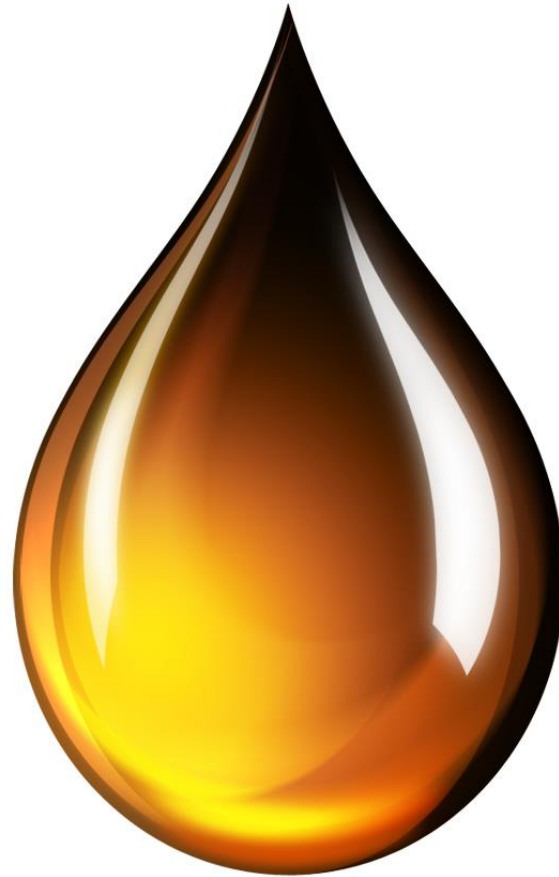


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# Lubrication Basics

[www.PSDgraphics.com](http://www.PSDgraphics.com)





# Training Topics

- Introduction
- Safety Moment
- What a Lubricant is Expected to do
- What is Friction (causes)
- Lubrication Regimens
- Lubrication Intervals
- One Minute Inspections



# Mike Hitchcock, CLS, OMA-1

Engineer

719-338-8436

[mhitchcock@acornpetroleuminc.com](mailto:mhitchcock@acornpetroleuminc.com)



Certified Lubrication Specialist (STLE)  
Certified Oil Monitoring Analyst (STLE)  
Integration Engineer

- Navistar Truck and Engine (Workhorse)
- General Motors
- Spartan Motors



# Who We Are





# Kettering Moment

**Problems are the price of progress. Don't bring me anything but trouble. Good news weakens me.**

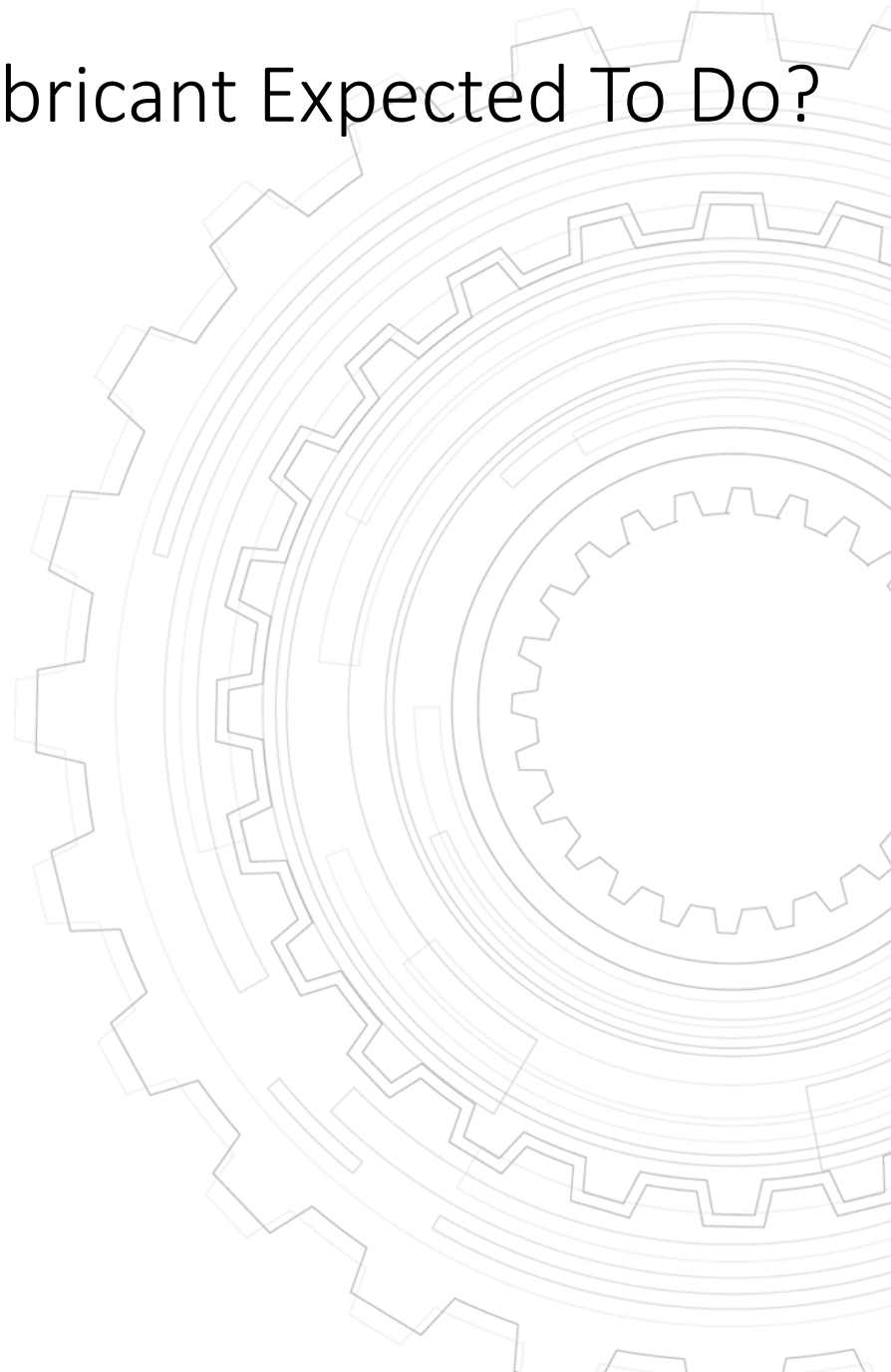
Charles Kettering





# What's a Lubricant Expected To Do?

- Reduce Friction
- Minimize Wear
- Cool Parts
- Prevent Corrosion
- Disperse Contaminants
- Act as a Sealant
- Transmit Power





# 3 Keys to Successful Lubrication

- **Viscosity**
- **Additives**
- **Lubrication Practices**



# Five Rights of Lubrication

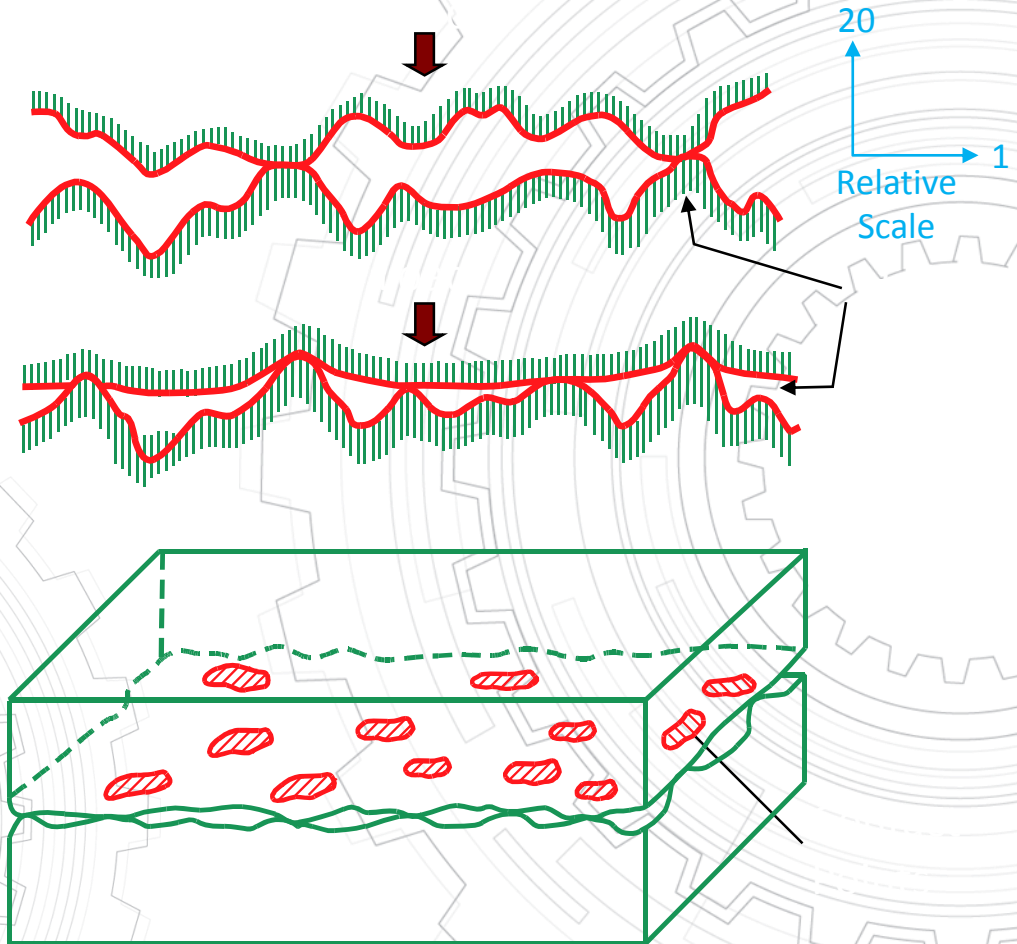
- Right Type of Lubricant
- Right Quality
- Right Amount
- Right Place
- Right Time





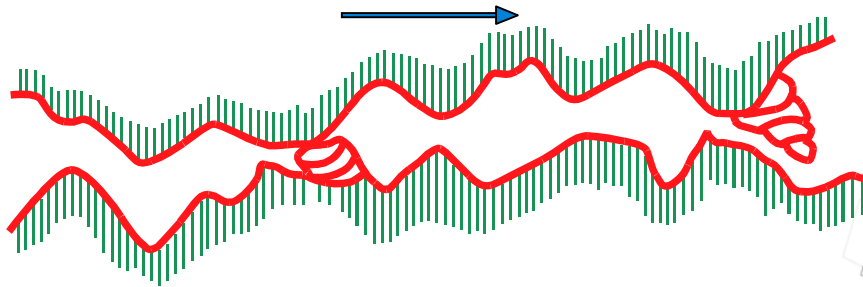
# Causes of Friction

- Friction is caused by interactions at the surfaces of adjoining parts
  - At a microscopic level, all surfaces are “rough”
  - Surface peaks (asperities) may bond to one another or protrude into adjoining surface

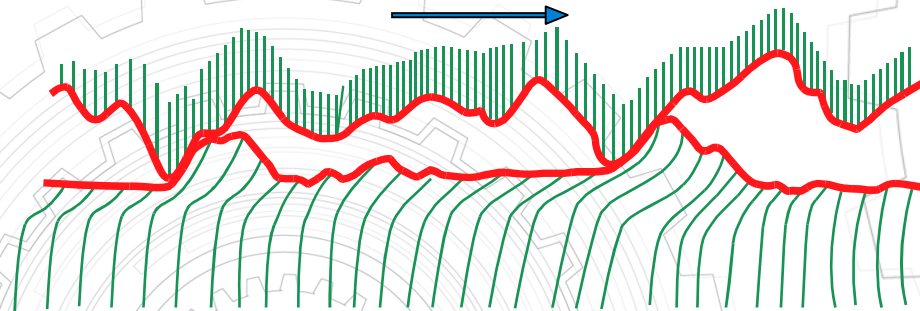


# Major Causes of Friction

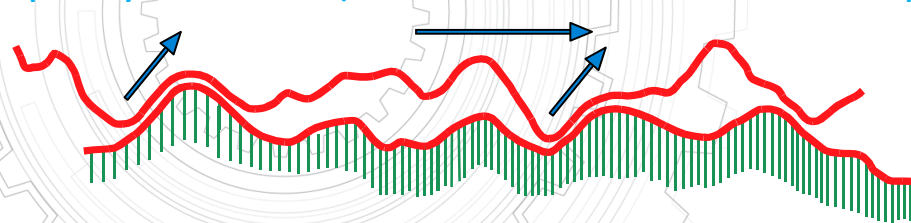
Adhesion (Micro "Spot-Welding")



Abrasive Deformation ("Plowing")



Asperity Override (With Adhesion → "Stick-Slip")

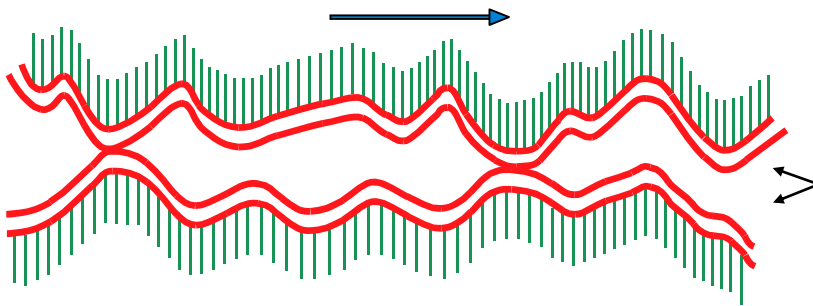


- **Movement of surfaces requires an applied force great enough to overcome microscopic surface interactions**
- **Friction can lead to high wear**

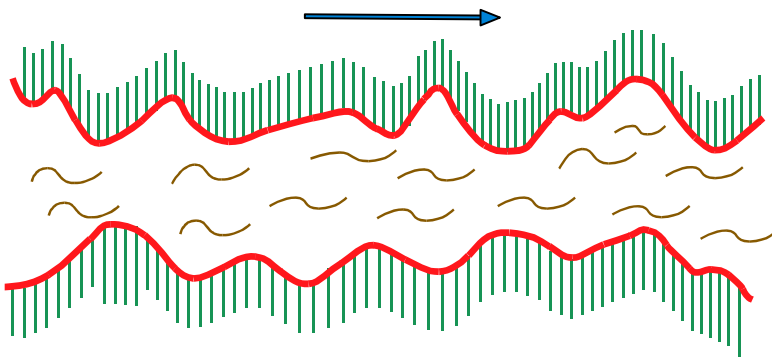


# Ways to Reduce Friction

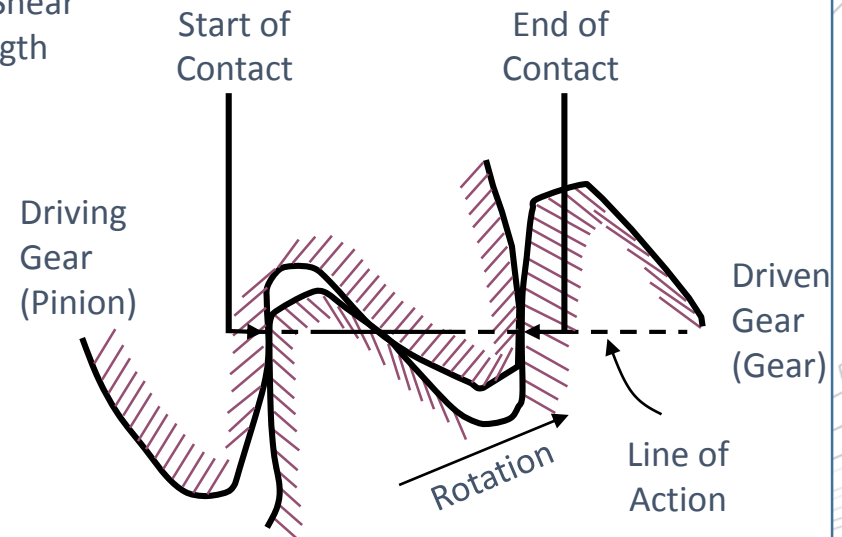
- Lower Adhesive



- Separate Surfaces With a Liquid ("Oil") Film



- Design moving parts to roll over each other (minimize slide/roll ratio)

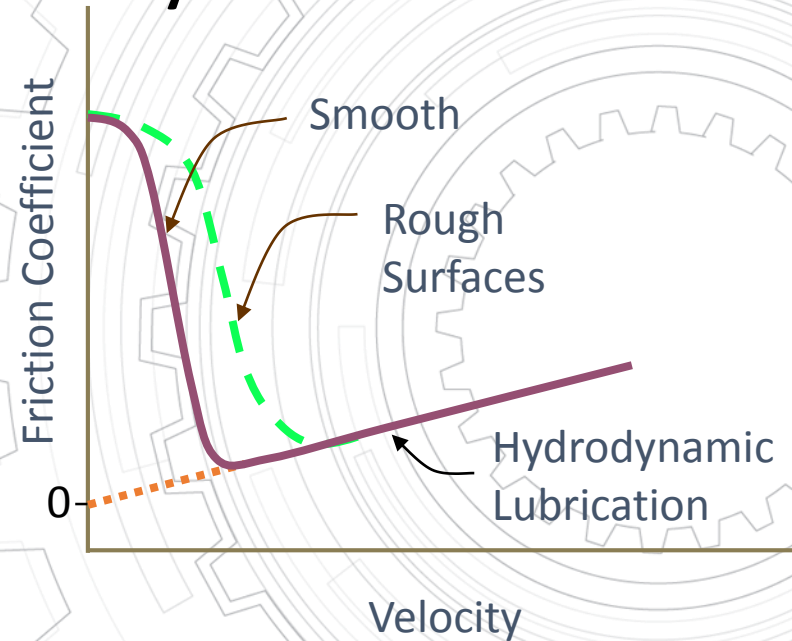
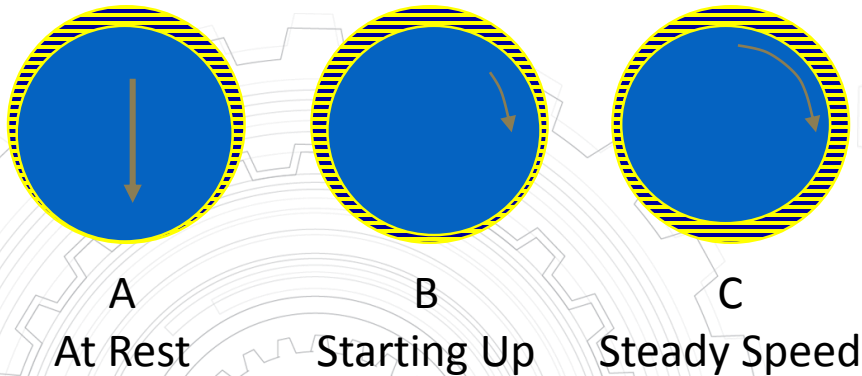




# Lubrication and Friction

## •Coefficient of Friction Varies With Velocity

Three Positions of a Shaft (Journal)  
in a Bearing





# Viscosity

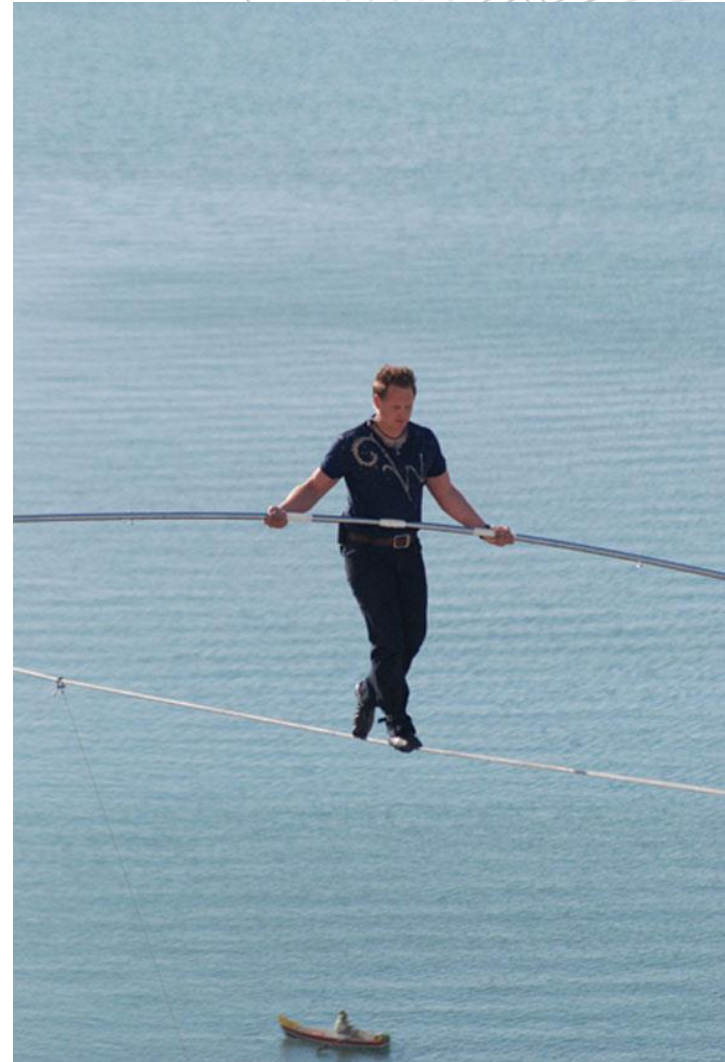
**Viscosity = Resistance to Flow**

**THE MOST IMPORTANT CHARACTERISTIC OF AN OIL!!**



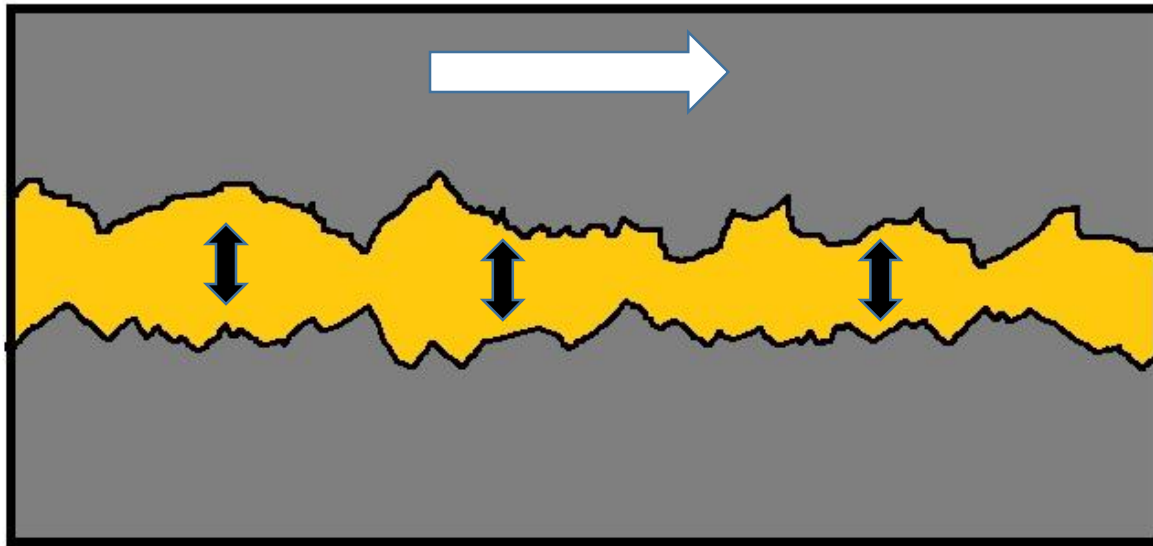
# Viscosity

- Viscosity is a delicate balance
  - Viscosity too high
    - More heat from liquid friction
  - Viscosity too low
    - Mechanical friction





# What Viscosity Does For Us

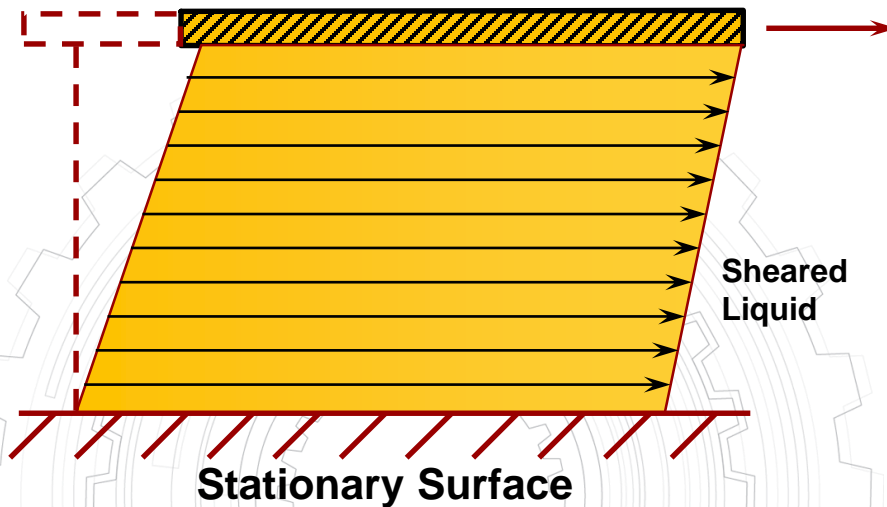




# Viscosity

- The force required to slide one object over another when the two surfaces are fully separated by a fluid is dependent on the fluid's viscosity

**Moving Surface**



The higher a fluid's viscosity, the greater the force (energy) required to slide the surfaces at a given speed and gap

$$\text{Viscosity} = \frac{\text{Shear Force (per area)}}{\text{Shear Rate (flow)}}$$

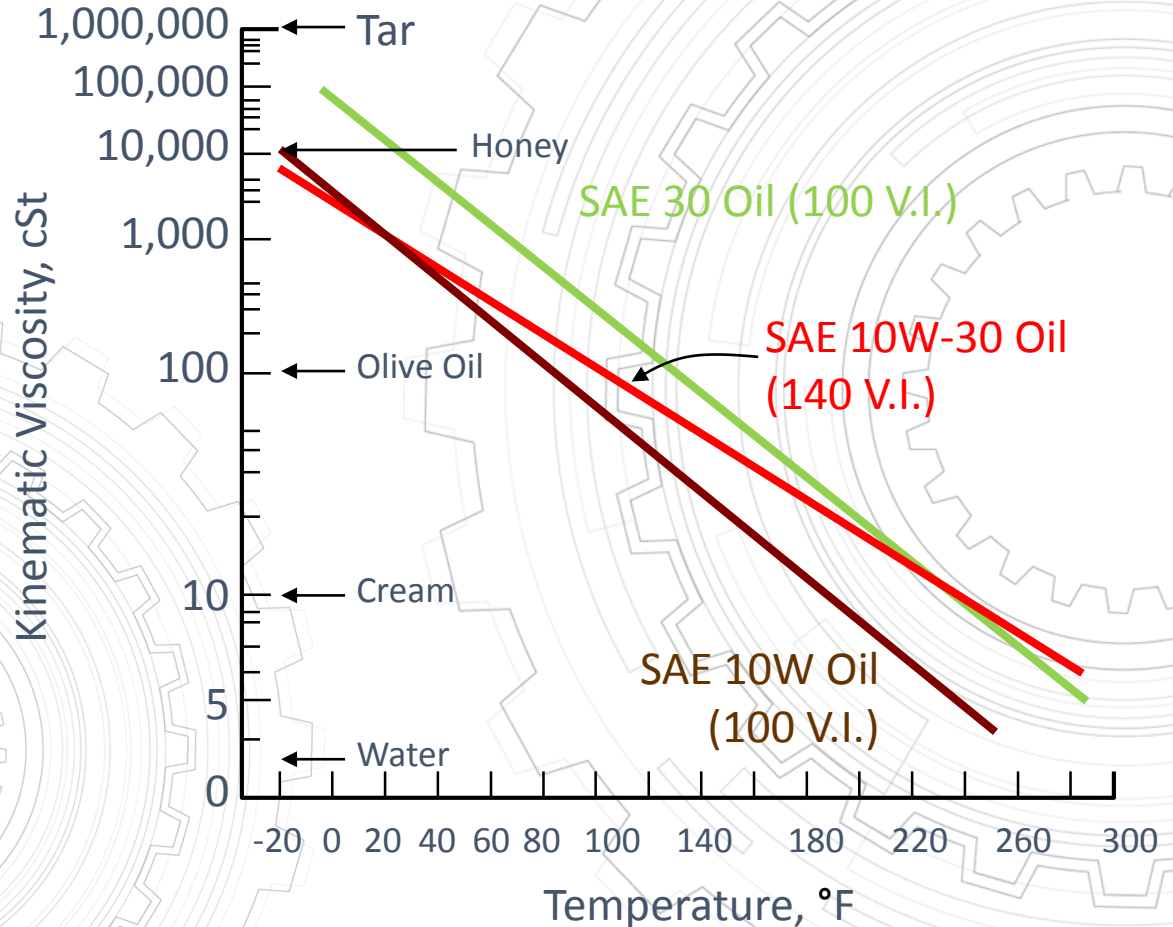
**Viscosity is defined as a measurement of a fluid's "RESISTANCE TO FLOW"**





# Viscosity and Temperature

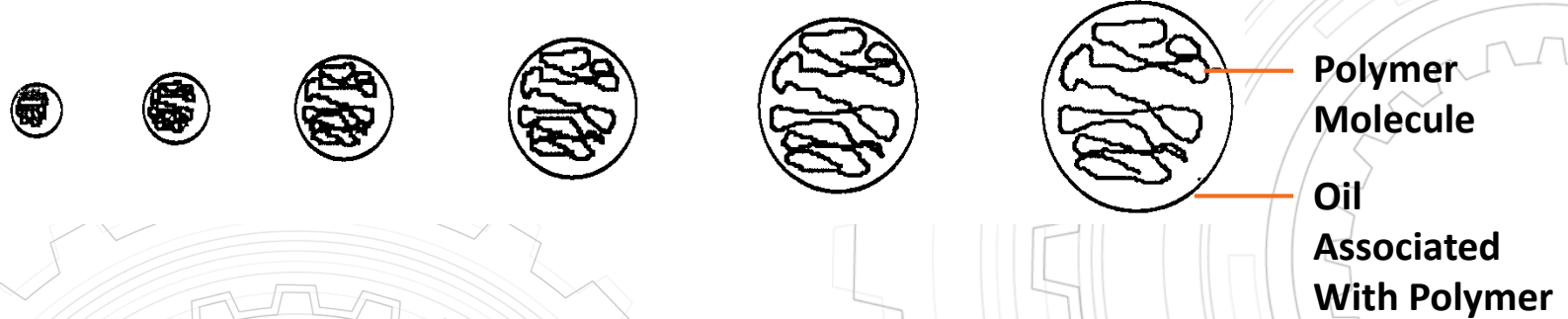
- Lubricant Viscosity Decreases Dramatically With Increasing Temperature [Log(Log X) Relationship]
- Viscosity Index (V.I.) is a Measure of an Oil's Viscosity-Temperature Behavior
- Multigrade Oils Have Higher V.I.'s Than Single Grades, i.e., Their Viscosity Changes Less With Temperature





# Viscosity Modifier Mechanism

Increasing Temperature



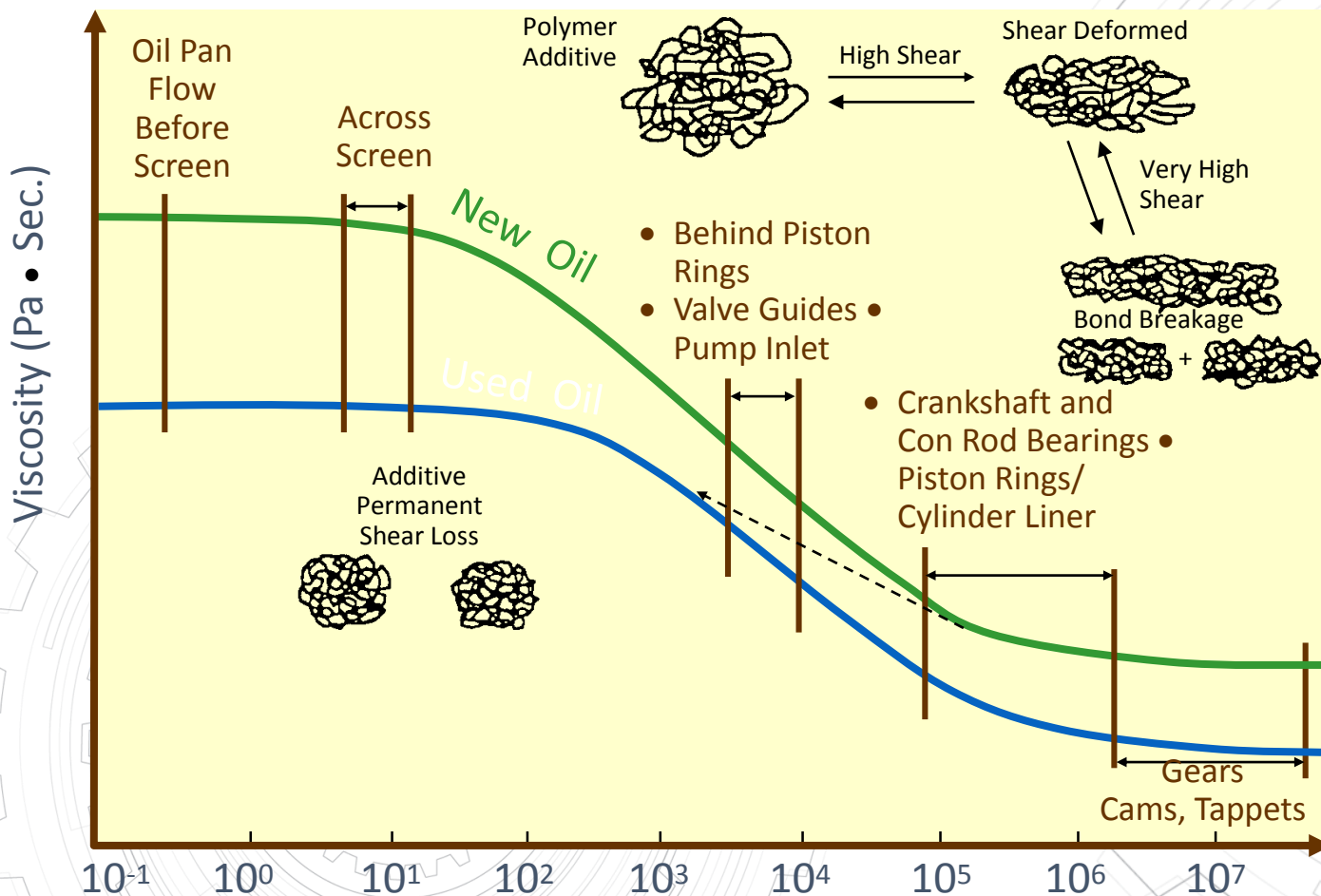
Increasing Viscosity Contribution

(Increasing Effective Size of Polymer)





# Viscosity and Shear Rate

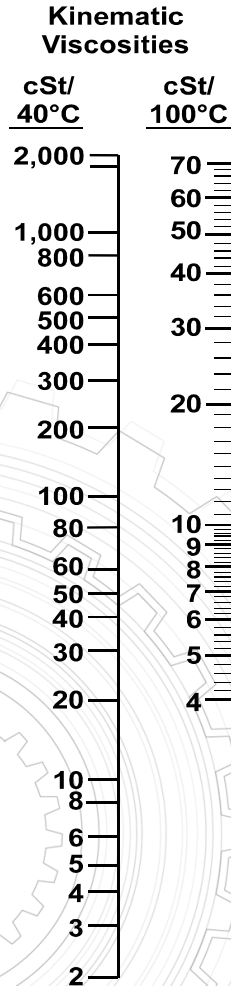


▪ High Speed Environments Cause Viscosity “Shear Down”

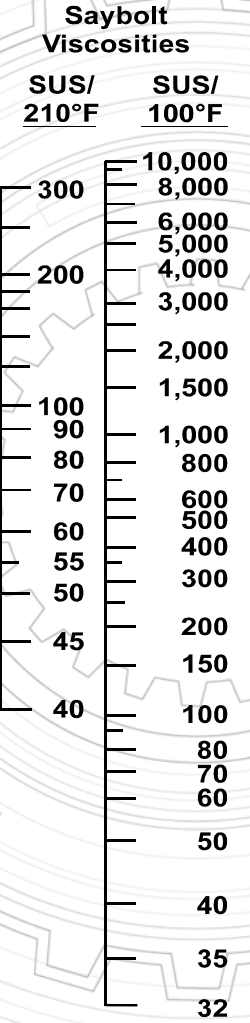
▪ Multigrade Oils Can Undergo Permanent Shear Losses With Age



# Viscosity Grade Equivalents



ISO VG	AGMA	SAE Grades Crankcase Oils	SAE Grades Gear Oils
1500			
1000	8A		250
680	8		140
460	7		90
320	6	50	85W
220	5	40	80W
150	4	25W-30	75W
100	3	20	
68	2	15W-20W	
46	1	10W	
32		0W-5W	
22			
15			
10			
7			
5			
3			
2			



Viscosities can be related horizontally only.  
 Viscosities based on 95 VI single-grade oils.  
 ISO and AGMA are specified at 40°C.  
 SAE Crankcase Oils and SAE Gear Oils are specified at 100°C.



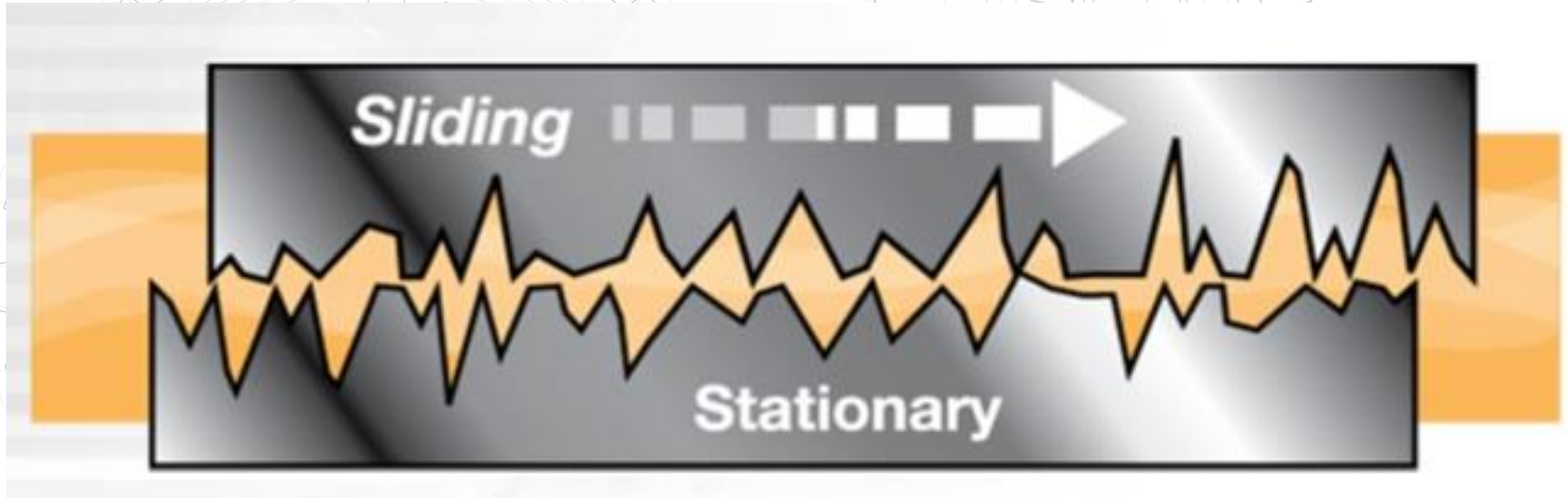
## Regimes of Lubrication (Dependent on Speed, Viscosity, and Load)

- Hydrodynamic
  - Thick oil films
- Elastohydrodynamic (High Pressure)
  - Thin oil films
- Extreme Pressure or Boundary Lubrication
  - No oil film



# BOUNDARY LUBRICATION

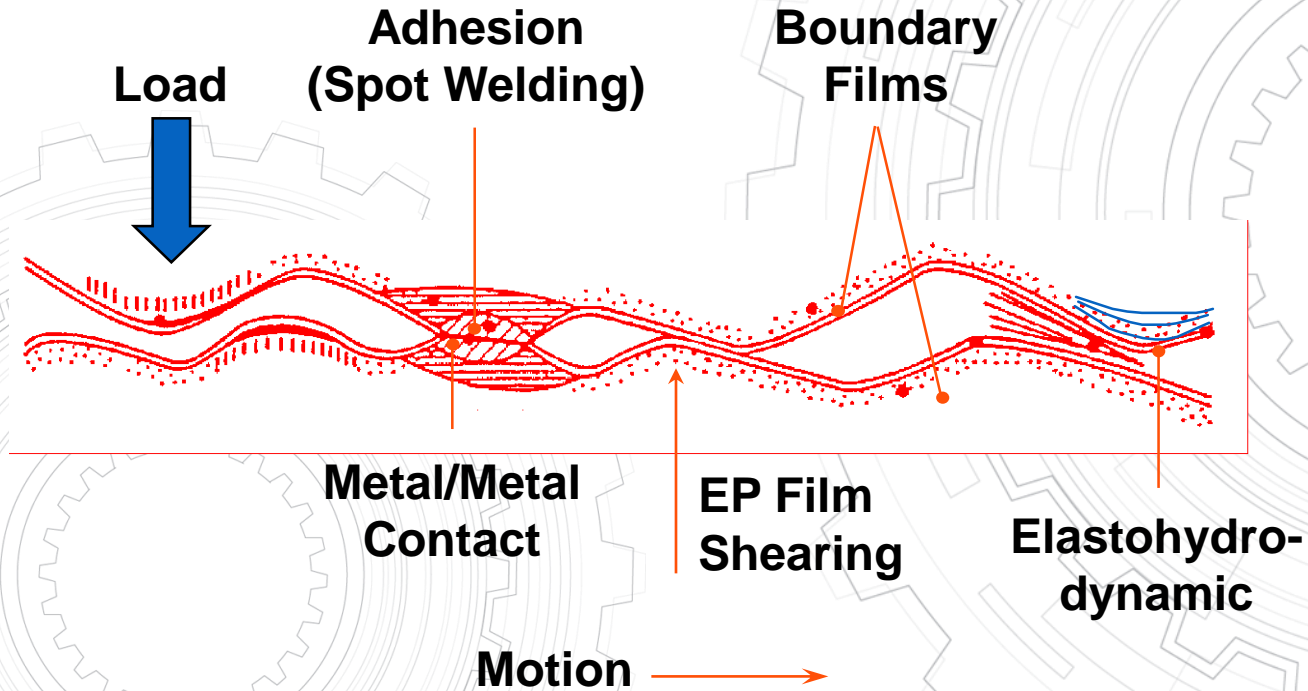
- Boundary Lubrication occurs in the absence of proper lubrication film. Additives can coat surfaces to prevent welding but tearing and damage can happen





# Mixed or Boundary or Extreme Pressure Lubrication

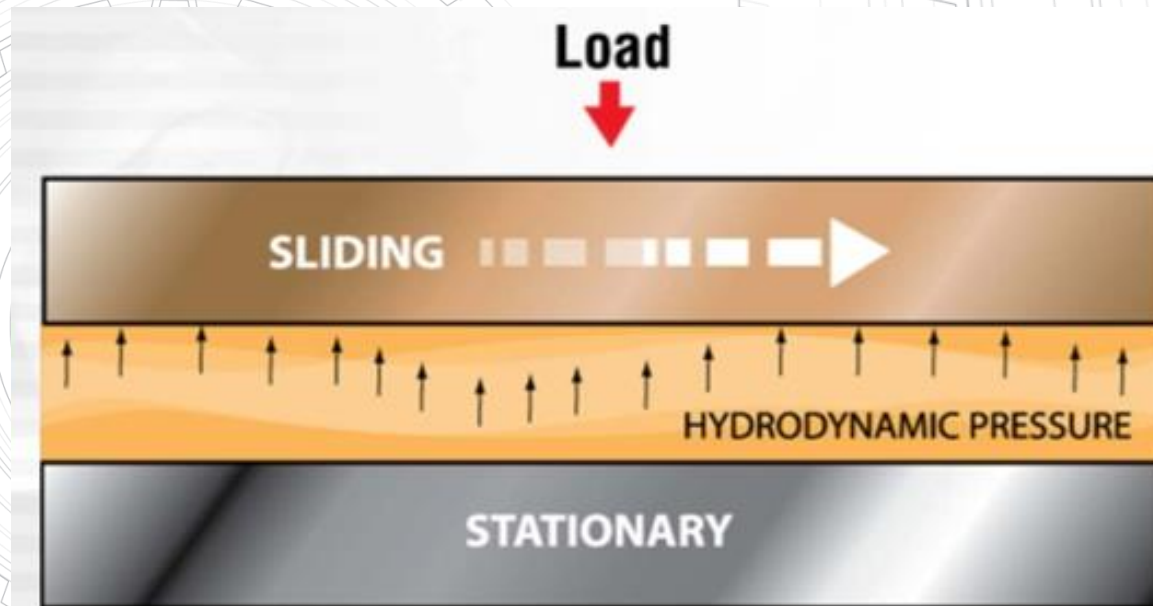
- Onset of metal/metal contact
- Need surface active anti-wear/anti-scuff (AW) and extreme pressure (EP) additive agents to prevent metal/metal adhesion and to lower shear forces (friction)





# HYDRODYNAMIC LUBRICATION

- Continuous full-fluid film prevents metal to metal contact . The entire load is supported by the hydrodynamic pressure created by the fluid. The viscosity of the fluid prevents the contact.







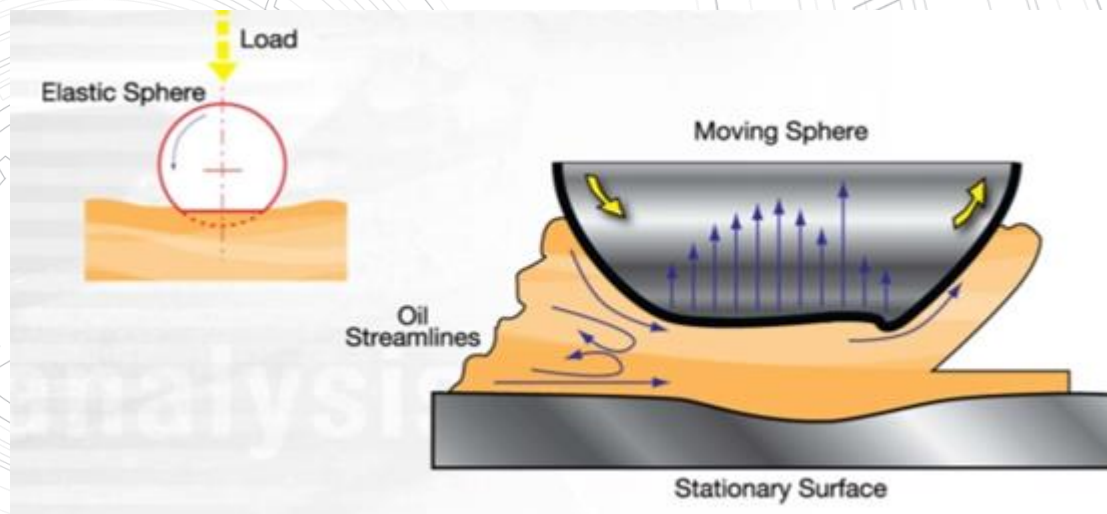
# Hydrodynamic Lubrication

- Characteristic:
  - Surfaces separated by an oil film
- Oil Film Thickness:
  - 0.003 – 0.0001 inch
- Typical Examples:
  - Plain and journal bearings such as pin and bushings, or engine main or rod bearings
- Wear (in Steady Operation):
  - Nil



# ELASTOHYDRODYNAMIC LUBRICATION

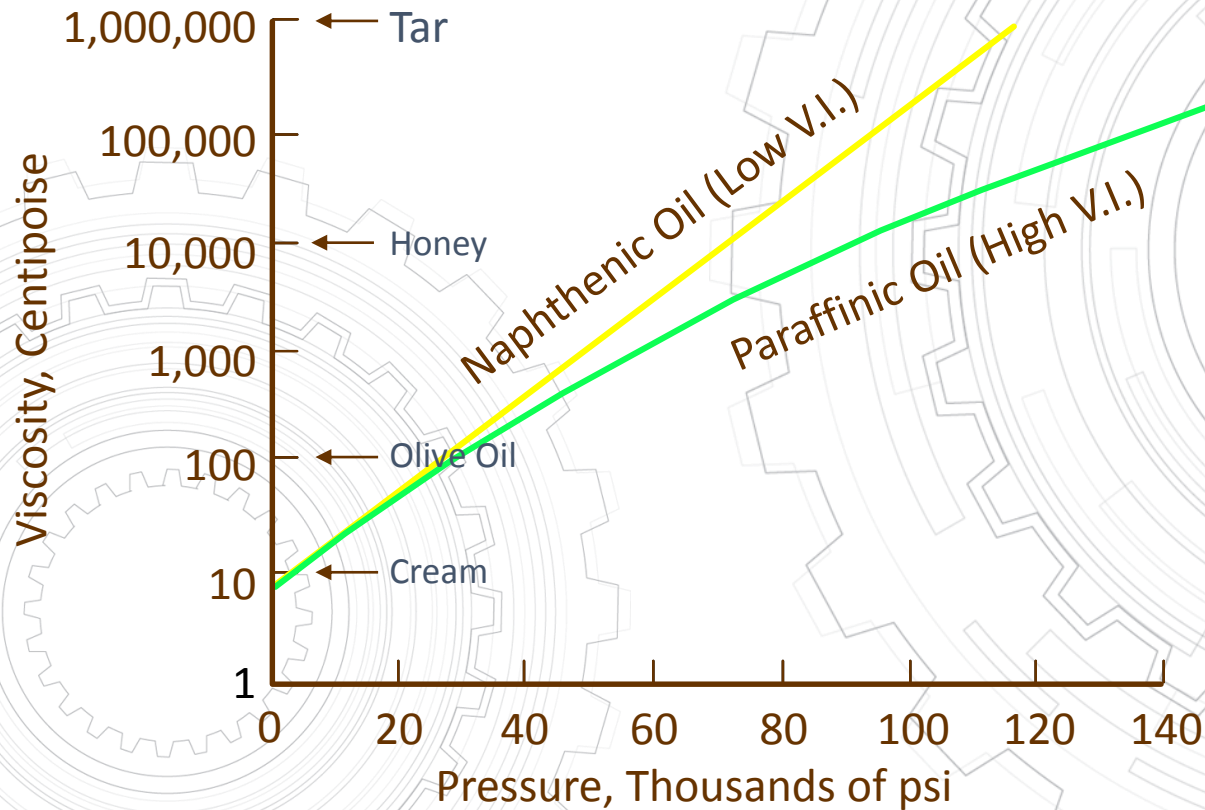
- Pressure increase in the contact zone increases the viscosity
- Trapped oil in the contact zone becomes a solid
- Metal surfaces in the contact zone are “elastically” deformed
- EHD friction (traction) from viscous shearing raises the contact zone temperatures
- Examples: Rolling element bearings, gears, cams and followers, and traction devices





# Viscosity Versus Pressure

- Viscosity Increases Dramatically With Pressure
- High V.I. Base Oils Exhibit Relatively Small Pressure-Viscosity Changes





# Particle Contamination

## How Big is a Micron?

### MICRON

Unit of Measurement

1 Millionth of a  
Meter (Micrometer)  
or 0.000039"

$\mu\text{m}$  = Micron Symbol

### PARTICLE SIZE

100  $\mu\text{m}$  = Grain of Table Salt

40  $\mu\text{m}$  = Lower Limit of Visibility

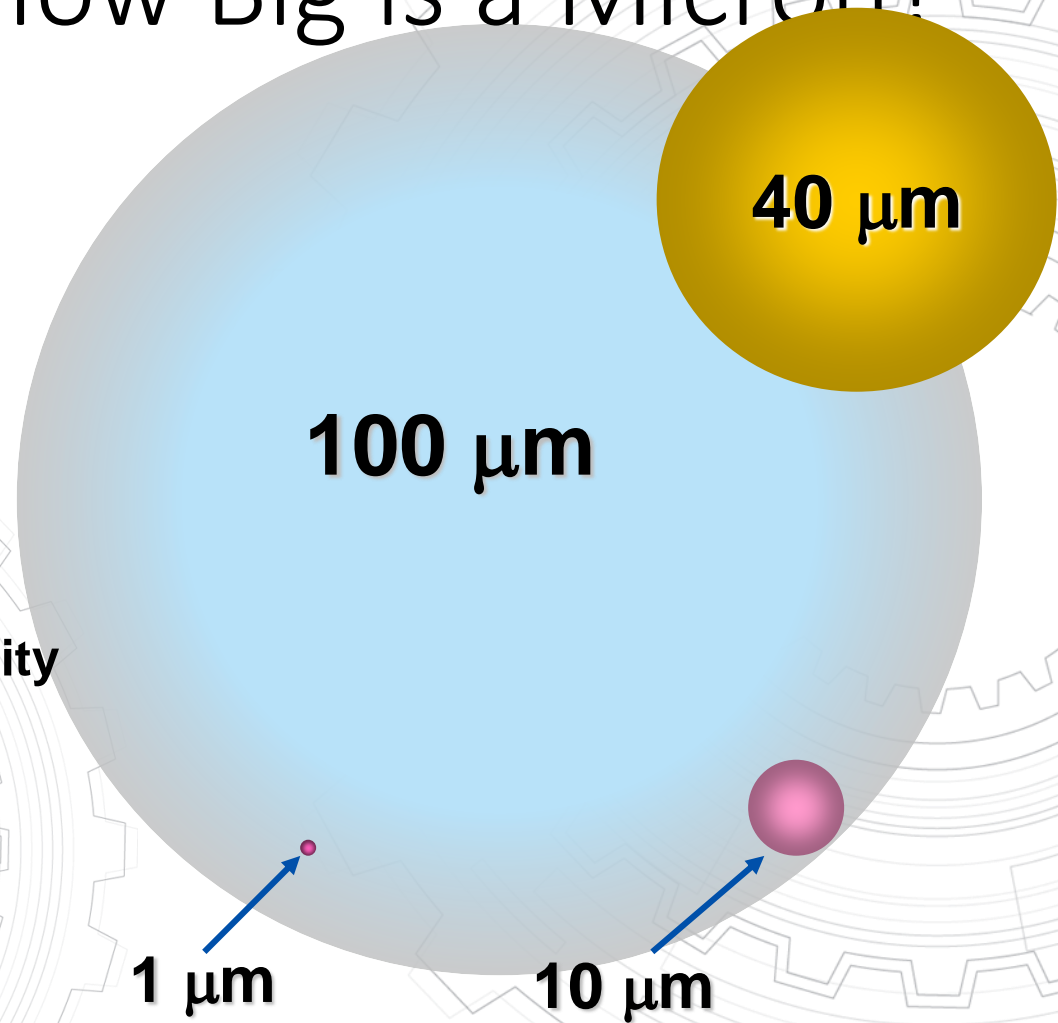
10  $\mu\text{m}$  = Talcum Powder

8  $\mu\text{m}$  = Red Blood Cells

2  $\mu\text{m}$  = Bacteria

Particles "Suspended" in Oil: <5-10  $\mu\text{m}$  in Size

Ref: Donaldson





# Mixed or Boundary or Extreme Pressure Lubrication

- Characteristic:
  - Surfaces separated by films of molecular dimensions
- Film Thickness:
  - About 0.08-0.4 microinch
- Examples:
  - Heavily loaded gears, diesel engine ring on liner at TDC, valve trains
- Wear:
  - High during running in period — then becomes moderate to low depending on lubricant and additive package



# Industry Standards

- Engine Oils
  - 250 Hours
- Hydraulic Oils
  - 500 - 1000 Hours
- Coolants
  - Annually
- Grease
  - Daily/Shift



# Industry Standards

Operating at 250 Hours is Equivalent to  
11,250 Miles.



# MODERN ENGINES

- MaxxForce 7

## Preventative Maintenance Intervals

- Change Engine Oil, Replace Oil Filter: 10,000 miles (16,100 km) / 350 hours / 1,000 gallons (3,800 L) / 6 months
- Replace Fuel Filter: 30,000 miles (48,280 km)
- Replace Coolant\*: 300,000 miles (482,803 km) / 5 years / 12,000 hours
- Valve Lash Adjustment: Not Required
- Crankcase Breather: 60,000 (96,561 km)

\*Add extender @ 150,000 miles (241,400 km) / 2.5 years / 6,000 hours



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# CONSTRUCTION EQUIPMENT.

newsletters subscribe

## THE RIGHT SPEC FOR THE JOB.

EVALUATIONS ASSET MANAGEMENT

EQUIPMENT TYPE 

### 350-HOUR OIL-CHANGE INTERVALS SAVE MORE THAN \$12,000 PER YEAR

Average-sized excavator relieves reliability concerns with a real-world test and careful oil analysis

By **Larry Stewart, Executive Editor**

February 01, 2003

Steve Fallert Profile

Steve Fallert,  
Bloomsdale Excavating  
Headquarters: Bloomsdale, Mo.

Specialties: Earthmoving for highways, industrial and commercial development, utility work

Equipment Value: \$20 million

Fleet: 120 total units, including 30 light trucks and cars



# MODERN ENGINES









Manufacturer	Navistar			Cummins	
Feature	MaxxForce DT	MaxxForce 9	MaxxForce 10	ISC8.3	ISL9
Oil Change Intervals	Up to 25,000 mi. / 825 hrs. / 3,100 Gals. Fuel	Up to 25,000 mi. / 825 hrs. / 3,100 Gals. Fuel	Up to 25,000 mi. / 825 hrs. / 3,100 Gals. Fuel	Up To 15,000 mi. / 500 hrs. / 6 mos.	20,000 mi. / 500 hrs. / 6 mos.



# MODERN ENGINES

## Cummins\*\*\*

(Cummins TSB101040 – Heavy Duty Product Oil Drain Intervals - 24 Aug-2010)

Engine Type	Light*	Normal*	Severe*
 EPA 2010 ISX 15**	35,000 miles – CES 20081 40,000 miles – CES 20078	25,000 miles – CES 20081 30,000 miles – CES 20078	15,000 miles – CES 20081 20,000 miles – CES 20078
 EPA 2010 ISX 11.9**	35,000 miles – CES 20081 40,000 miles – CES 20078	25,000 miles – CES 20081 30,000 miles – CES 20078	15,000 miles – CES 20081 20,000 miles – CES 20078
 EPA 2010 ISL 9**	Check with Cummins	20,000 miles 500 Hours	Check with Cummins
 EPA 2010 ISC 8.3**	Check with Cummins	20,000 miles 500 Hours	Check with Cummins
 EPA 2010 ISB 6.7**	Check with Cummins	20,000 miles 500 Hours	Check with Cummins
 EPA 07 ISX**	35,000 miles – CES 20081 40,000 miles – CES 20078	25,000 miles – CES 20081 30,000 miles – CES 20078	15,000 miles – CES 20081 20,000 miles – CES 20078
 EPA 07 ISM**	35,000 miles – CES 20081 40,000 miles – CES 20078	25,000 miles – CES 20081 30,000 miles – CES 20078	15,000 miles – CES 20081 20,000 miles – CES 20078
 EPA 07 ISC**	Check with Cummins	15,000 miles 500 Hours	Check with Cummins

\*Light Duty > 6.5 mpg or < 70,000 lbs gross weight; Normal Duty = 5.5 to 6.5 mpg or 80,000 lbs gross weight; Severe Duty < 5.5 mpg or > 80,000 lbs gross weight

\*\*CES 20081 refers to an API CJ-4 approved oil like Delo 400 LE 15W-40; CES 20078 refers to an API CI-4 Plus Oil like Delo 400 Multigrade 15W-40

\*\*\* For any Cummins engine models with light or normal service duty; Cummins allows an additional 5,000 mile drains when using Cummins Premium Blue & Valvoline Premium Blue Extreme



# MODERN ENGINES

## Detroit Diesel

(Detroit Diesel Service and Maintenance Intervals Bulletin)



Engine Type	Severe*	Short-Haul*	Long-Haul*
DD15**	25,000 miles 640 hours	35,000 miles 895 hours	50,000 miles 1,280 hours
DD13**	25,000 miles 640 hours	35,000 miles 895 hours	50,000 miles 1,280 hours
DD16**	25,000 miles 640 hours	35,000 miles 895 hours	50,000 miles 1,280 hours
Series 60***	Check with Detroit Diesel	Check with Detroit Diesel	30,000 miles
MBE 4000***	10,000 miles	15,000 miles	30,000 miles
MBE 900***	6,000 miles	15,000 miles	20,000 miles

\*Severe Duty is up to 30,000 miles annually and for vehicles that average 5 mpg or less; Short Haul is between 30,001 and 60,000 miles annually and average between 5.1 and 5.9 mpg; Long Haul is over 60,001 miles annually and average greater than 6 mpg.

\*\* Use engine oils approved against DD 93K218 – API CJ-4 oils like Delo® 400 LE 15W-40

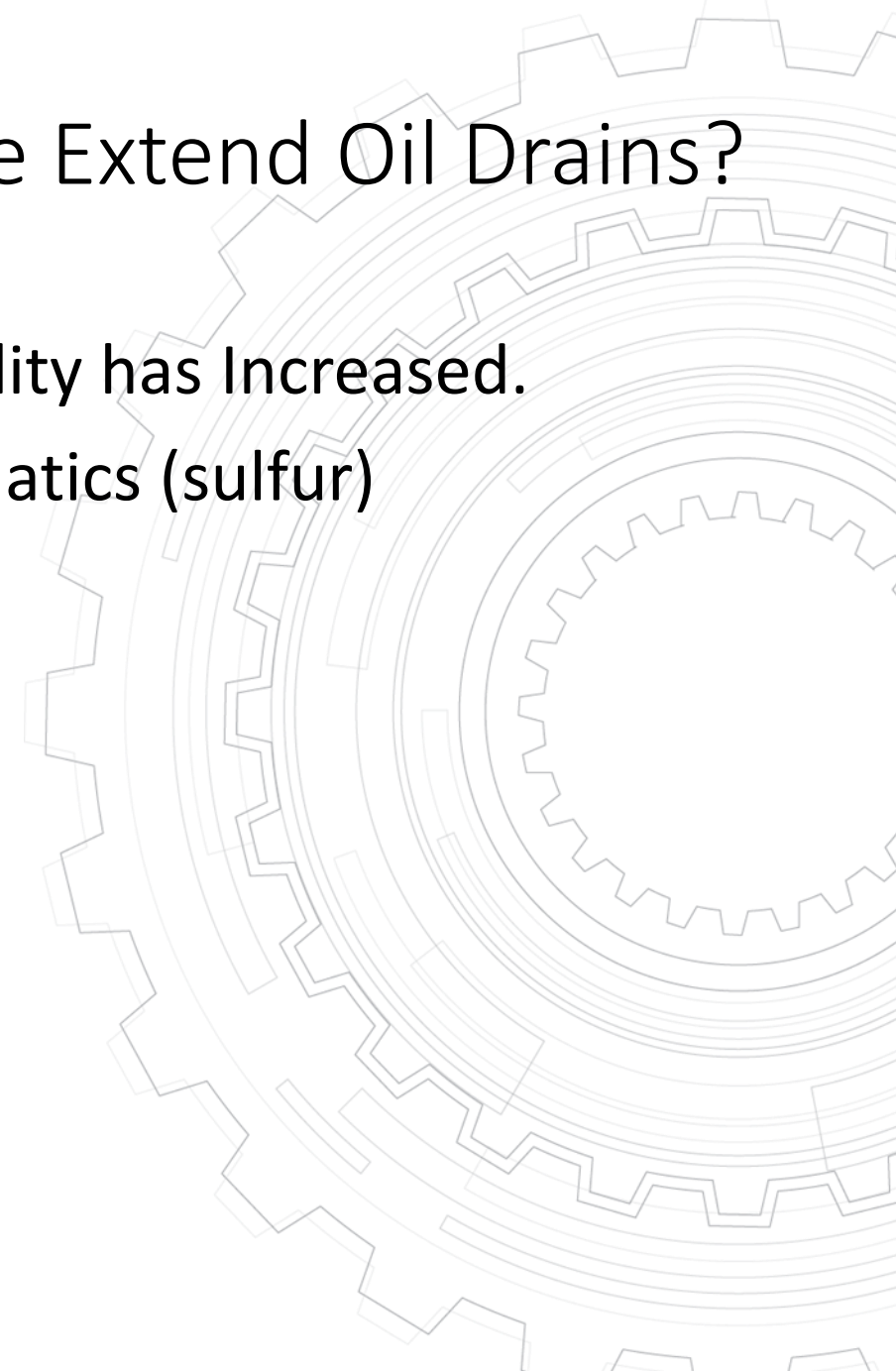
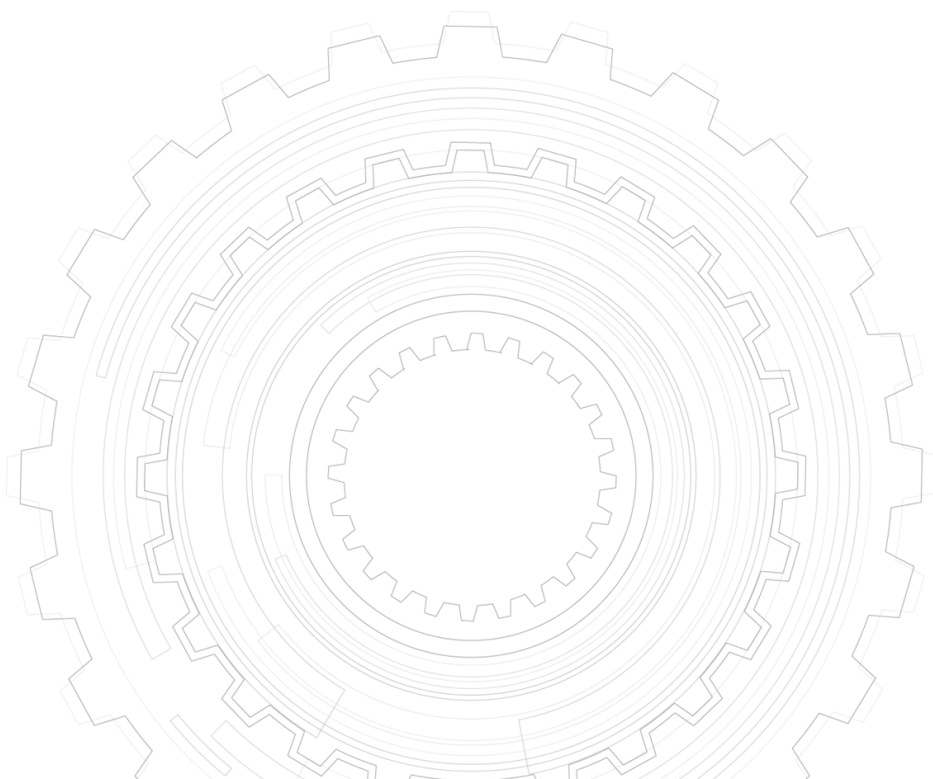
\*\*\*Use Engine Oils approved against DD 93K214 – API CI-4 Plus Oils like Delo 400 Multigrade 15W-40





# How Can We Extend Oil Drains?

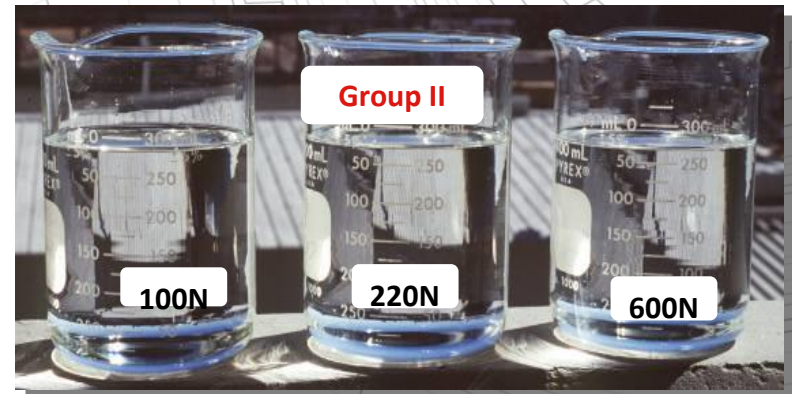
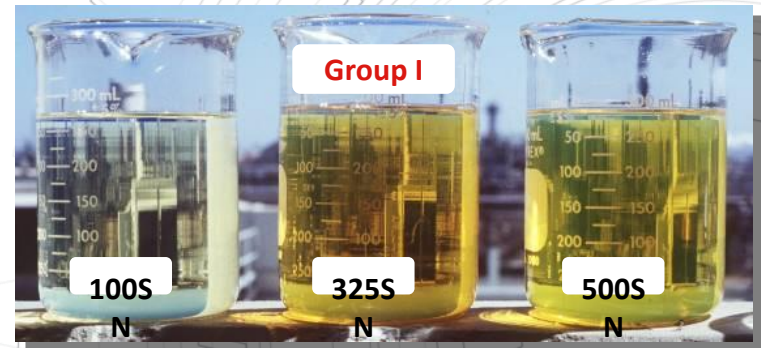
- OEM's Understand Oil Quality has Increased.
- Modern Oils Have no Aromatics (sulfur)





# New Oil Technology

- Older Technology leaves impurities that aids in product deterioration
- Group II oils





# Maintenance

Acronym to Remember is “FLAB”

- Fasteners
- Lubrication
- Alignment
- Balance

Drew Troyer is the originator of this Acronym



# Where Do We Start

- Control Intrusion  
Reduce Silica  
Contamination







# Where Do We Start

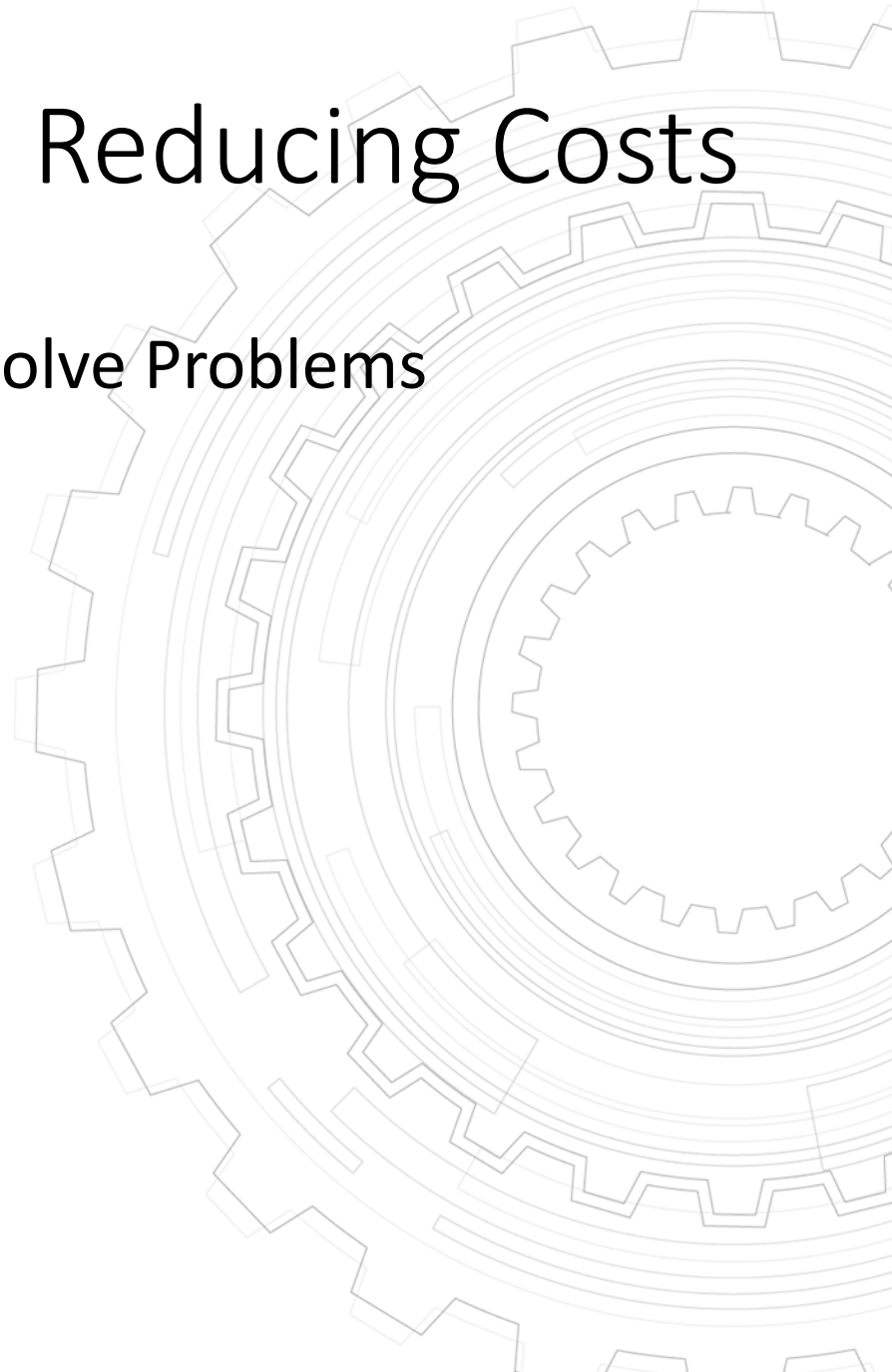
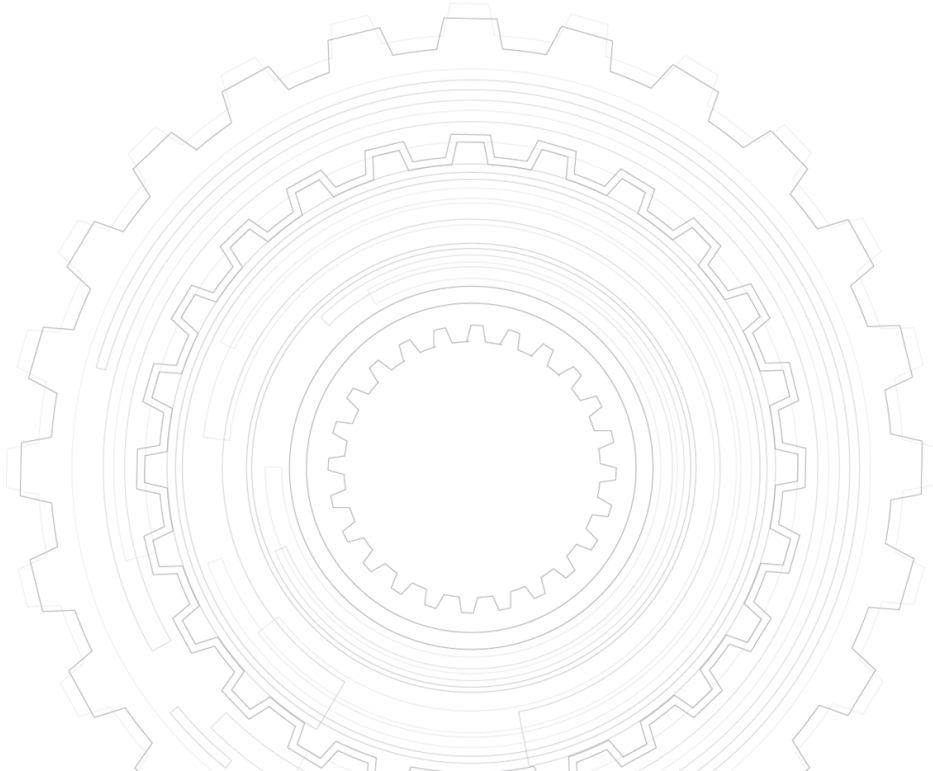
- Control Intrusion
  - Reduce Silica Contamination
  - Reduce Water Contamination





# Reducing Costs

Using Analysis to Solve Problems





# Reducing Costs

Using Analysis to Solve Problems

A Oil Analysis Program is at the heart of any “BEST PRACTICES” program.





# Life Extension Table

NEW CLEANLINESS LEVEL (ISO CODE)

CURRENT CLEANLINESS (ISO CODE)

	20/17		19/16		18/15		17/14		16/13		15/12		14/11		13/10		12/9		11/8		10/7	
26/23	5	3	7	3.5	9	4	>10	5	>10	6	>10	7.5	>10	9	>10	>10	>10	>10	>10	>10	>10	>10
	4	2.5	4.5	3	6	3.5	6.5	4	7.5	5	8.5	6.5	10	7	>10	9	>10	10	>10	>10	>10	>10
25/22	4	2.5	5	3	7	3.5	9	4	>10	5	>10	6	>10	7	>10	9	>10	>10	>10	>10	>10	>10
	3	2	3.5	2.5	4.5	3	5	3.5	6.5	4	8	5	9	6	10	7.5	>10	9	>10	>10	>10	>10
24/21	3	2	4	2.5	6	3	7	4	9	5	>10	6	>10	7	>10	8	>10	10	>10	>10	>10	>10
	2.5	1.5	3	2	4	2.5	5	3	6.5	4	7.5	5	8.5	6	9.5	7	>10	8	>10	10	>10	>10
23/20	2	1.5	3	2	4	2.5	5	3	7	3.5	9	4	>10	5	>10	6	>10	8	>10	9	>10	>10
	1.7	1.3	2.3	1.5	3	2	3.7	2.5	5	3	6	3.5	7	4	8	5	10	6.5	>10	8.5	>10	10
22/19	1.6	1.3	2	1.6	3	2	4	2.5	5	3	7	3.5	8	4	>10	5	>10	6	>10	7	>10	>10
	1.4	1.1	1.8	1.3	2.3	1.7	3	2	3.5	2.5	4.5	3	5.5	3.5	7	4	8	5	10	5.5	>10	8.5
21/18	1.3	1.2	1.5	1.5	2	1.7	3	2	4	2.5	5	3	7	3.5	9	4	>10	5	>10	7	>10	10
	1.2	1.1	1.5	1.3	1.8	1.4	2.2	1.6	3	2	3.5	2.5	4.5	3	5	3.5	7	4	9	5.5	10	8
20/17			1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4	9	5	>10	7	>10	9
			1.2	1.05	1.5	1.3	1.8	1.4	2.3	1.7	3	2	3.5	2.5	5	3	6	4	8	5.5	10	7
19/16					1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4	9	6	>10	8
					1.2	1.1	1.5	1.3	1.8	1.5	2.2	1.7	3	2	3.5	2.5	5	3.5	7	4.5	9	6
18/15							1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4.5	>10	6
							1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.7	3	2	3.5	2.5	5.5	3.7	8	5
17/14									1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	6	3	8	5
									1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.7	3	2	4	2.5	6	3.5
16/13											1.3	1.2	1.6	1.5	2	1.7	3	2	4	3.5	6	4
											1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.8	3.7	3	4.5	3.5
15/12													1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5
													1.2	1.1	1.5	1.4	1.8	1.5	2.3	1.8	3	2.2
14/11															1.3	1.3	1.6	1.6	2	1.8	3	2
															1.3	1.2	1.6	1.4	1.9	1.5	2.3	1.8
13/10																	1.4	1.2	1.8	1.5	2.5	1.8
																	1.2	1.1	1.6	1.3	2	1.6

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



# Life Extension Table

NEW CLEANLINESS LEVEL (ISO CODE)

CURRENT CLEANLINESS (ISO CODE)

	20/17		19/16		18/15		17/14		16/13		15/12		14/11		13/10		12/9		11/8		10/7	
26/23	5	3	7	3.5	9	4	>10	5	>10	6	>10	7.5	>10	9	>10	>10	>10	>10	>10	>10	>10	>10
	4	2.5	4.5	3	6	3.5	6.5	4	7.5	5	8.5	6.5	10	7	>10	9	>10	10	>10	>10	>10	>10
25/22	4	2.5	5	3	7	3.5	9	4	>10	5	>10	6	>10	7	>10	9	>10	>10	>10	>10	>10	>10
	3	2	3.5	2.5	4.5	3	5	3.5	6.5	4	8	5	9	6	10	7.5	>10	9	>10	>10	>10	>10
24/21	3	2	4	2.5	6	3	7	4	9	5	>10	6	>10	7	>10	8	>10	10	>10	>10	>10	>10
	2.5	1.5	3	2	4	2.5	5	3	6.5	4	7.5	5	8.5	6	9.5	7	>10	8	>10	10	>10	>10
23/20	2	1.5	3	2	4	2.5	5	3	7	3.5	9	4	>10	5	>10	6	>10	8	>10	9	>10	>10
	1.7	1.3	2.3	1.5	3	2	3.7	2.5	5	3	6	3.5	7	4	8	5	10	6.5	>10	8.5	>10	10
22/19	1.6	1.3	2	1.6	3	2	4	2.5	5	3	7	3.5	8	4	>10	5	>10	6	>10	7	>10	>10
	1.4	1.1	1.8	1.3	2.3	1.7	3	2	3.5	2.5	4.5	3	5.5	3.5	7	4	8	5	10	5.5	>10	8.5
21/18	1.3	1.2	1.5	1.5	2	1.7	3	2	4	2.5	5	3	7	3.5	9	4	>10	5	>10	7	>10	10
	1.2	1.1	1.5	1.3	1.8	1.4	2.2	1.6	3	2	3.5	2.5	4.5	3	5	3.5	7	4	9	5.5	10	8
20/17			1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4	9	5	>10	7	>10	9
			1.2	1.05	1.5	1.3	1.8	1.4	2.3	1.7	3	2	3.5	2.5	5	3	6	4	8	5.5	10	7
19/16					1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4	9	6	>10	8
					1.2	1.1	1.5	1.3	1.8	1.5	2.2	1.7	3	2	3.5	2.5	5	3.5	7	4.5	9	6
18/15							1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4.5	>10	6
							1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.7	3	2	3.5	2.5	5.5	3.7	8	5
17/14									1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	6	3	8	5
									1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.7	3	2	4	2.5	6	3.5
16/13											1.3	1.2	1.6	1.5	2	1.7	3	2	4	3.5	6	4
											1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.8	3.7	3	4.5	3.5
15/12													1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5
													1.2	1.1	1.5	1.4	1.8	1.5	2.3	1.8	3	2.2
14/11															1.3	1.3	1.6	1.6	2	1.8	3	2
															1.3	1.2	1.6	1.4	1.9	1.5	2.3	1.8
13/10																	1.4	1.2	1.8	1.5	2.5	1.8
																	1.2	1.1	1.6	1.3	2	1.6

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



Up To The Task

Operators are the **FIRST** line of defense when it comes to maintenance issues



Where Do We Go From Here?

**OMI**

**One Minute Inspections**



# OMI

- Temperature
  - Touch
  - Gauges
  - Heat Guns

Doing this we discover a host of issues that can be easily solved.

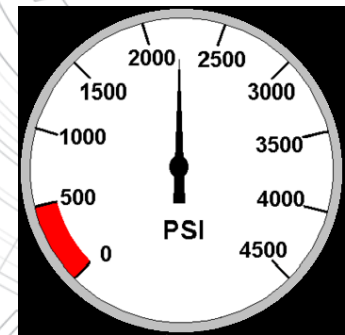
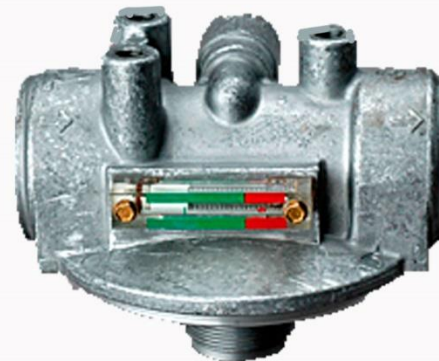
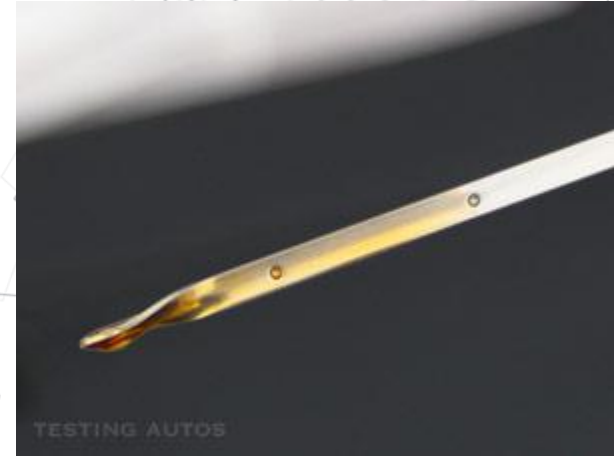






# OMI

- Oil Volume
  - Sight Gauges
  - Dip Sticks
- Pressure
  - Gauges or sensors at multiple locations
- Filter
  - Delta P gauges
  - Bypass indicators





- BS&W
  - Samples at bottom of reservoir
  - BS&W Bowls
- Ventilation
  - Breathers
  - Fumes

OMI





OMI

- Clear and Bright
  - Samples
  - Sight glass
- Leakage
  - Fittings and Gaskets
  - Hoses





OMI

- Fluid Surface and Headspace

- Foam
- Varnish
- Sludge

- Points of Entry

- Ingression Points
  - Breathers
  - Open covers





OMI

- Dirty Exterior
  - Dirty outside = Dirty inside
- Vibration, Spits and Sputters
  - Noise is a huge indicator of problems
- Grease Condition/Color
  - Change in color (darkens)
  - Watery discharge from bearings
  - Hardening



# Where to Start

- Independent Survey
- Assess Where You Are In The Process
- Equipment Status
- Training Requirements
- Commitment
- Call.



# What we Talked About

- Introduction
- Safety Moment
- What a Lubricant is Expected to do
- What is Friction (causes)
- Lubrication Regimens
- Lubrication Intervals
- One Minute Inspections



# Questions

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