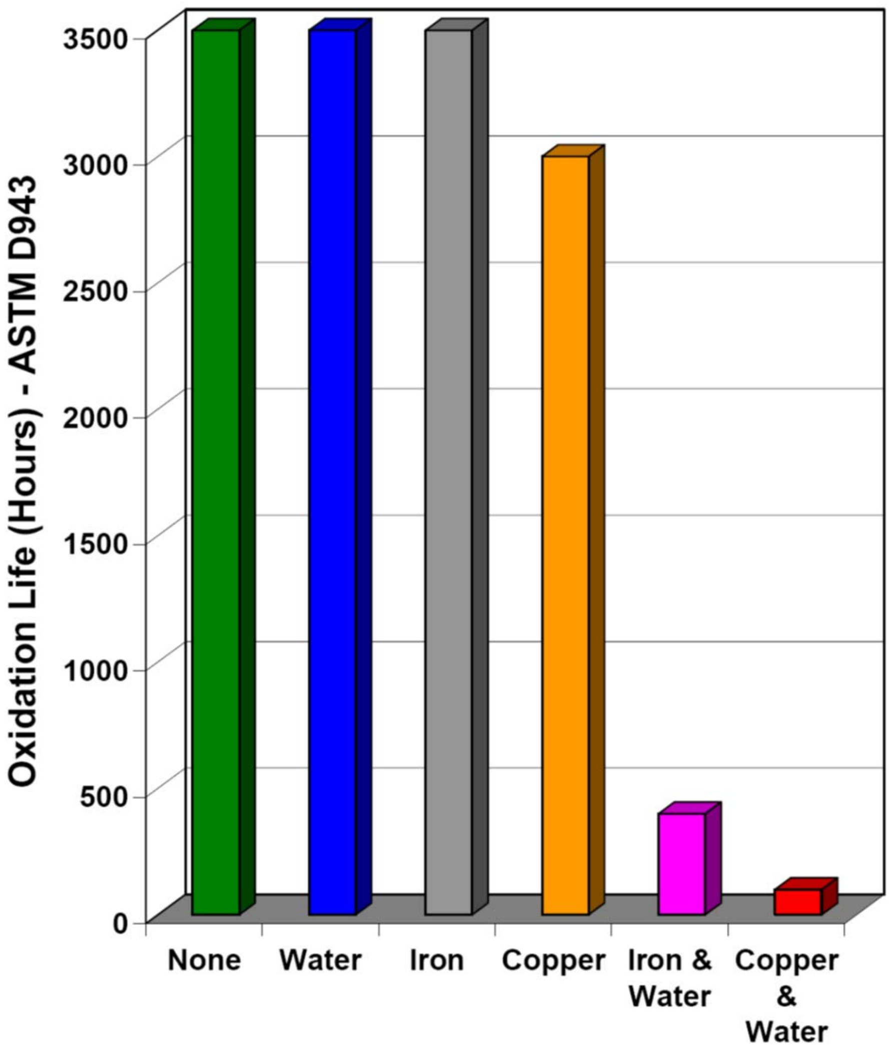
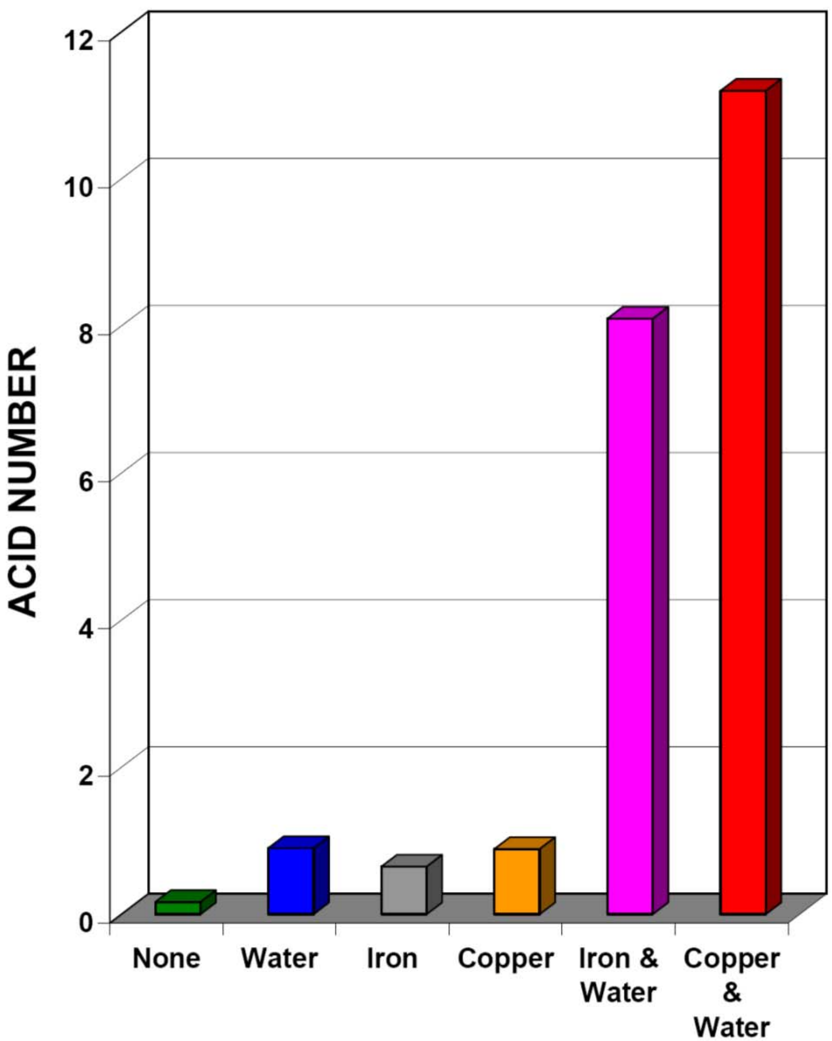
WATER + CATALYST ON OXIDATION LIFE

PETRO-CANADA

150 SSU @100°F Turbine Oil

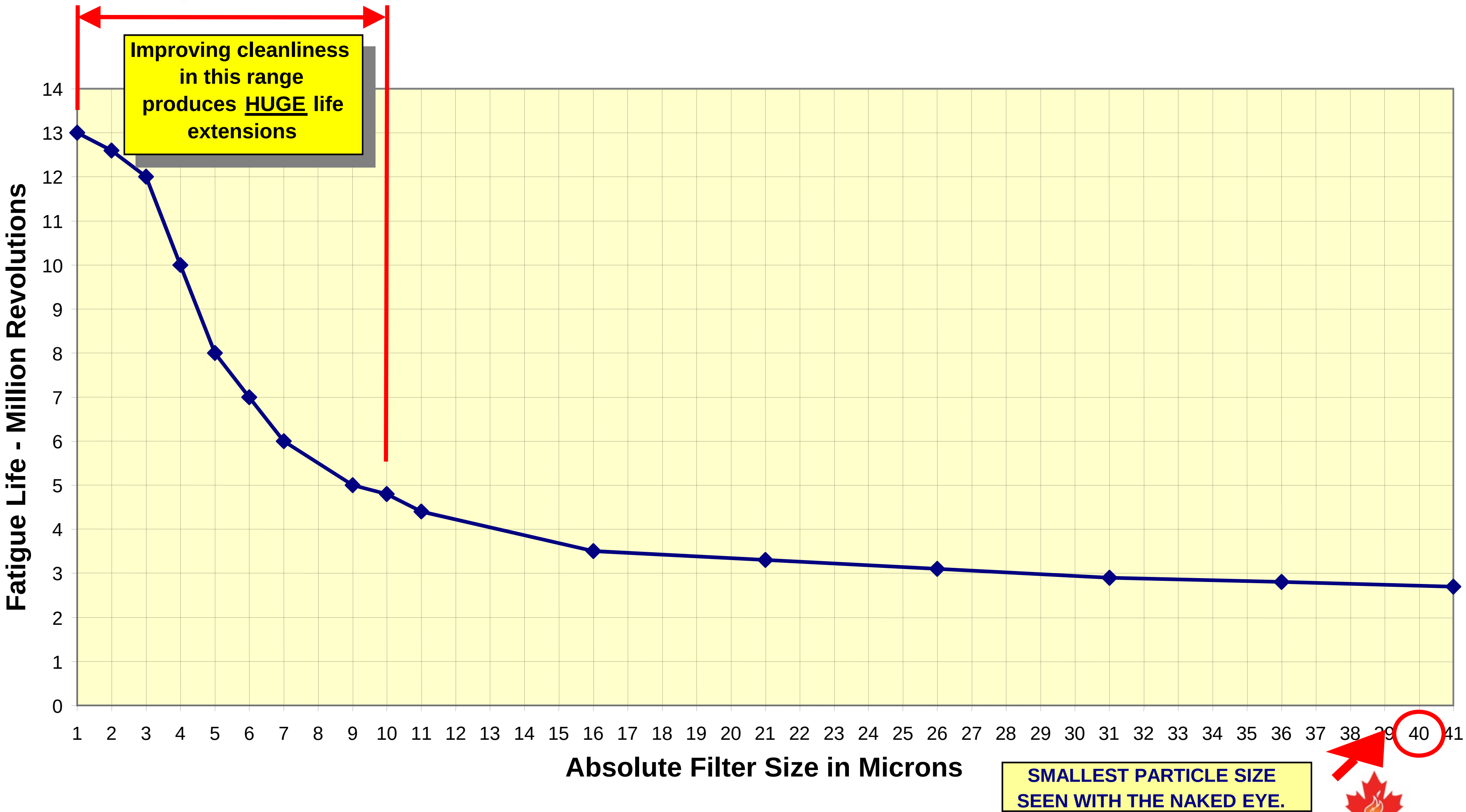
(32 cSt @ 37.8°C)





Ref: Volume XXIII – Proceedings of National Conference on Fluid Power, 1969, Weinschelbaum, M.

BEARING LIFE VS. PARTICLE SIZE



Ref: SKF Ball Bearing Journal #242

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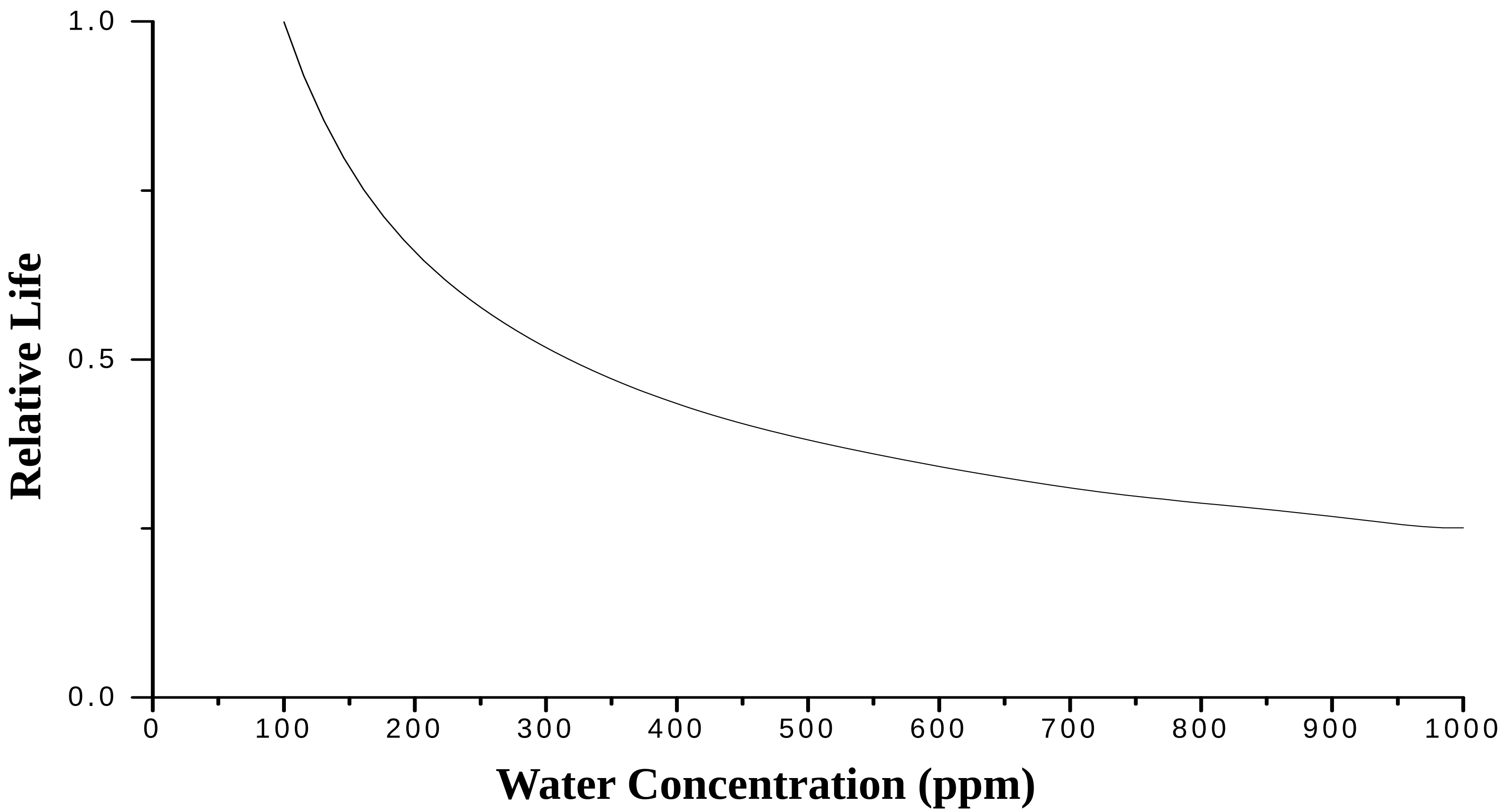
WATER ON BEARING LIFE



***Cantley, R., “The Effect of Water in Lubricating Oil on Bearing Fatigue Life”**

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HOW CLEAN IS CLEAN?

PETRO-CANADA

Typical Operating Dynamic Film Thickness

COMPONENT	THICKNESS (µ)
Roller Bearings	0.4 – 1
Ball Bearings	0.1 – 0.7
Journal Bearings	0.5 – 100
Vane Pump	0.5 – 13
Piston Pump	0.5 – 40
Diesel Engine	5 – 45
Gears	0.1 - 1

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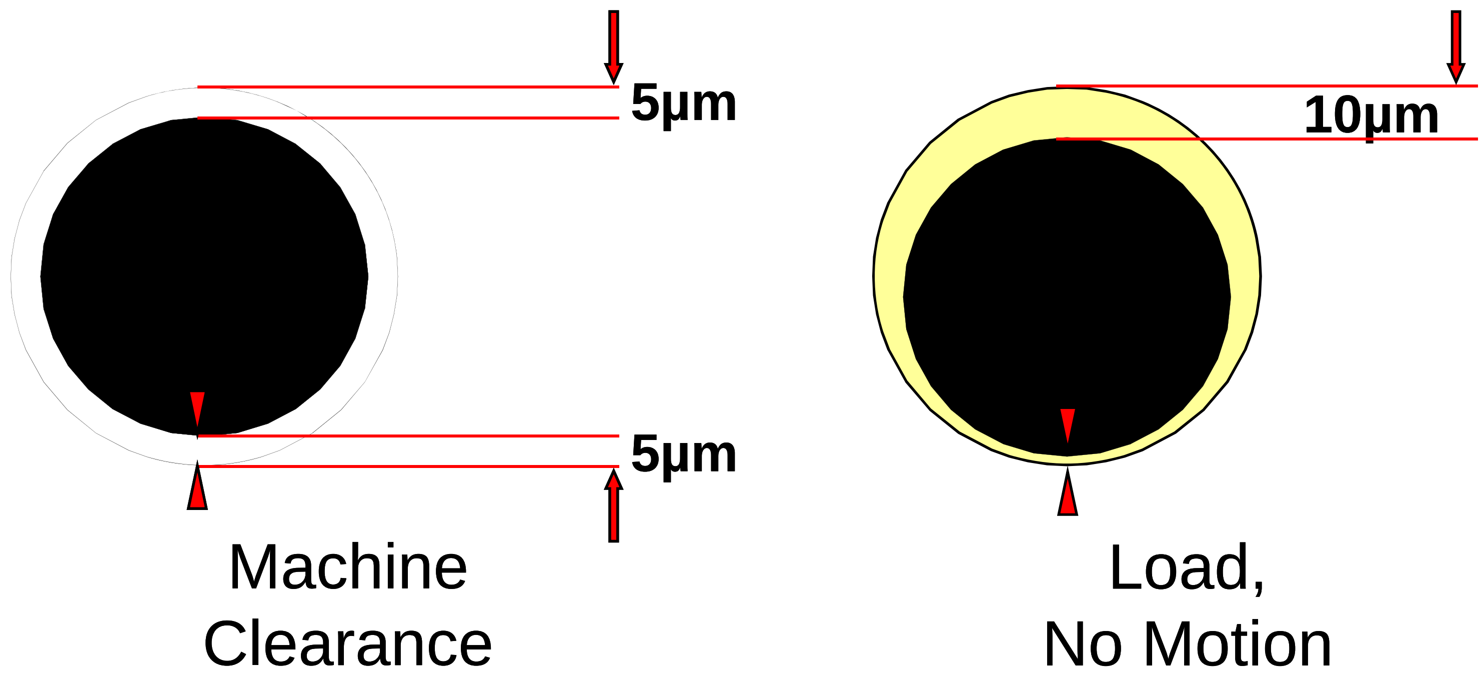
BEARING FILM THICKNESS



The operating or dynamic clearance is not equal to the machine clearance, but depends upon the load, speed and lubricant viscosity. A lubricant film separates moving surfaces to prevent metal-to-metal contact.

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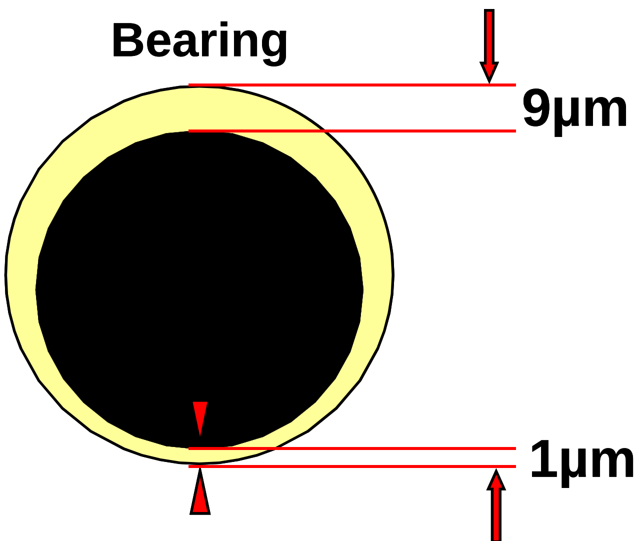
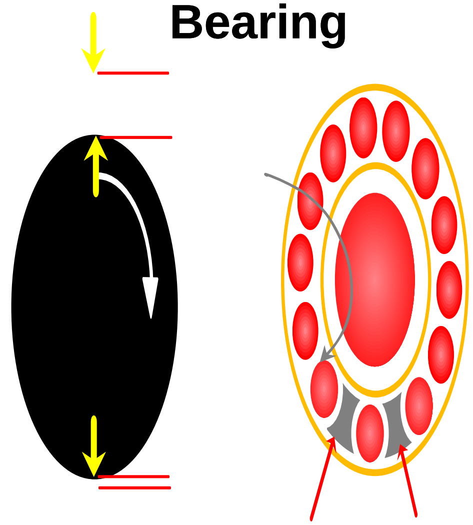
BEARING FILM THICKNESS

Journal Bearing



Load & Motion & Lubricant

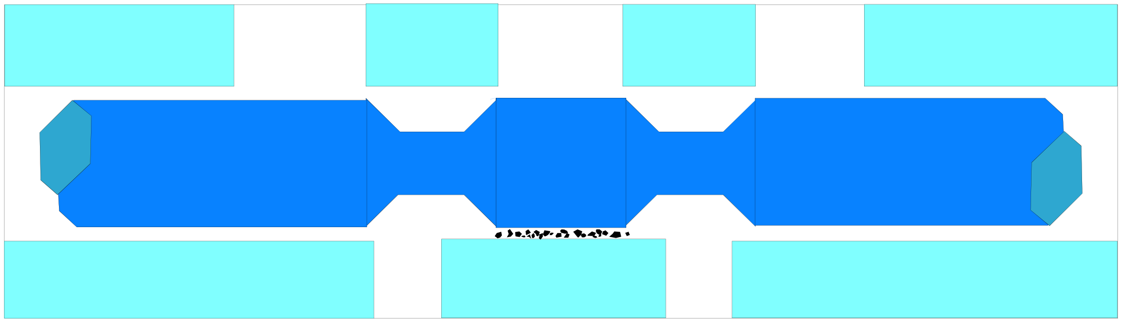
Rolling Element Bearing



Cage

Lubricant Film

VALVE WEAR/STICTION



Valve Dynamic Clearances

Servo valve	1 - 4 µm
Proportional valve	1 - 6 µm
Directional control valve	2 - 8 µm

Clearance Size Particles Cause:

- Slow response, instability
- Spool jamming/stiction
- Surface erosion
- Solenoid burnout

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EFFECTS OF CONTAMINATION

PETRO-CANADA

- Cylinder Drift
- Jerky Steering
- Slower Performance
- Erratic Operation
- Shorter Service Intervals
- Higher Operating Costs
- Lost Productivity

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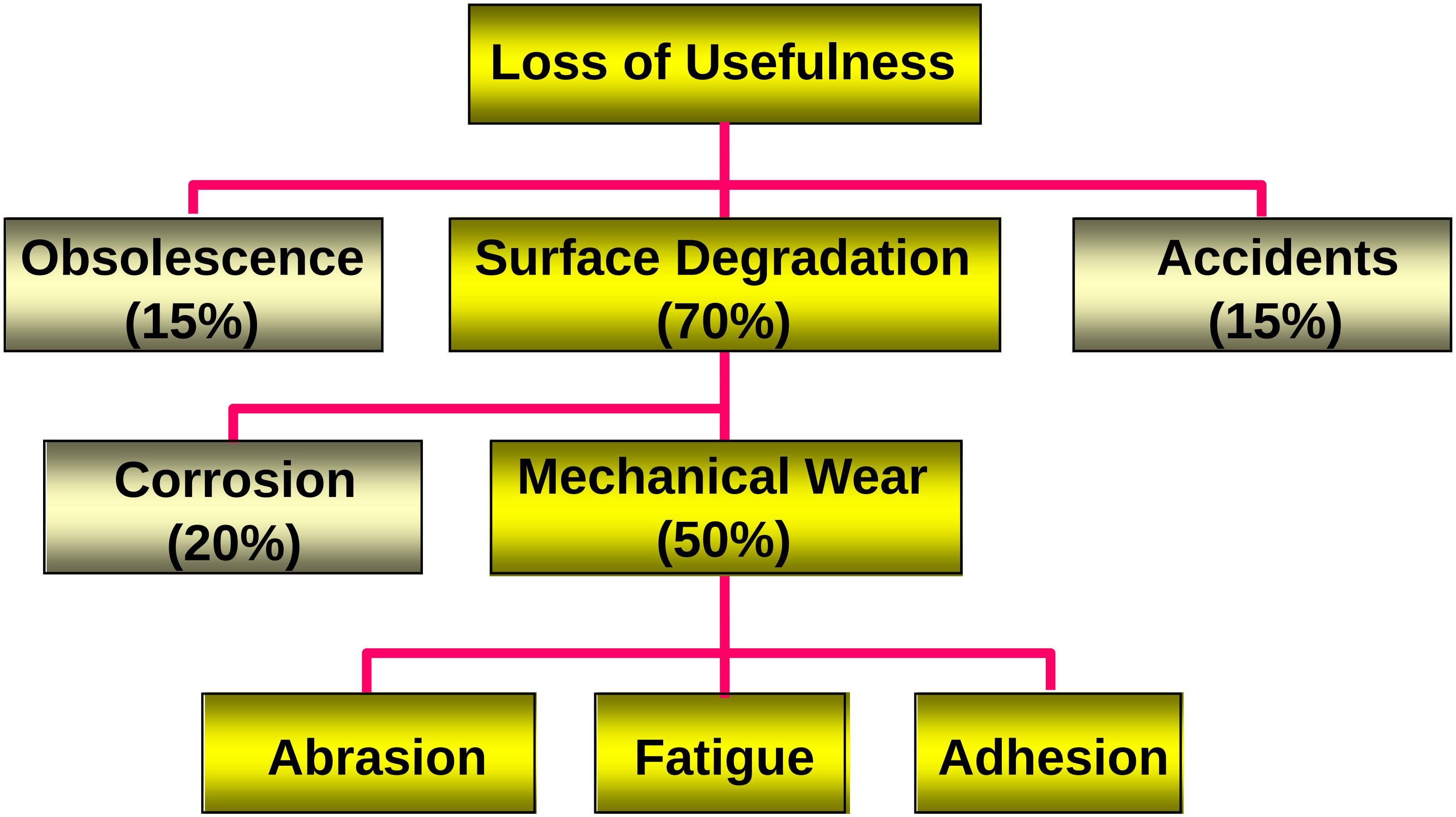
LOSS OF EQUIPMENT LIFE



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CONTAMINATION SOURCES

- Generated
  - Corrosion
  - Wear Debris
- Ingress
  - Airborne
  - Moisture
  - Dirty Oil
- Wrong Lubricant

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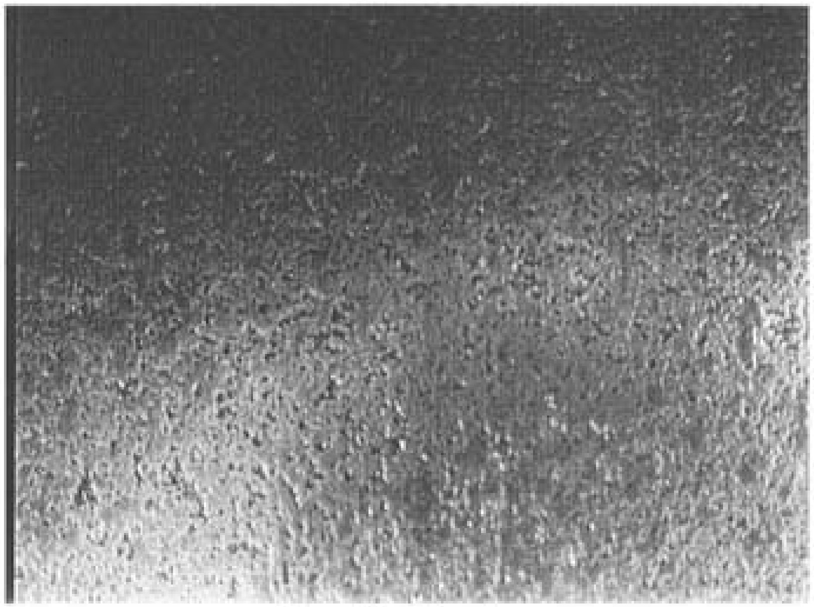
CORROSIVE WEAR

Corrosion is a chemical attack on the material

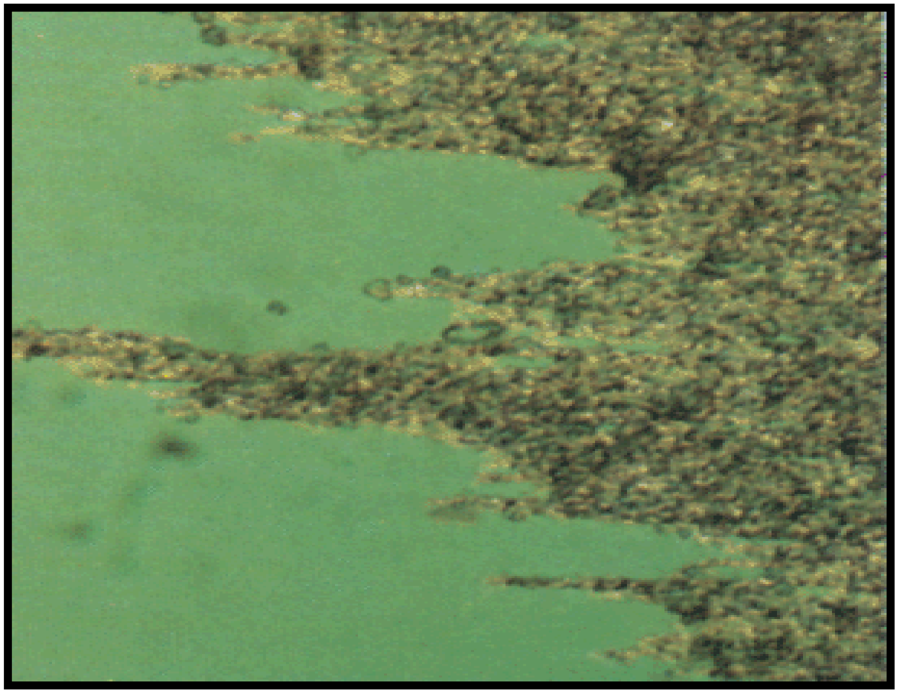
- ✓ Causes pitting
- ✓ Produces a corrosion product



Magnification 4x

CORROSIVE WEAR

- Acids formed during oil **oxidation**
- Internal combustion engines will generate acids in the oil



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CORROSIVE WEAR

PETRO-CANADA

- **CONDITIONS PROMOTING WEAR**
  - Corrosive environment
  - Corrodible metals
  - Rust promoting conditions
  - High temperatures
- **CONTROL**
  - Eliminate corrosive material
  - Use more corrosion resistant metal
  - Reduce operating temperature
- **LUBRICANT**
  - Remove corrosive material such as too chemically active additive and contaminates
  - Corrosion inhibitor
  - Use fresh oil

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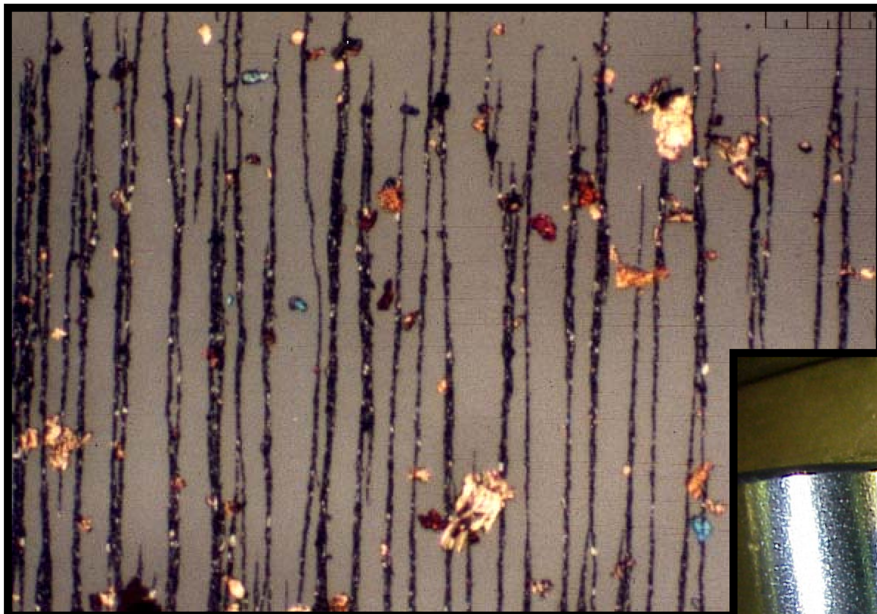
GENERATED: WEAR DEBRIS



TYPES OF WEAR

1. **Adhesive Wear**

   Metal to metal contact (loss of fluid)

2. **Abrasive Wear**

   Particles between adjacent moving surfaces

3. **Fatigue Wear**

   Particle damaged surfaces subjected to repeated stress

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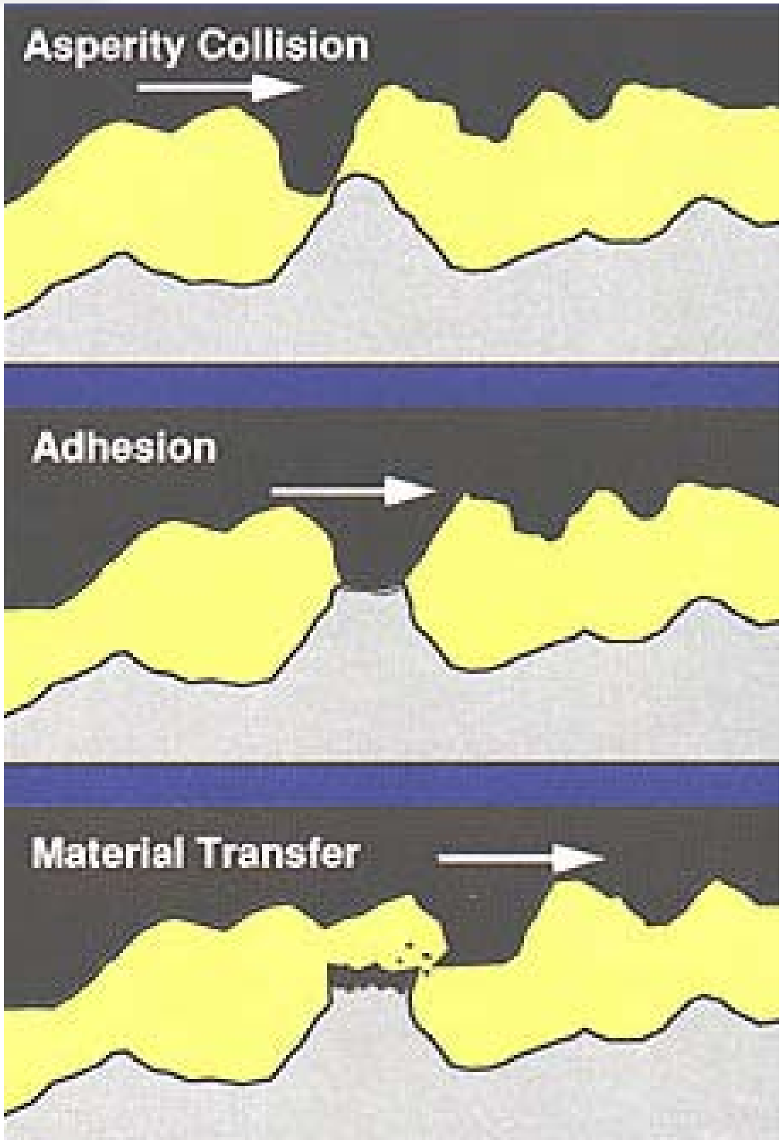
ADHESIVE WEAR



- Metal-to-metal contact
- Heat is generated
  - Some discoloration
- Welding or micro welding
- Metal breakage or transfer

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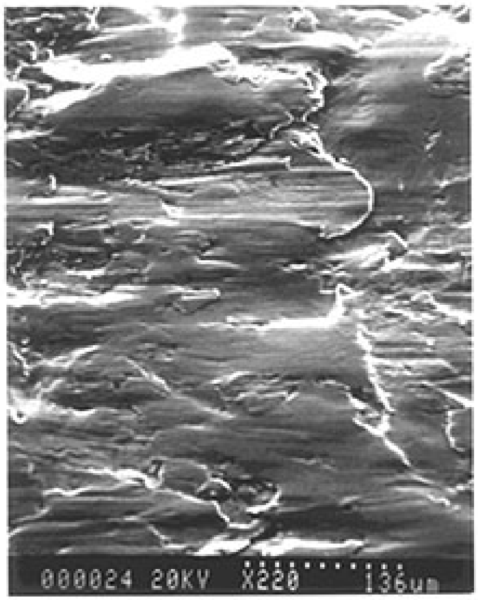
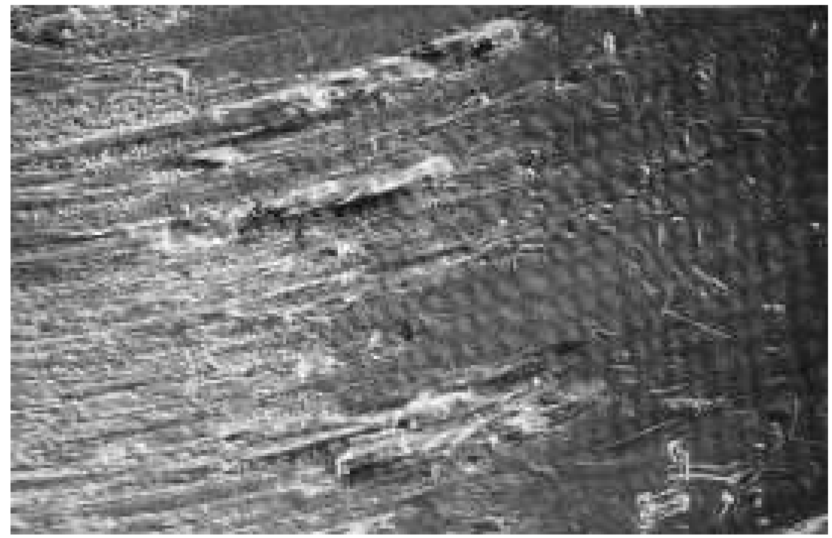
ADHESIVE WEAR

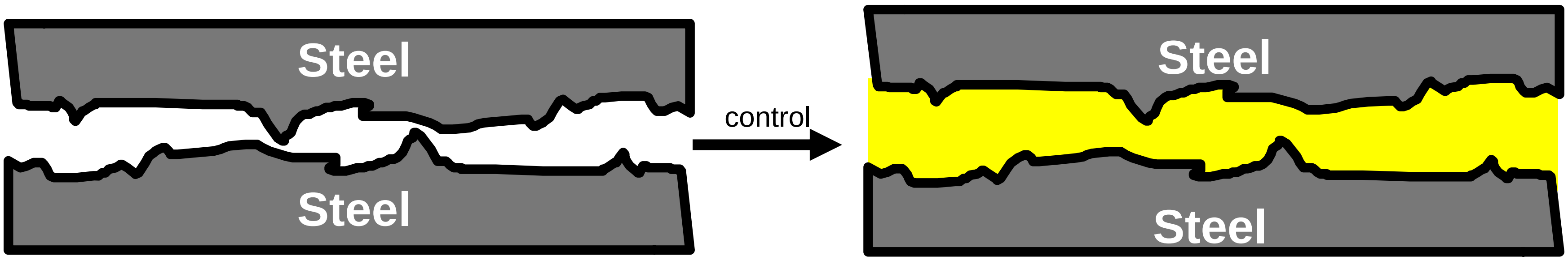
Roller-Follower Roller Interior Severe Adhesive Wear



Interior of Roller
Magnification 220x

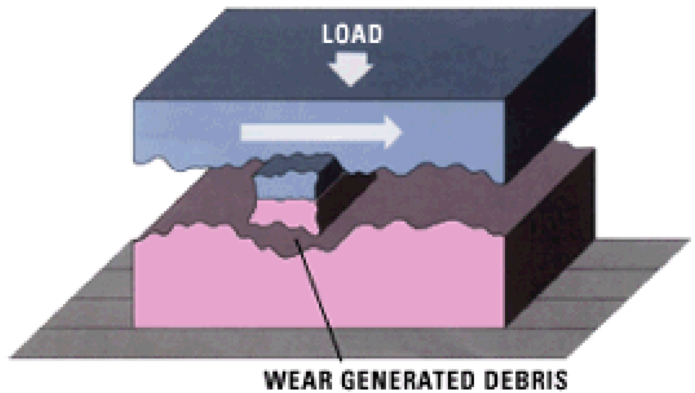


CONTROL OF ADHESIVE WEAR



Metal-to-metal contact

Control: lubrication



Preventing Adhesive wear is primarily controlled by selecting the right viscosity and the right additive package.

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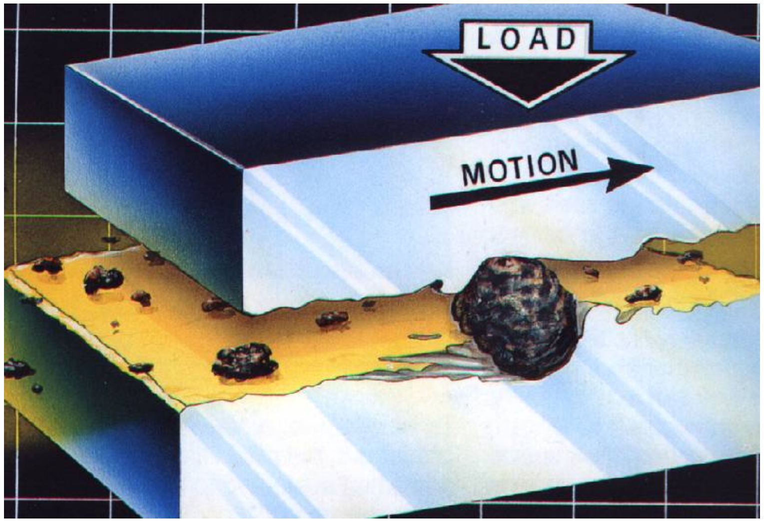
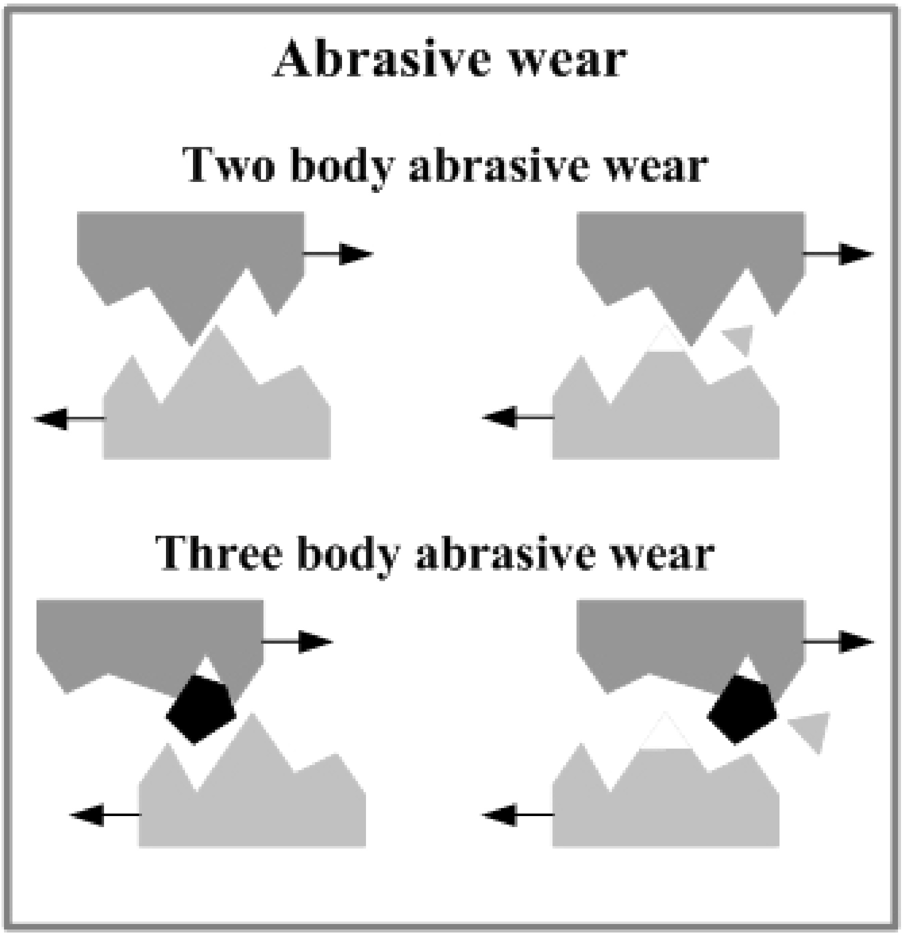
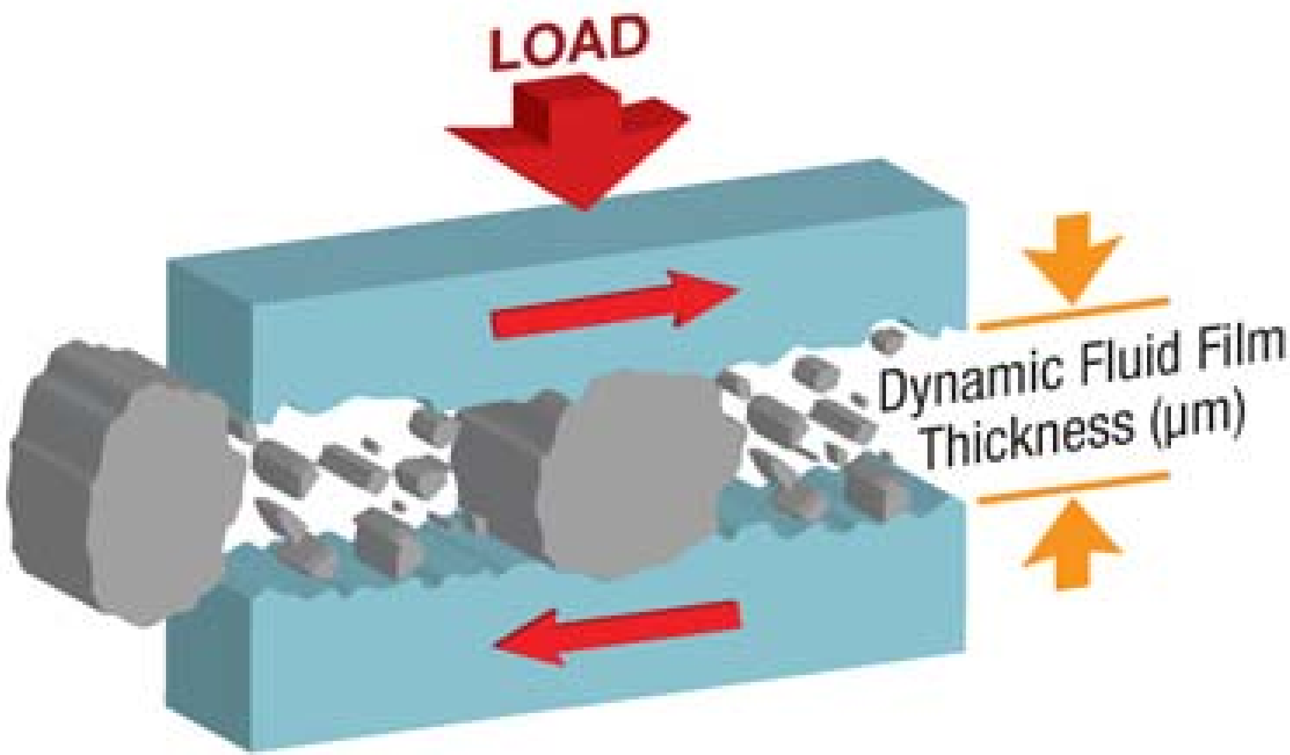
ABRASIVE WEAR





ABRASIVE WEAR

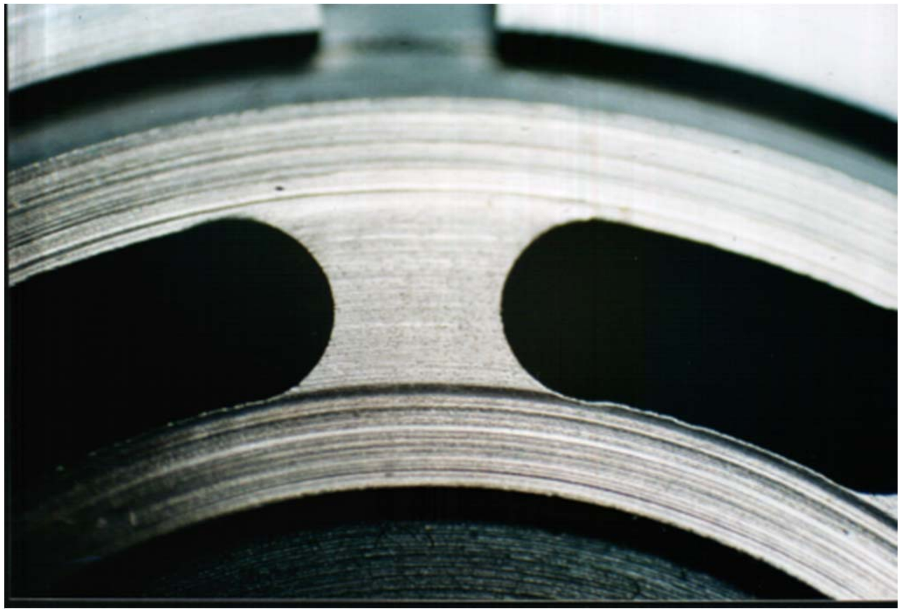


Abrasive wear effects -
- Dimensional changes
- Leakage
- Lower efficiency
- Generated wear : more wear

Typical components subjected to Abrasion -
- Hydraulic pumps (gear, vane, piston pumps)
- Hydraulic cylinders (rod seals, piston seals and bearings)
- Hydraulic motors
- Journal bearings

ABRASIVE WEAR

Piston Pump



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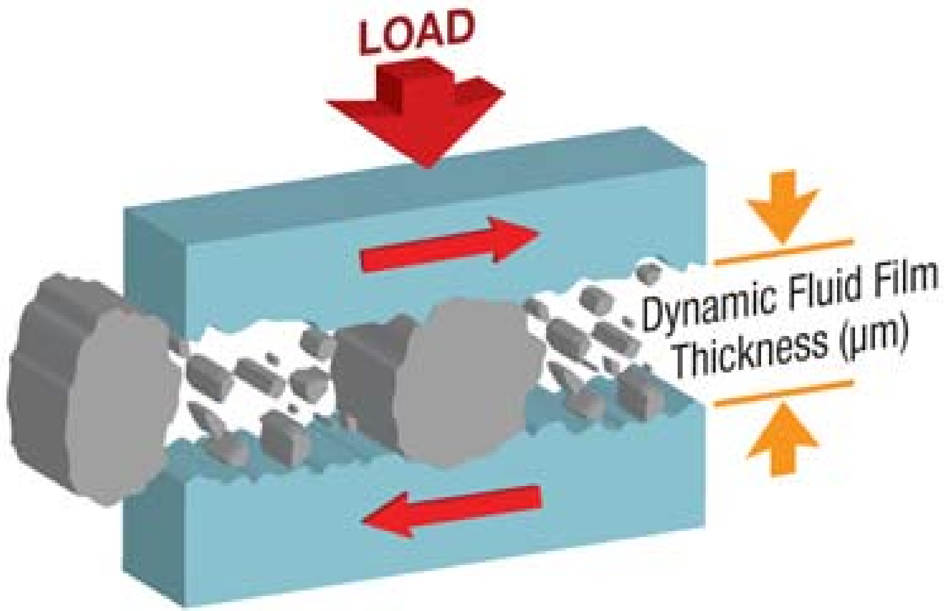
ABRASIVE WEAR

- Control of Abrasive Wear
  - Filtration/Clean Handling/Good Housekeeping



FATIGUE WEAR

- **NORMAL FATIGUE**
  - When designed fatigue life is met.
  - When designed service conditions are followed.

    Ex: load 100 lbs, life will be 5 years
- **PREMATURE FATIGUE**
  - When designed life is not met
  - Could be a function of load or material

    ex. Designed load = 100 lbs

    actual load =300 lbs
  - Initial Surface Damage

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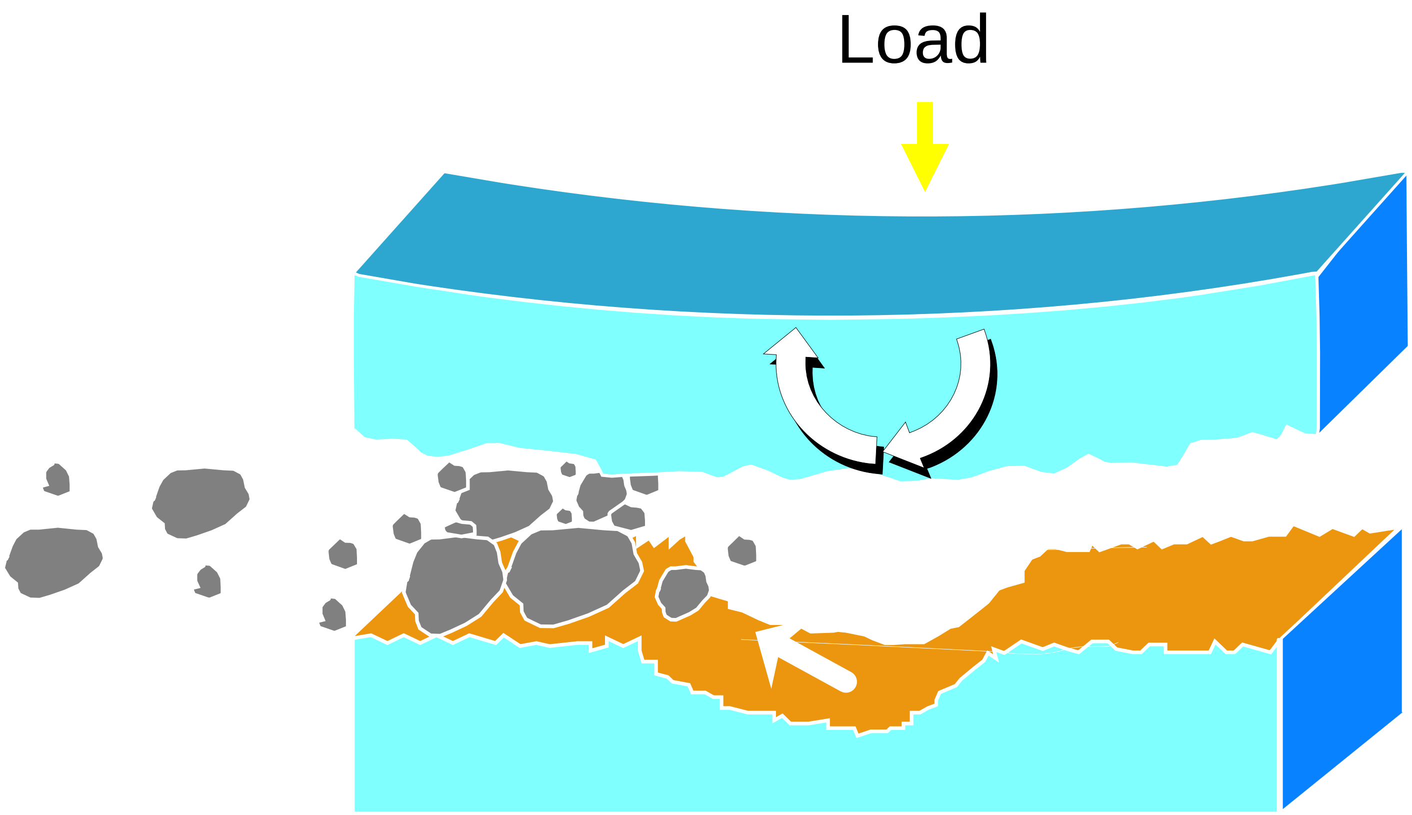
FATIGUE WEAR

After "N" cycles, fatigue wear occurs characterized by spalling of surface



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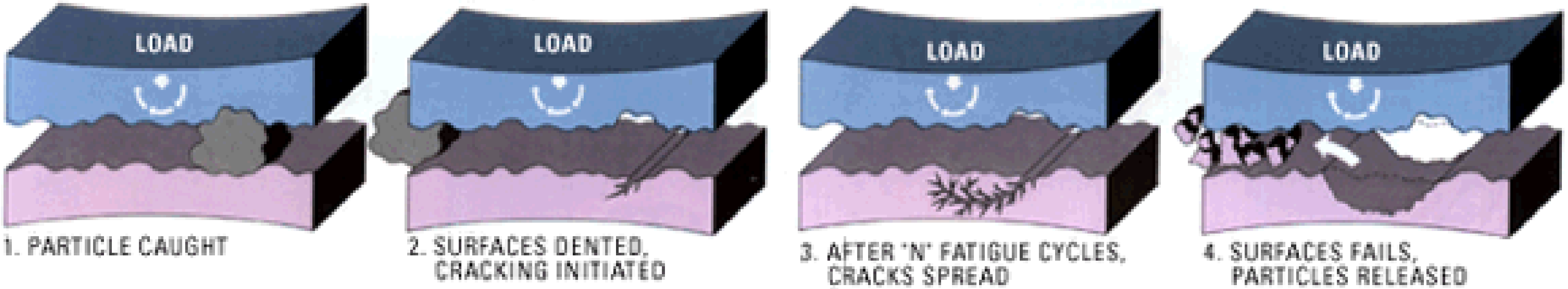
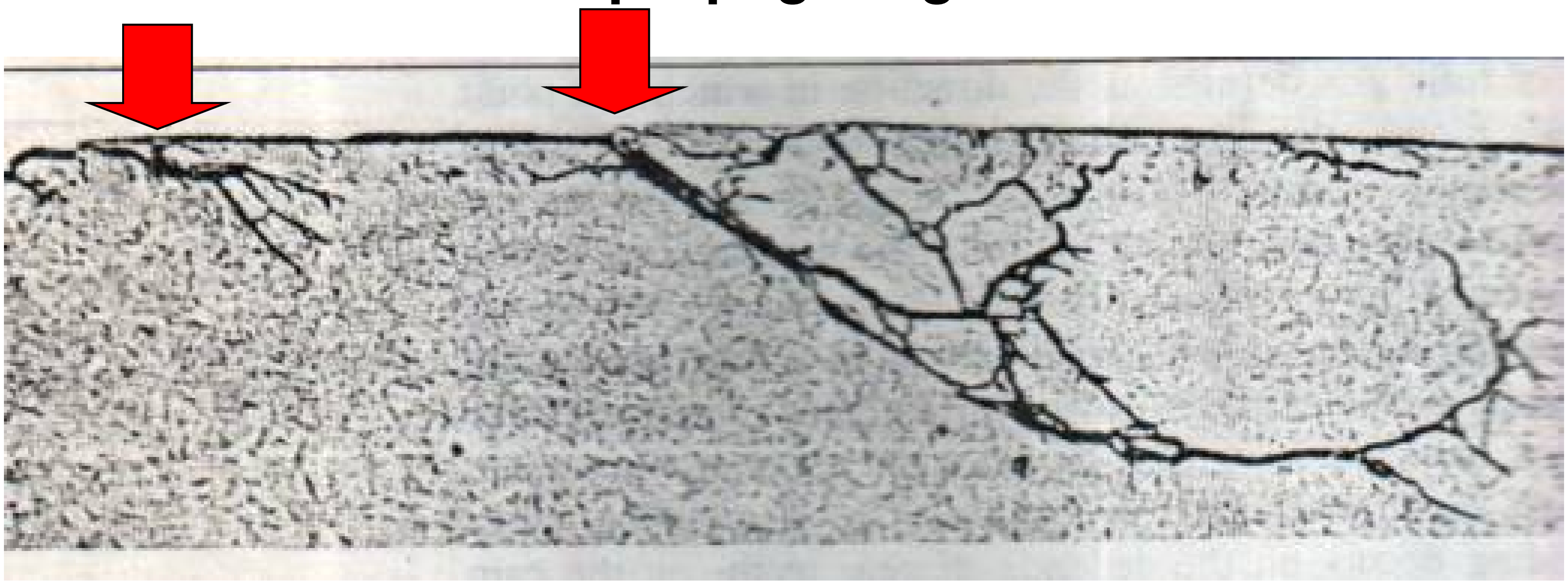
FATIGUE WEAR

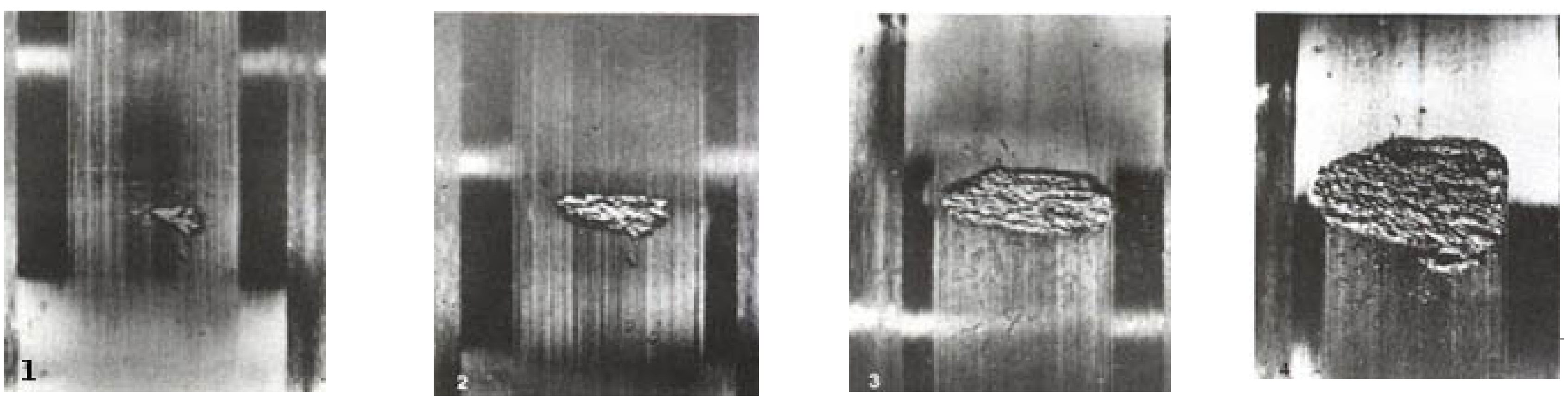


Cracks from surface propagating downwards



FATIGUE WEAR

- **Factors affecting Fatigue Life:**
  - Load and high stress points
  - Material
  - Temperature
  - Time or cycle



CONTAMINATION SOURCES

- Generated
  - Corrosion
  - Wear Debris
- Ingress
  - Airborne
  - Moisture
  - Dirty Oil
- Wrong Lubricant

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TWO TYPES OF CONTAMINATION

PETRO-CANADA

- **"Dirt You Can See"**
- 40 Microns & Larger
- Weld Splatter
- Shot Blast
- Paint Chips
- Machine Chips

G
R
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S

"Dirt You Can't See"

- Under 40 Microns
- Wear Metals
- Silica
- Coal
- Dirt
- Soot

F
I
N
E

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AIRBORNE CONTAMINANTS

Example of air contaminants that only became visible with the camera flash

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The environment maybe reality – but what prevents reality from getting into the system?

Sometimes the normal job function opens the component to the environment!
Is there another option? What about a sight glass?

OEM breathers may not be adequate for protecting your equipment from the working environment.

INGRESSED MOISTURE

It's not just the water itself that is an issue. Many EP additives contain sulphur which may react with the moisture to create other unwanted acids.

PETRO-CANADA

DIRTY OIL

Did the rag do its job and keep the container clean?

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Pick a container – any container will do?   NO!!!!!

CONTAMINATION SOURCES

- Generated
  - Corrosion
  - Wear Debris
- Ingress
  - Airborne
  - Moisture
  - Dirty Oil
- Wrong Lubricant

PETRO-CANADA

FIT FOR USE?

This container is guaranteed to have lube oil in it. Which One????

AGENDA

- INTRODUCTION
- CONTAMINATION SOURCES
  - Internal
    - Corrosion
    - Wear Debris
  - Ingress
    - Airborne Contaminants
    - Moisture
    - Dirty Oil
  - Wrong Lubricant
- **ISO PARTICLE COUNT SYSTEM**
- PREVENTION
  - Storage
    - Lube Rooms, Dispensing
  - Handling and Distribution

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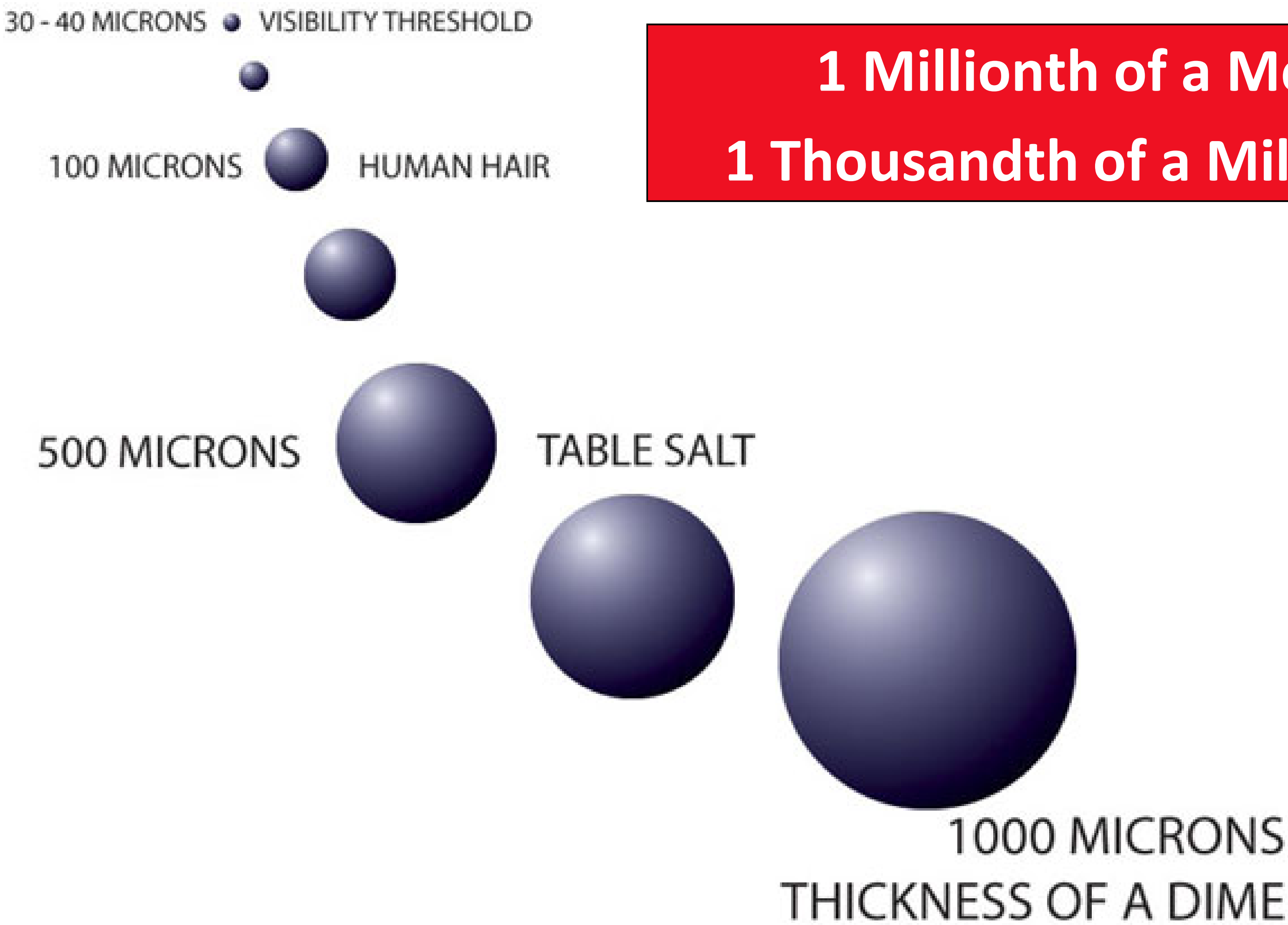
BUT FIRST - WHAT IS A MICRON?



1 Millionth of a Meter

1 Thousandth of a Millimeter

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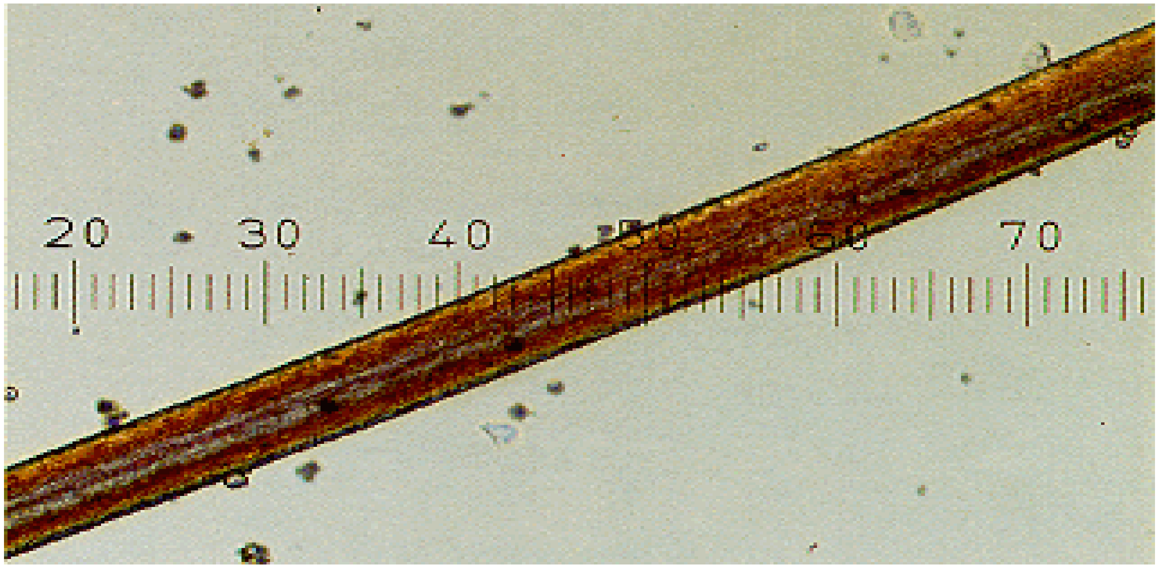
MEASURING CONTAMINANTS

PETRO-CANADA

The Micrometer (µm)

- Smallest dot you can see with the naked eye = 40 µm
- 25 µm = 1/1000 of an inch
- 1µm = 0.00004 inch



Human hair (80 µm), particles (10 µm) at 100x (14 µm/division)

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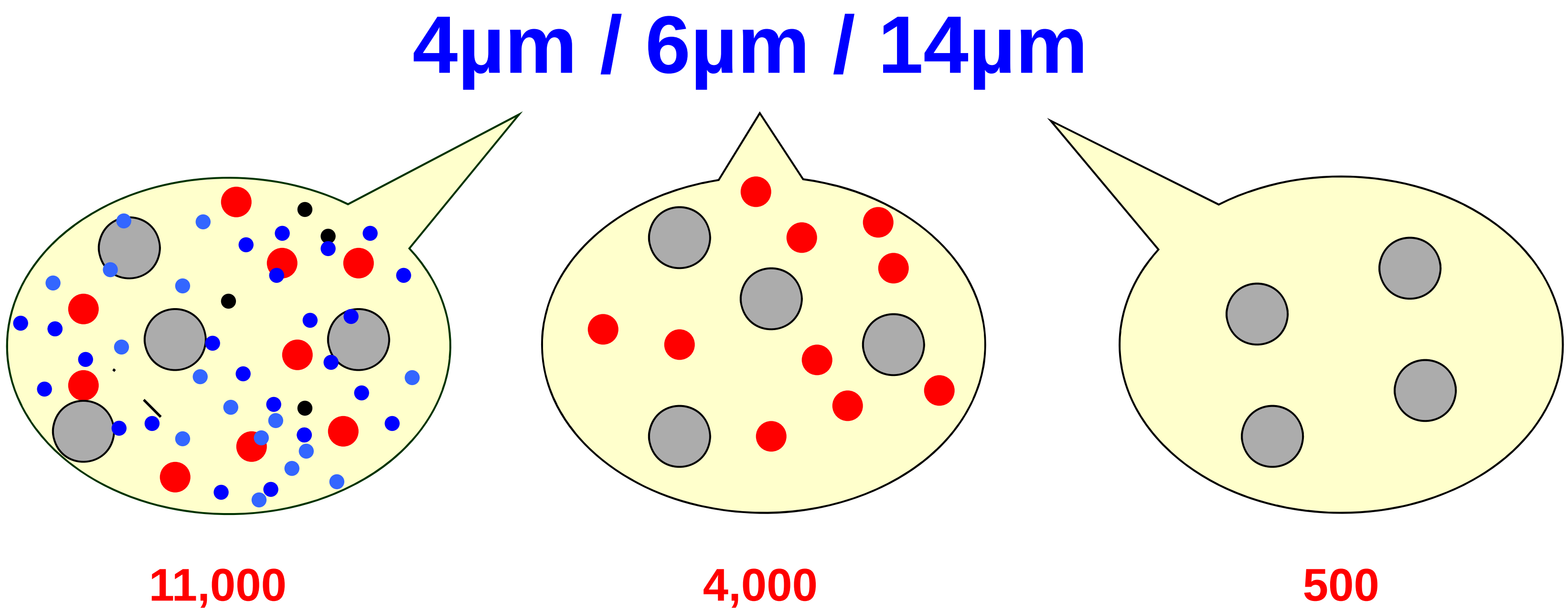
ISO CLEANLINESS CODE

- Identifies quantity of contaminant in one mL of Fluid



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Understanding ISO Particle Counts

Example Particle Count	
Size (Microns)	Count Larger Than Size per ml
4	**2136**
6	**463**
10	161
14	**63**
20	29
50	6
75	2
100	1

ISO 4406:99
$R_4/R_6/R_{14}$

2136 particles > 4 µm/ml

463 particles > 6 µm/ml

63 particles > 14 µm/ml

= ISO 18/16/13

Number of Particles per ml		
More Than	Up to and including	Range Number (R)
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	**2,500**	**18**
640	1,300	17
320	**640**	**16**
160	320	15
80	160	14
40	**80**	**13**
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8
0.64	1.3	7
0.32	0.64	6
0.16	0.32	5
0.08	0.16	4
0.04	0.08	3
0.02	0.04	2
0.01	0.02	1

Under ISO 4406:99, a sample is given a fluid cleanliness rating using the above table. To do this, the number of particles greater than three size ranges, (4, 6 and 14 microns) are determined in the equivalent of one milliliter of sample. In the above example, the particle count distribution shown in the table on the left translates to an ISO 4406:99 rating of 18/16/13

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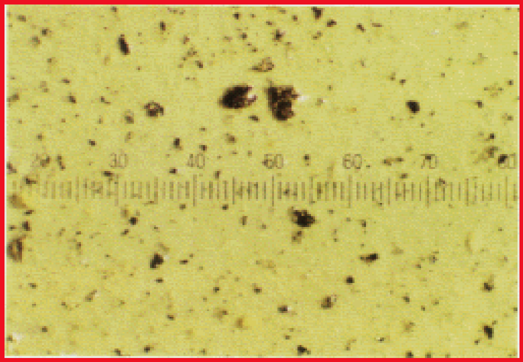
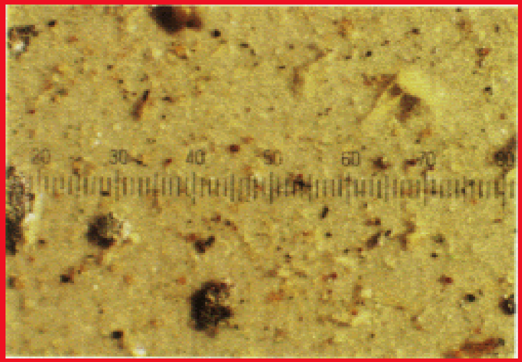
TYPICAL CLEANLINESS LEVELS

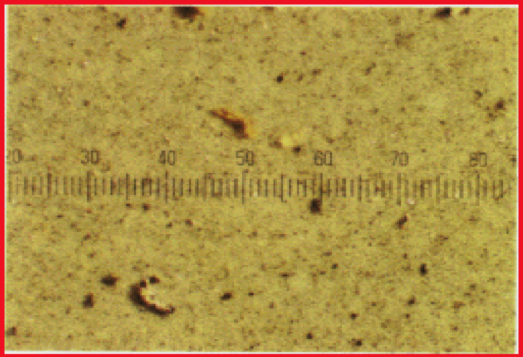
New Oil From Barrel 23/20/18



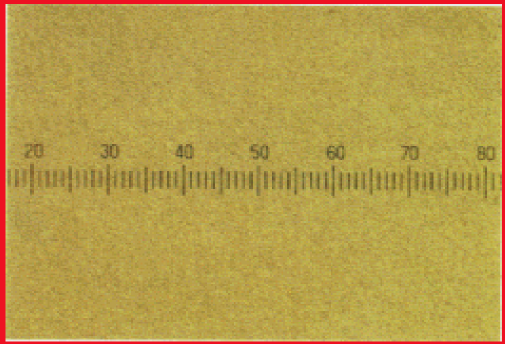
New System w/ Built-in Contaminants 23/22/20



System With Typical Hydraulic Filtration 20/18/16



System with B_3 >200 Clearance Protection Filtration 16/13/11



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TYPICAL HYDRAULIC CLEANLINESS TARGETS

Operating Pressure		<1,500 psi	1,500-2,500 psi	>2,500 psi
Servo Valve		16/14/12	15/13/11	14/12/10
Proportional Valve		17/15/12	16/14/12	15/13/11
Variable Volume Pump		17/16/13	17/15/12	16/14/12
Cartridge Valve		18/16/14	17/16/13	17/15/12
Fixed Piston Pump		18/16/14	17/16/13	17/15/12
Vane Pump		19/17/14	18/16/14	17/16/13
Pressure/Flow Control Valve		19/17/14	18/16/14	17/16/13
Solenoid Valve		19/17/14	18/16/14	18/16/14
Gear Pump		19/17/14	18/16/14	18/16/14

Adjust to cleaner levels for duty cycle severity, machine criticality, fluid type (for example, water base) and safety concerns.

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TYPICAL CELANLINESS TARGET

MACHINE ELEMENT	ISO TARGET
Roller Bearing	16/14/12
Journal Bearing	17/15/12
Industrial Gearbox	17/15/12
Mobile Gearbox	17/16/13
Steam Turbine	18/15/12

Guidelines only – confirm with OEM

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CONTAMINATION CONTROL EXAMPLE

Amount of "Dirt" in Oil	Amount of "Dirt" Flowing Through Pump in One Year
ISO 21/18	630 lb/yr
ISO 18/15	79 lb/yr
ISO 16/13	20 lb/yr

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AGENDA

- INTRODUCTION
- CONTAMINATION SOURCES
  - Internal
    - Corrosion
    - Wear Debris
  - Ingress
    - Airborne Contaminants
    - Moisture
    - Dirty Oil
  - Wrong Lubricant
- ISO PARTICLE COUNT SYSTEM
- **PREVENTION**
  - Storage
    - Lube Rooms, Dispensing
  - Handling and Distribution

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MANAGE CONTAMINATION

The single greatest opportunity for increasing component life and lowering operating costs is to effectively manage fluid cleanliness.

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HOUSEKEEPING FAILURES

- Sweep floors daily
- Clean up spills immediately
- Keep work benches uncluttered and free of debris
- Limit use of floor storage

NOW THAT'S BETTER!!

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NOW THAT'S BETTER!!

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STORAGE

- Take measures to exclude contaminants from becoming part of the lubricant or fluid
- This must happen in the main warehouse and at the individual storage stations throughout your plant.

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STORAGE

- Oil Room Design
  - Contributing factors for oil room design:
    - – Location, location, location
    - – Fire safety
    - – Workers safety
    - – Ergonomics
    - – Lubricant mixing control
    - – Lubricant contamination ingress control
    - – Procedures for bringing new oil into service
    - – Ability to document actions (record keeping)

Courtesy Proactive Lube Manager Inc.

STORAGE

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Buildings and Oil Room Design

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STORAGE

Custom Lube Tank Dispensing Stand
Oil Filtered In and Filtered Out

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STORAGE

Cabinets: Multiple Manufacturers
Fire Rated, Safety Rated
Multiple Sizes and Options

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HANDLING

- Preserving the integrity of the fluid while getting it from storage to usage
- Bear in mind that often the best ways are also the easiest and most efficient ways

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HANDLING

<u>Top up / small oil change out, containers</u>

HANDLING

Containers that reduce the potential and risk of adding unwanted contamination.

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HANDLING

<u>Don’t be afraid to go one step better.</u>

- Consider retro-fitting containers with air breathers, and hand pumps with quick couplers.

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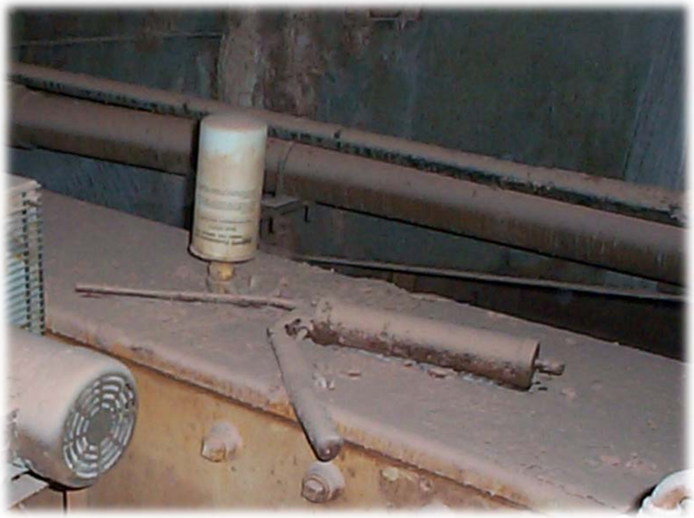
HANDLING

Colour PVC Tags and Vinyl Labels

Courtesy Proactive Lube Manager Inc.

HANDLING

- Grease is more susceptible to particulate contamination



Single and multi point auto-greasers have gained acceptance for reducing particulate ingress risk, and over and under greasing of components.

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HANDLING

- Grease guns are handled improperly

Transparent greasing tools eliminate the age-old problem of picking up the wrong grease gun and mixing products.

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HANDLING

Clear Tube or Colour Grease Guns
Colour (LBC) Fitting Covers: Sonic

Courtesy Proactive Lube Manager Inc.

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DISTRIBUTION

HD Portable, (outside) Filtered
"Barrel Buggy" Drum Dispensers

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EXCLUSION

- The cost of cleaning dirty oil is 10X higher than keeping it clean in the first place!

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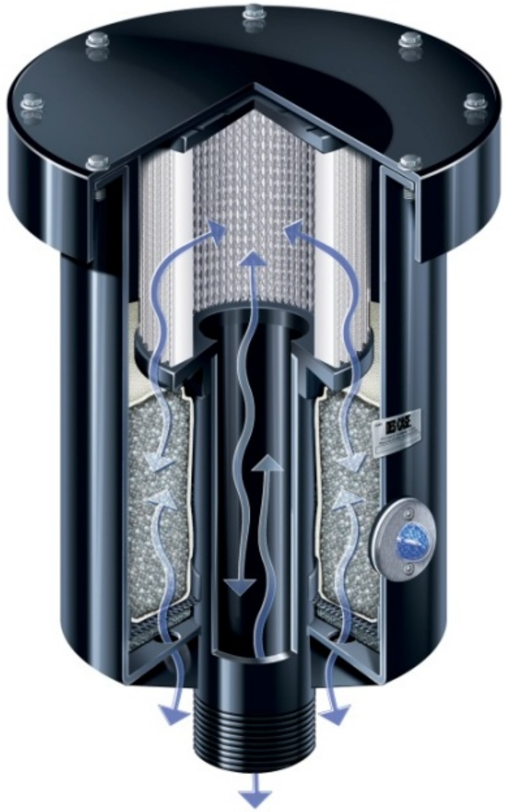
BREATHERS

- There are breathers that will exclude particles as small as ½ micron
- These same breathers are rated at 20 CFM of air or an equivalent of 150 gpm change in tank fluid level
- Look for desiccant breathers to exclude moisture



Courtesy Des-Case.

BREATHERS

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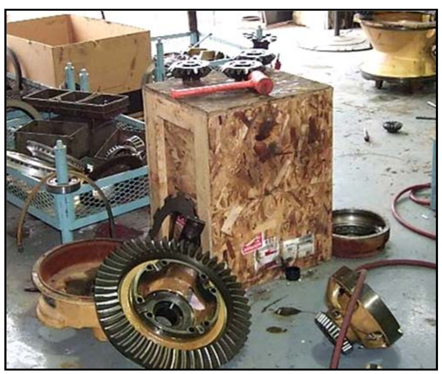
PARTS HANDLING AND STORAGE

- Keep components packaged until ready to install
- Return parts to storage in packaging
- Protect in-process components
- Wash components before assembly



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LIFE EXTENSION - CLEANLINESS

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LET – Cleanliness Level
ISO Codes, Complete

Source: *Noria Corp.*

Current Machine Cleanliness (ISO Code)	Expected Cleanliness level (ISO Code)									
	21/19/16	**20/18/15**	**19/17/14**	**18/16/13**	**17/15/12**	**16/14/11**	**15/13/10**	**14/12/9**	**13/11/8**	**12/10/7**
24/22/19	2 1.6 1.8 1.3	3 2 2.3 1.7	4 2.5 3 2	6 3 3.5 2.5	7 3.5 4.5 3	8 4 5.5 3.5	>10 5 7 4	>10 6 8 5	>10 7 10 5.5	>10 >10 >10 8.5
23/21/18	1.5 1.5 1.5 1.3	2 1.7 1.8 1.4	3 2 2.2 1.6	4 2.5 3 2	5 3 3.5 2.5	7 3.5 4.5 3	9 4 5 3.5	>10 5 7 4	>10 7 9 5.5	>10 10 10 8
22/20/17	1.3 1.2 1.2 1.05	1.6 1.5 1.5 1.3	2 1.7 1.8 1.4	3 2 2.3 1.7	4 2.5 3 2	5 3 3.5 2.5	7 4 5 3	9 5 6 4	>10 7 8 5.5	>10 9 10 7
21/19/16		1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.3	2 1.7 1.8 1.5	3 2 2.2 1.7	4 2.5 3 2	5 3 3.5 2.5	7 4 5 3.5	9 6 7 4.5	>10 8 9 6
20/18/15			1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.3	2 1.7 1.8 1.5	3 2 2.3 1.7	4 2.5 3 2	5 3 3.5 2.5	7 4.6 5.5 3.7	>10 6 8 5
19/17/14				1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.3	2 1.7 1.8 1.5	3 2 2.3 1.7	4 2.5 3 2	6 3 4 2.5	8 5 6 3.5
18/16/13					1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.3	2 1.7 1.8 1.5	3 2 2.3 1.8	4 3.5 3.7 3	6 4 4.5 3.5
17/15/12						1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.4	2 1.7 1.8 1.5	3 2 2.3 1.8	4 2.5 3 2.2
16/14/11							1.3 1.3 1.3 1.2	1.6 1.6 1.6 1.4	2 1.8 1.9 1.5	3 2 2.3 1.8
15/13/10								1.4 1.2 1.2 1.1	1.8 1.5 1.6 1.3	2.5 1.8 2 1.6

Hydraulics and Diesel Engines	**Rolling Element Bearings**
Journal Bearings and Turbo Machinery	**Gear Boxes and others**

LIFE EXTENSION - MOSITURE

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LEM - MOISTURE Level

Source: *Noria Corp.*

Current Moisture Level, ppm	Life Extension Factor								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
50,000	12,500	6,500	4,500	**3,125**	2,500	2,000	1,500	1,000	782
25,000	6,250	3,250	2,250	**1,563**	1,250	1,000	750	500	391
10,000	2,500	1,300	900	**625**	500	400	300	200	156
5,000	1,250	650	450	**313**	250	200	150	100	78
2,500	**625**	**325**	**225**	**156**	125	100	75	50	39
1,000	250	130	90	63	50	40	30	20	16
500	125	65	45	31	25	20	15	10	8
260	63	33	23	16	13	10	8	5	4
100	25	13	9	6	5	4	3	2	2

1% water = 10,000 ppm. • Estimated life extension for mechanical systems utilizing mineral-based fluids.

Example: By reducing average fluid moisture levels from 2500 ppm to 156 ppm, machine life (MTBF) is extended by a factor of 5.

BENEFIT SUMMARY

COMPONENT	IMPROVEMENT
Pump/Motor	4 – 10x increase in pumps and motor life
Roller Bearing	50x extension of roller bearing fatigue life
Journal Bearing	10x extension of journal bearing life
Hydrostatic Transmission	4 – 10x increase in life
Valves	5 – 300x increase in valve life
Valve Spool	Elimination of valve stiction
Fluid	Extension of fluid life through reduced oxidation

METHODS TO ACHIEVE THESE BENEFITS

- Start with Clean Tanks
- Filtration
  - Prior to bulk tank
  - Post bulk tank
  - Dispensing point (drop reels)
- High Efficiency Breathers
- Proper labeling
- Use oil-safe containers
- CLEAN CLEAN CLEAN

Use the RIGHT oil in the RIGHT component

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