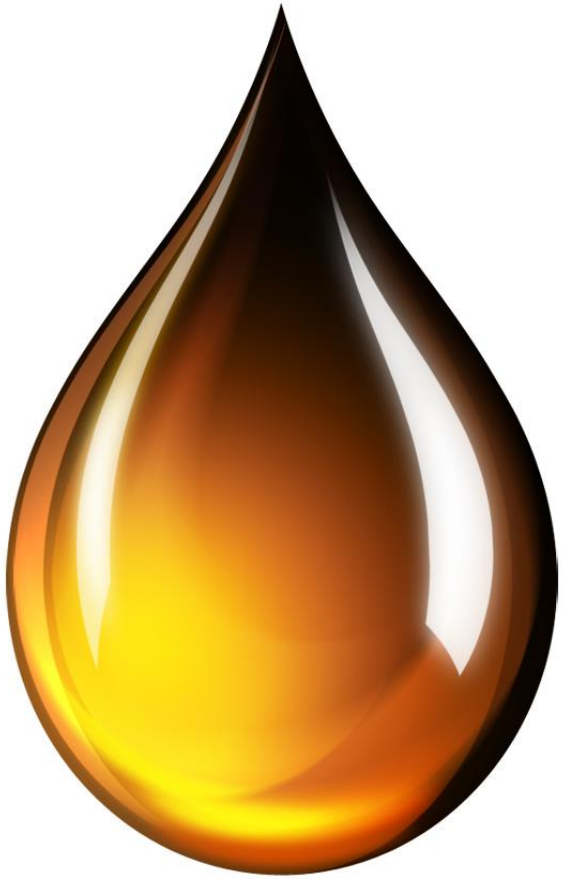
Lubrication Basics



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

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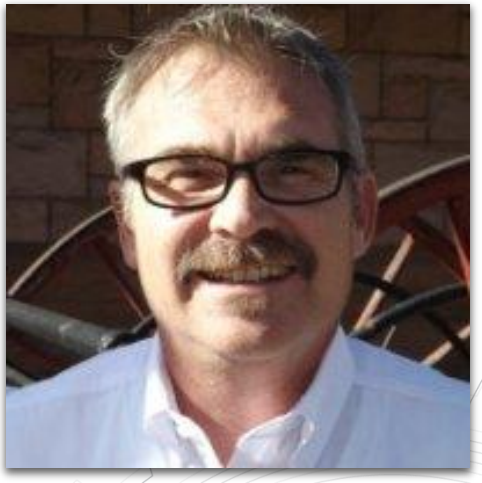


Certified Lubrication Specialist (STLE)
Certified Oil Monitoring Analyst (STLE)
Integration Engineer

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

ACORN PETROLEUM

Who We Are

BALDWIN FILTERS

POLARIS Laboratories

Chevron Lubricants

CFN

WRIGHT EXPRESS

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

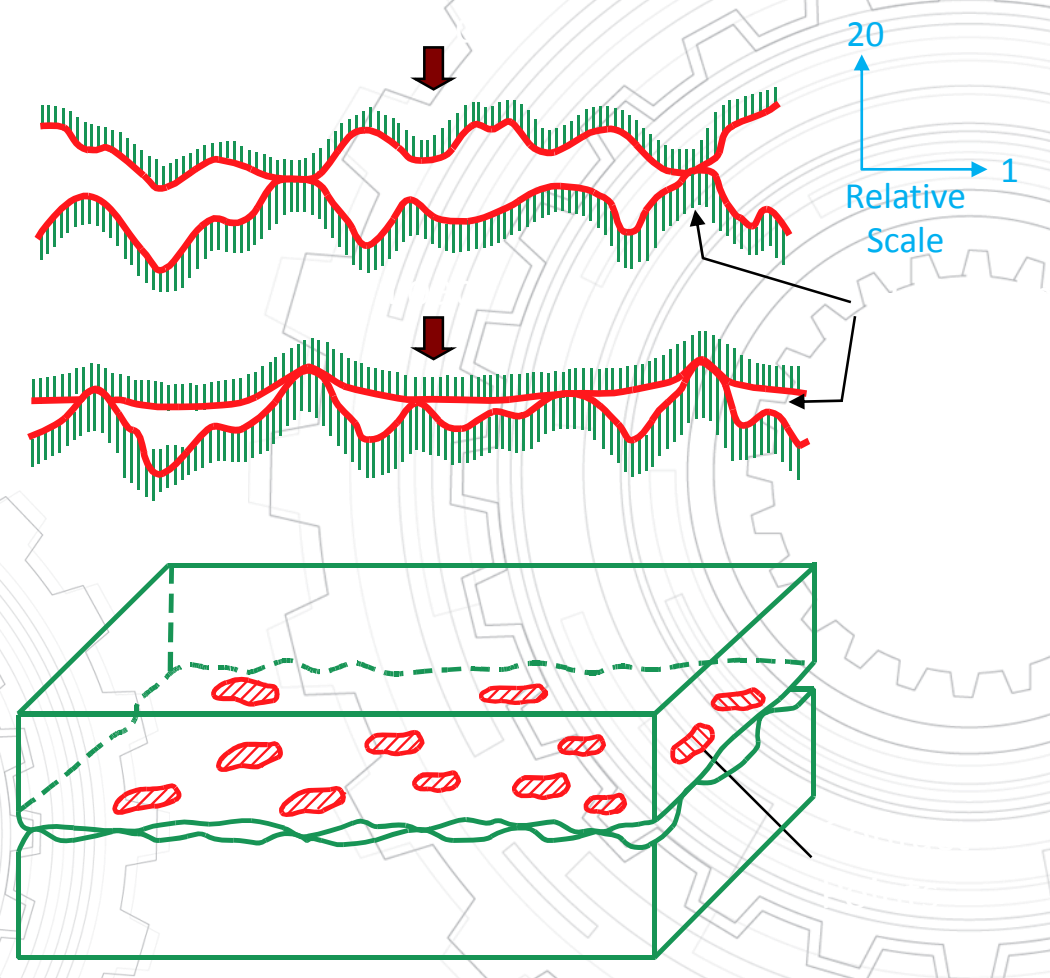
- Viscosity
- Additives
- Lubrication Practices

Five Rights of Lubrication

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

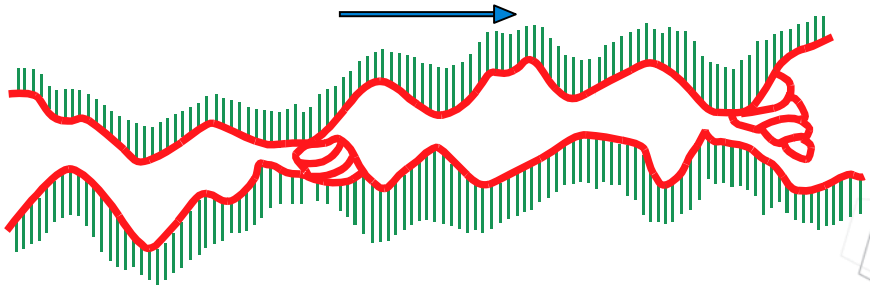
Causes of Friction

- **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**

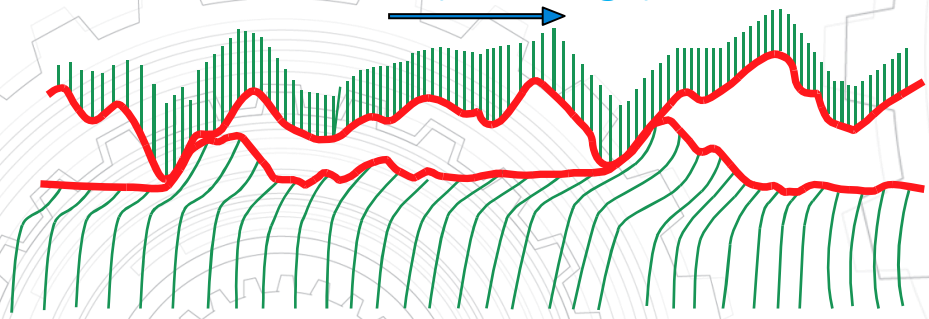


Major Causes of Friction

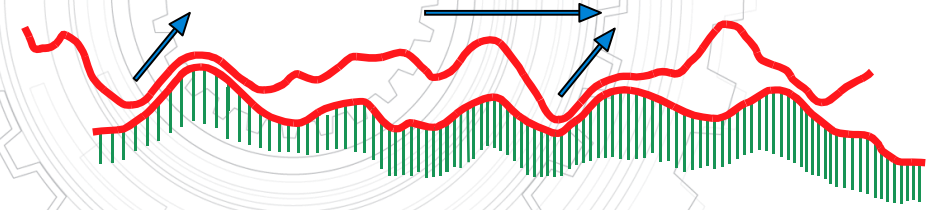
Adhesion (Micro "Spot-Welding")



Abrasive Deformation ("Plowing")



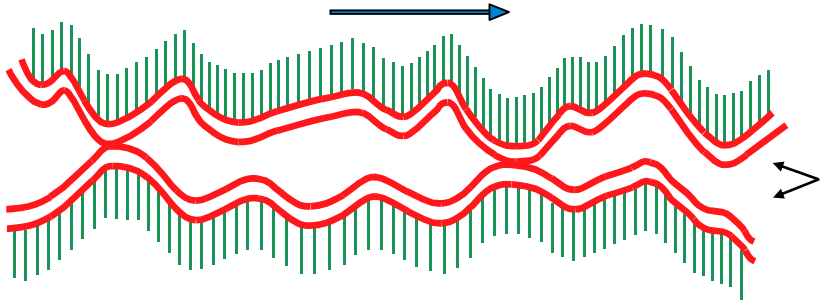
Asperity Override (With Adhesion → "Stick-Slip")



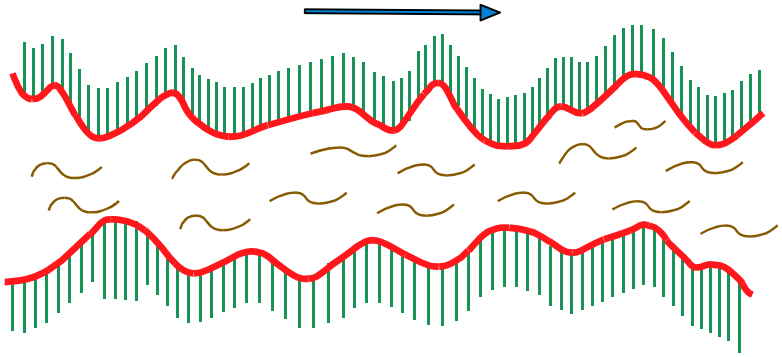
- **Movement of surfaces requires an applied force great enough to overcome microscopic surface interactions**
- **Friction can lead to high wear**

Ways to Reduce Friction

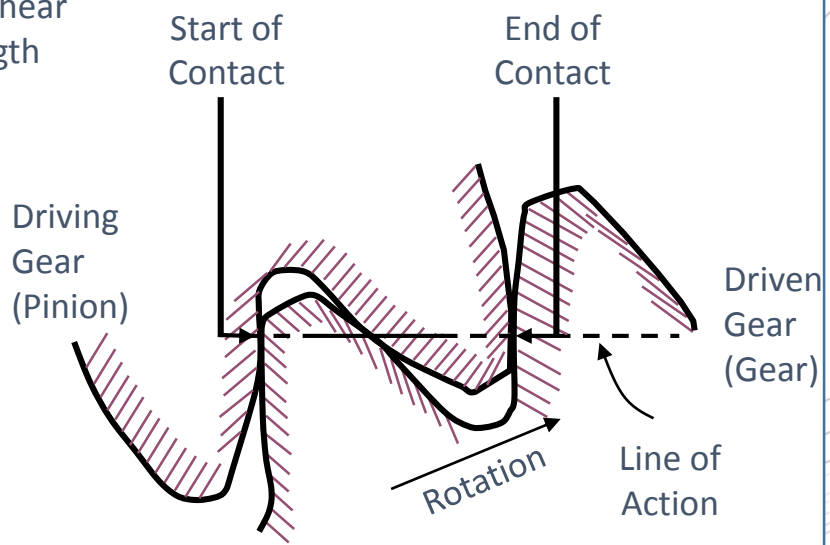
- **Lower Adhesive**



- **Separate Surfaces With a Liquid (“Oil”) Film**



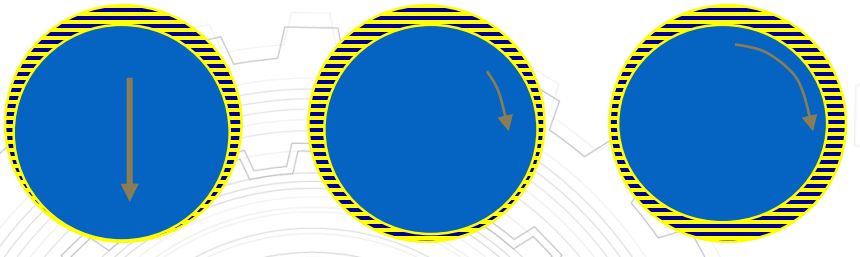
- Design moving parts to roll over each other (minimize slide/roll ratio)



Lubrication and Friction

- **Coefficient of Friction Varies With Velocity**

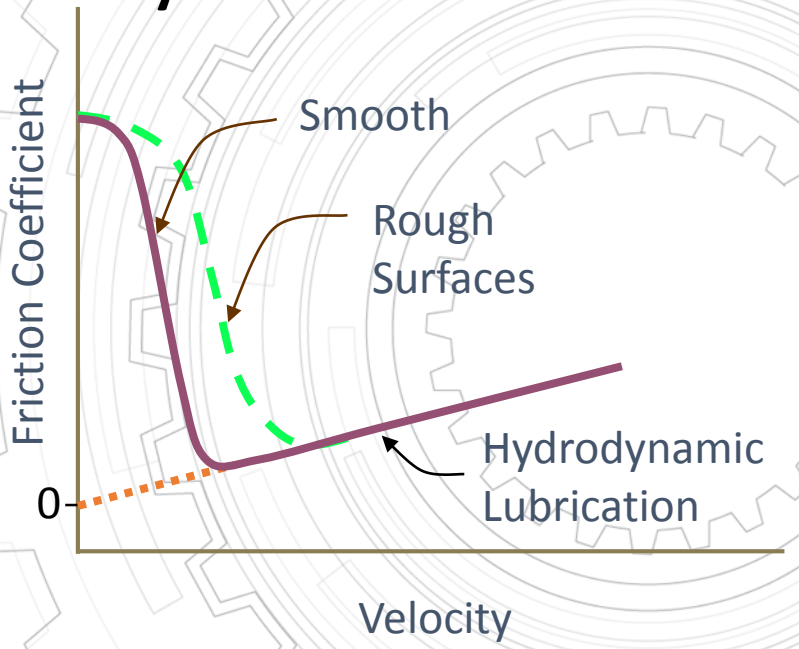
Three Positions of a Shaft (Journal) in a Bearing



A
At Rest

B
Starting Up

C
Steady Speed



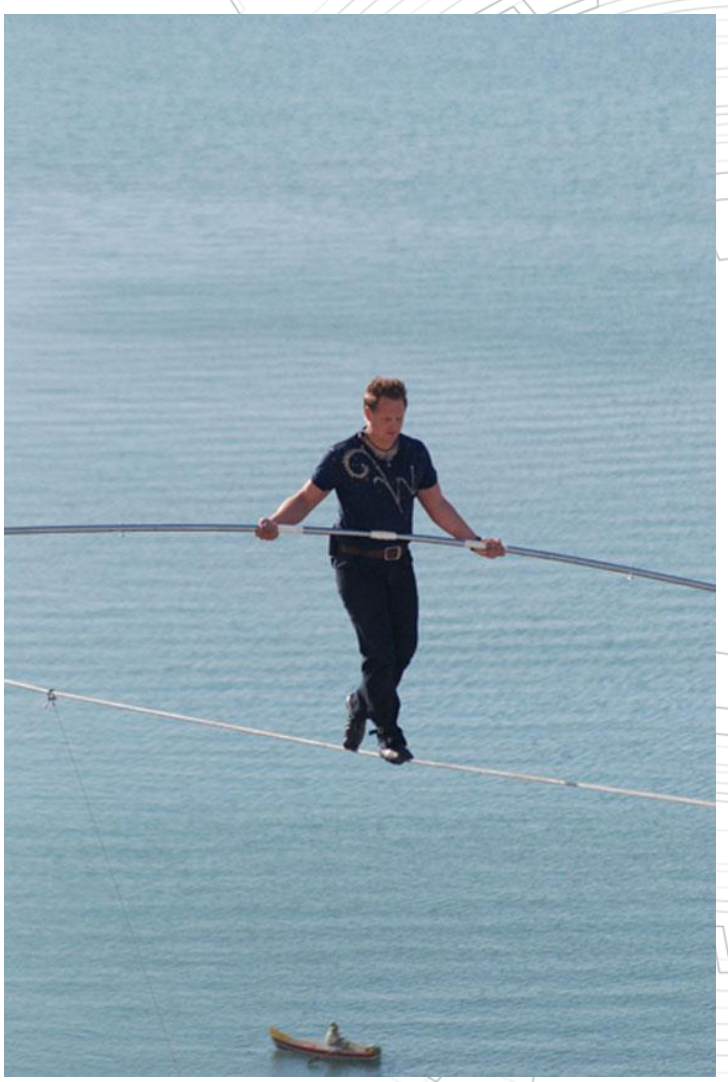
Viscosity

Viscosity = Resistance to Flow

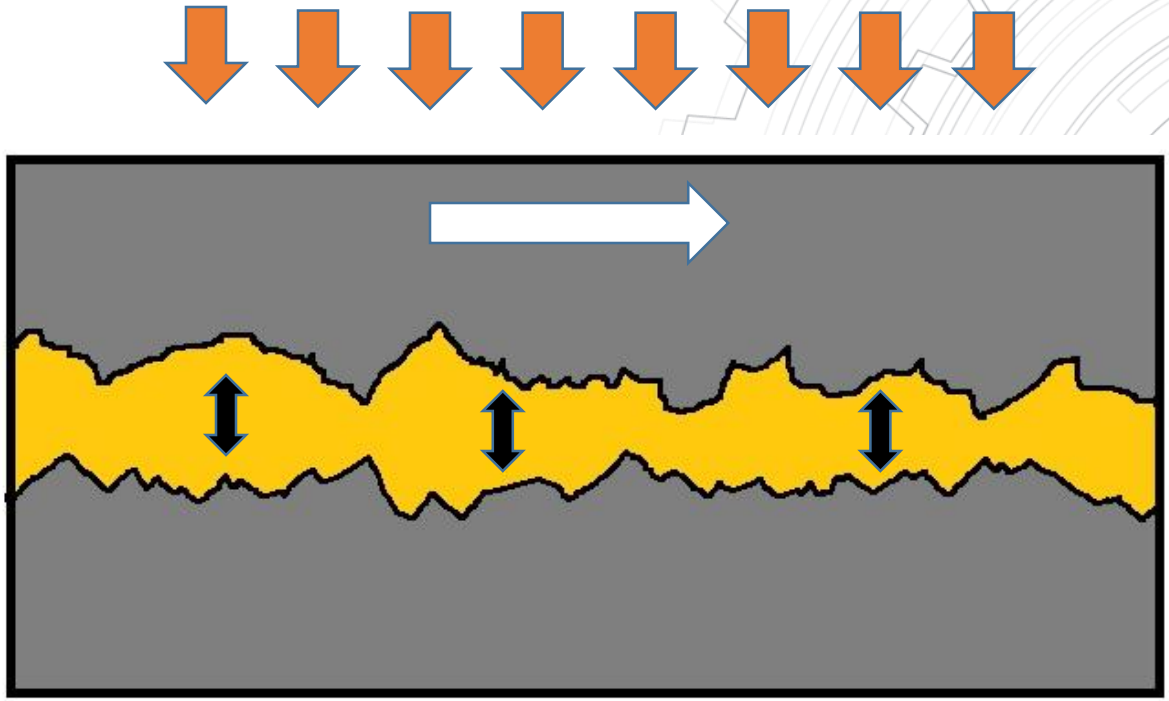
THE MOST IMPORTANT CHARACTERISTIC OF AN OIL!!

Viscosity

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

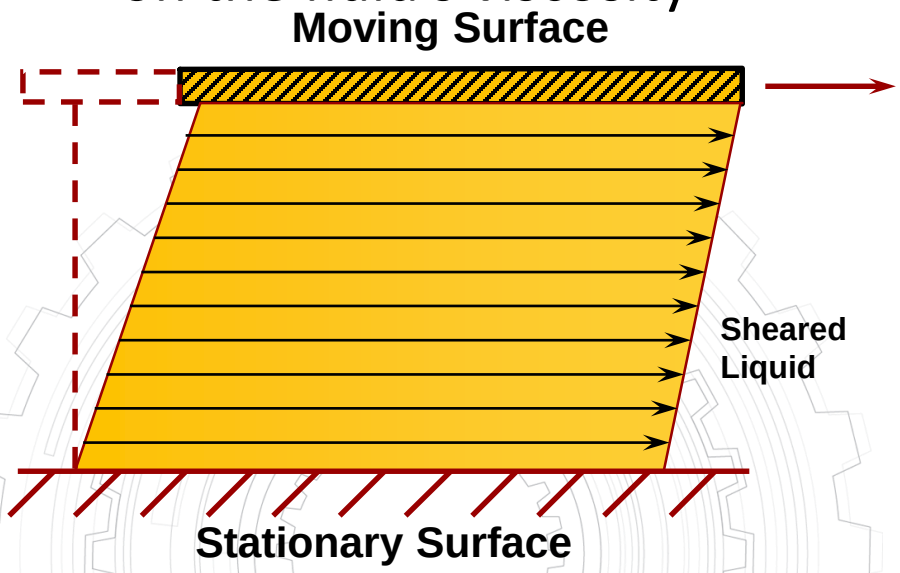


What Viscosity Does For Us



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



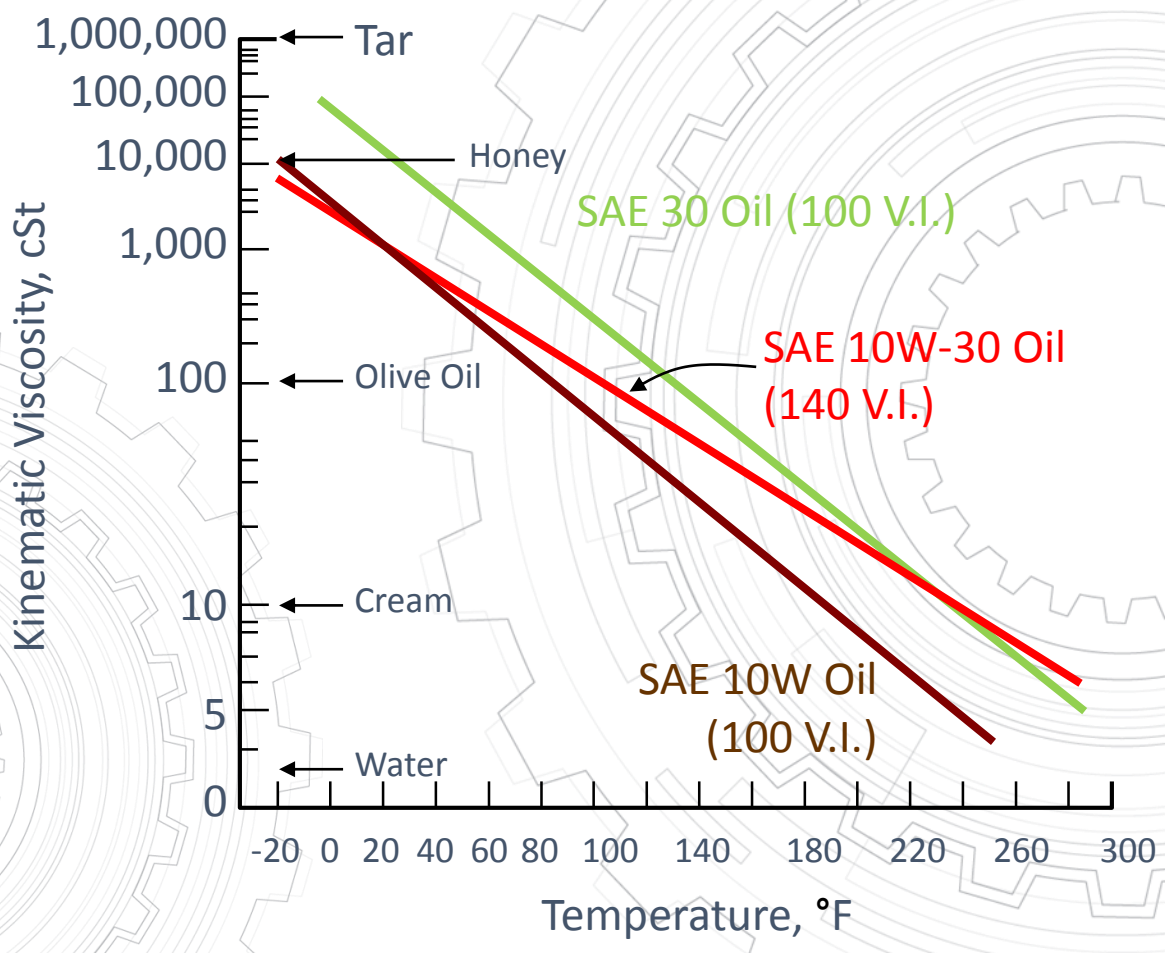
The higher a fluid's viscosity, the greater the force (energy) required to slide the surfaces at a given speed and gap

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

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

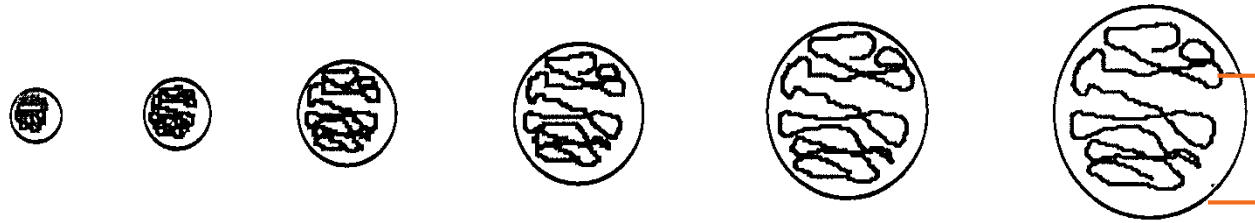
Viscosity and Temperature

- **Lubricant Viscosity Decreases <u>Dramatically</u> 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

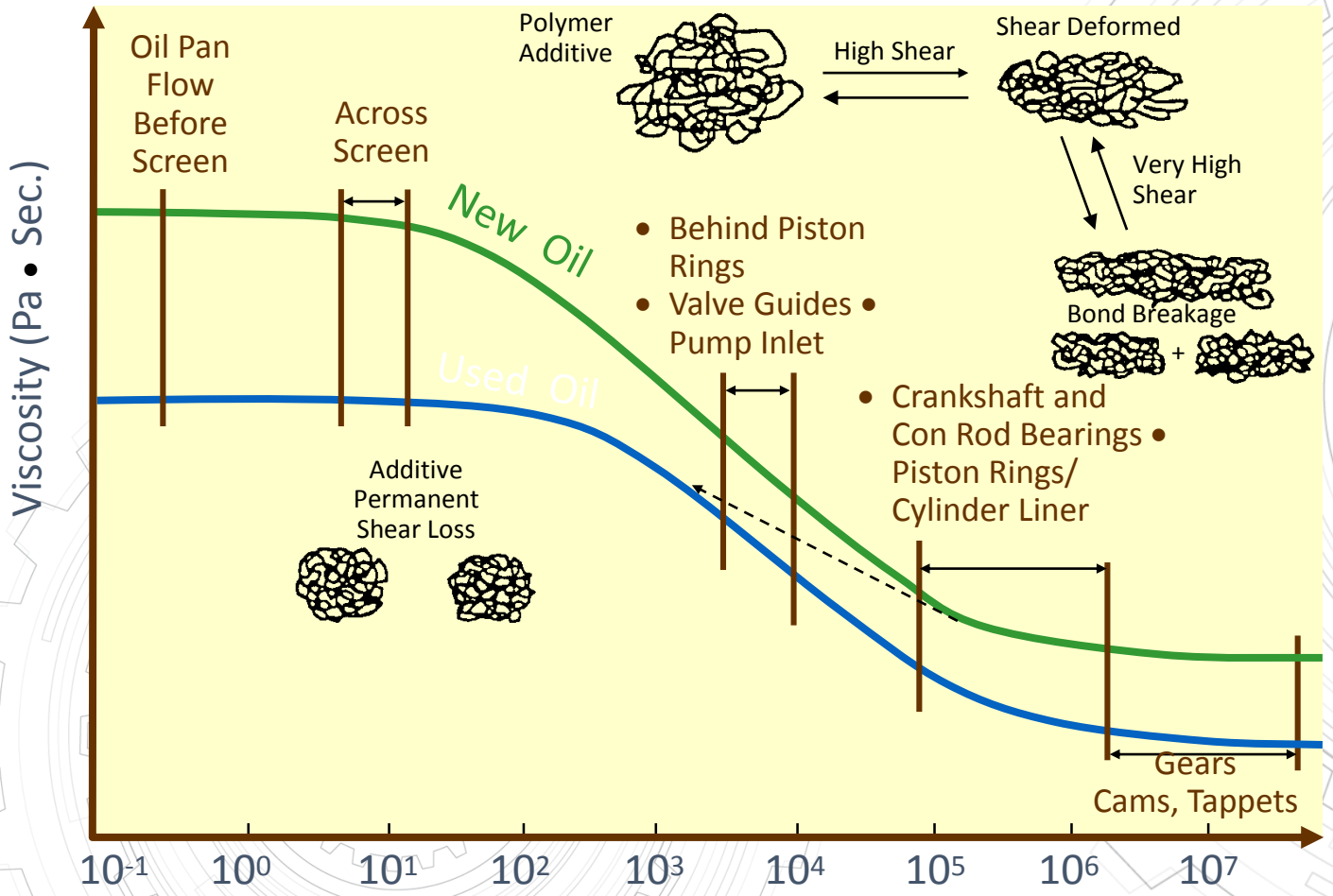
Increasing Temperature



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**

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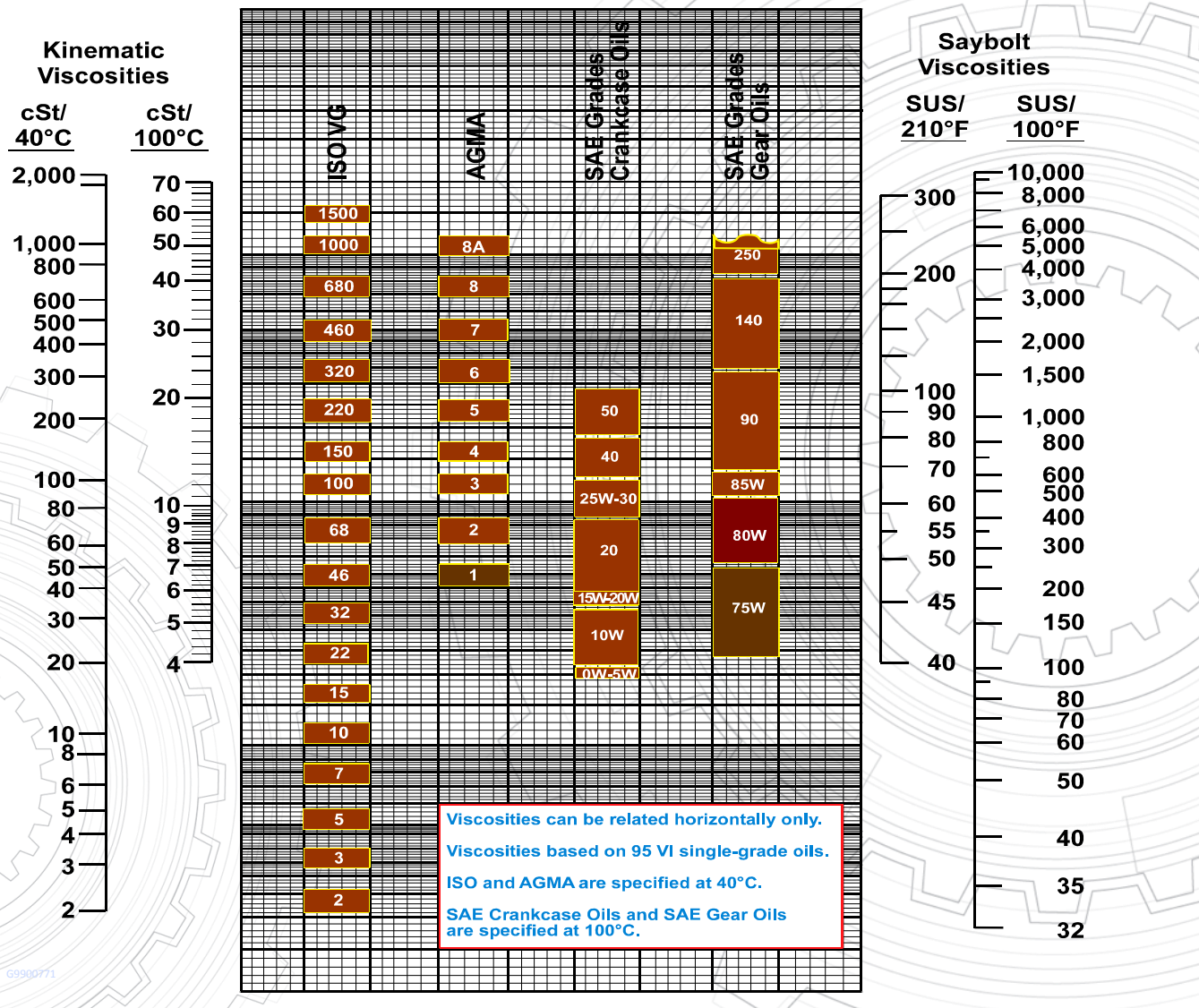
Viscosity Grade Equivalents

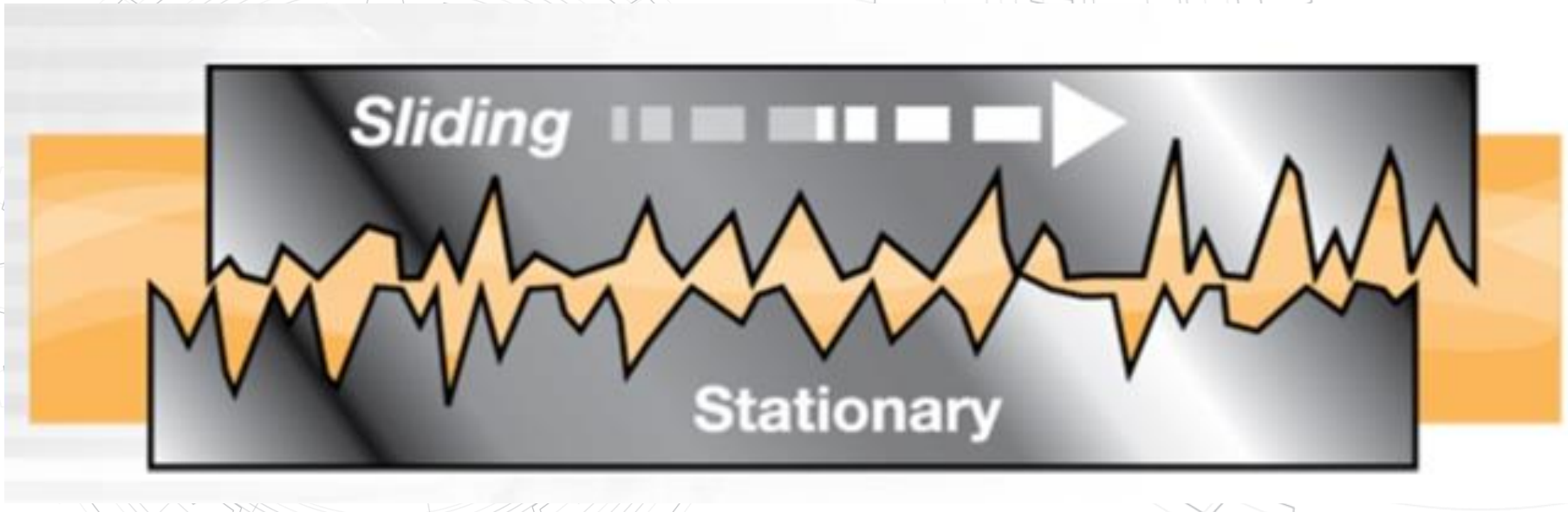


Regimes of Lubrication
(Dependent on Speed, Viscosity, and Load)

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

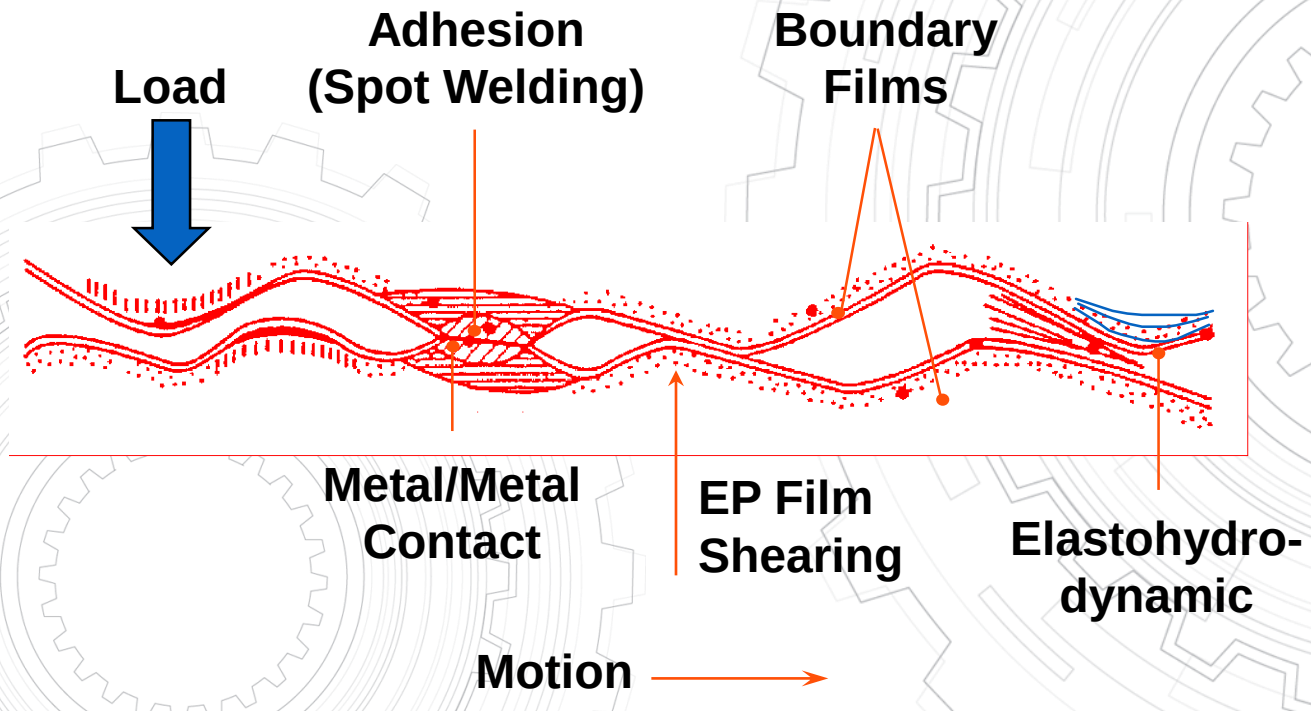
BOUNDARY LUBRICATION

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



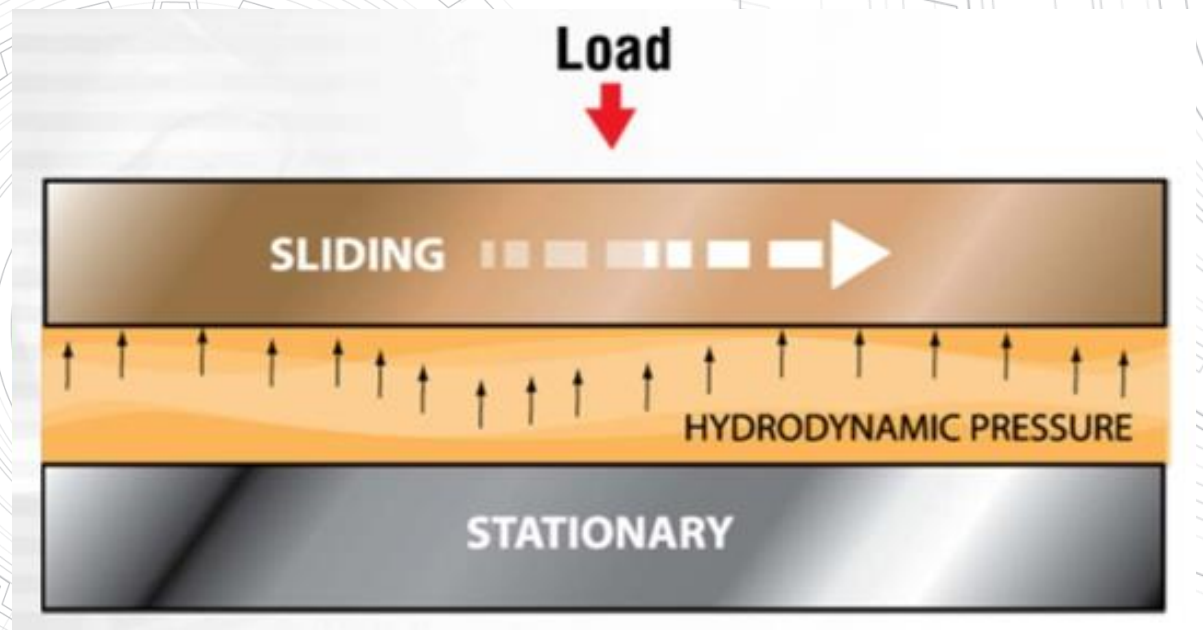
Mixed or Boundary or Extreme Pressure Lubrication

- 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.

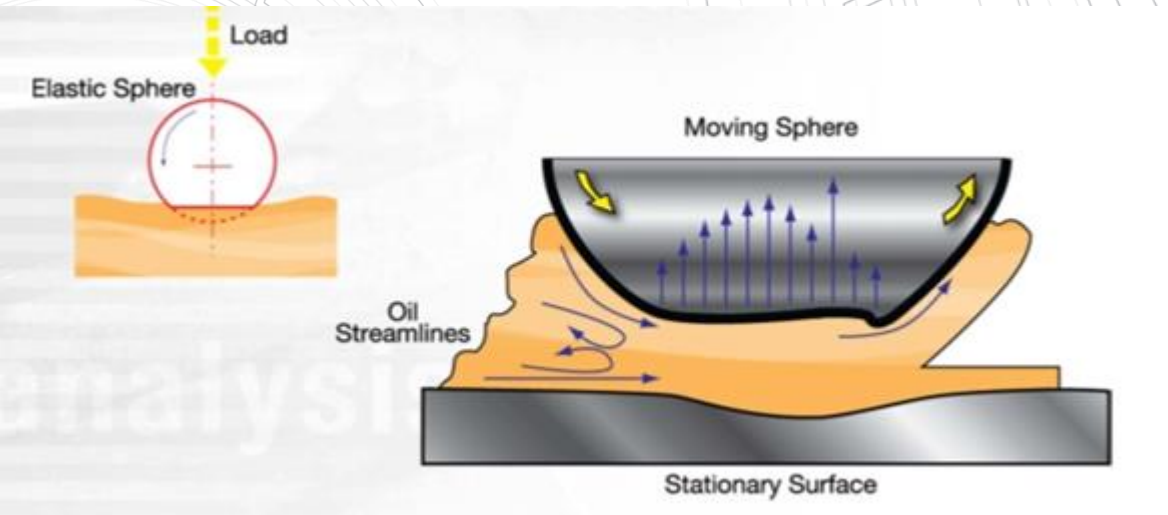


Hydrodynamic Lubrication

- 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

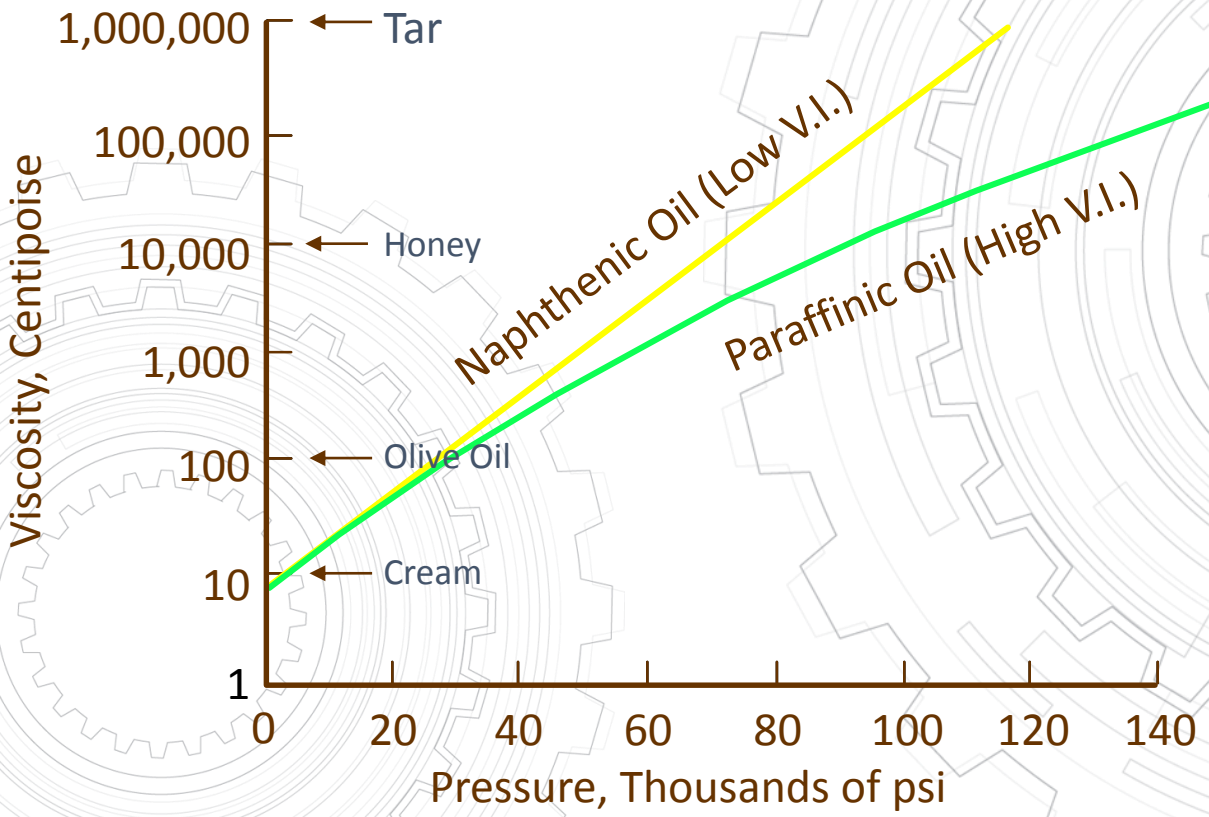
ELASTOHYDRODYNAMIC LUBRICATION

- 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"

µm = Micron Symbol

PARTICLE SIZE

100 µm = Grain of Table Salt

40 µm = Lower Limit of Visibility

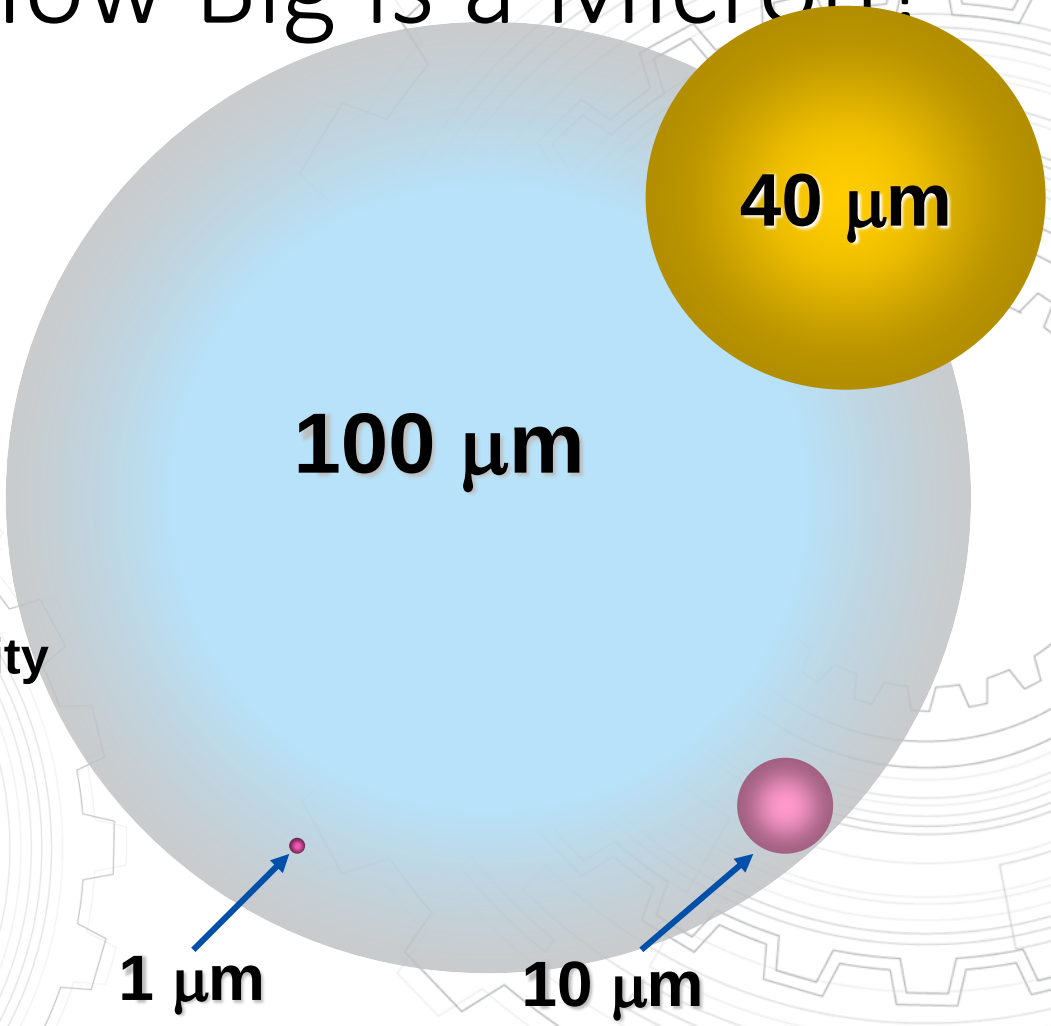
10 µm = Talcum Powder

8 µm = Red Blood Cells

2 µm = Bacteria

Particles "Suspended" in Oil: <5-10 µm 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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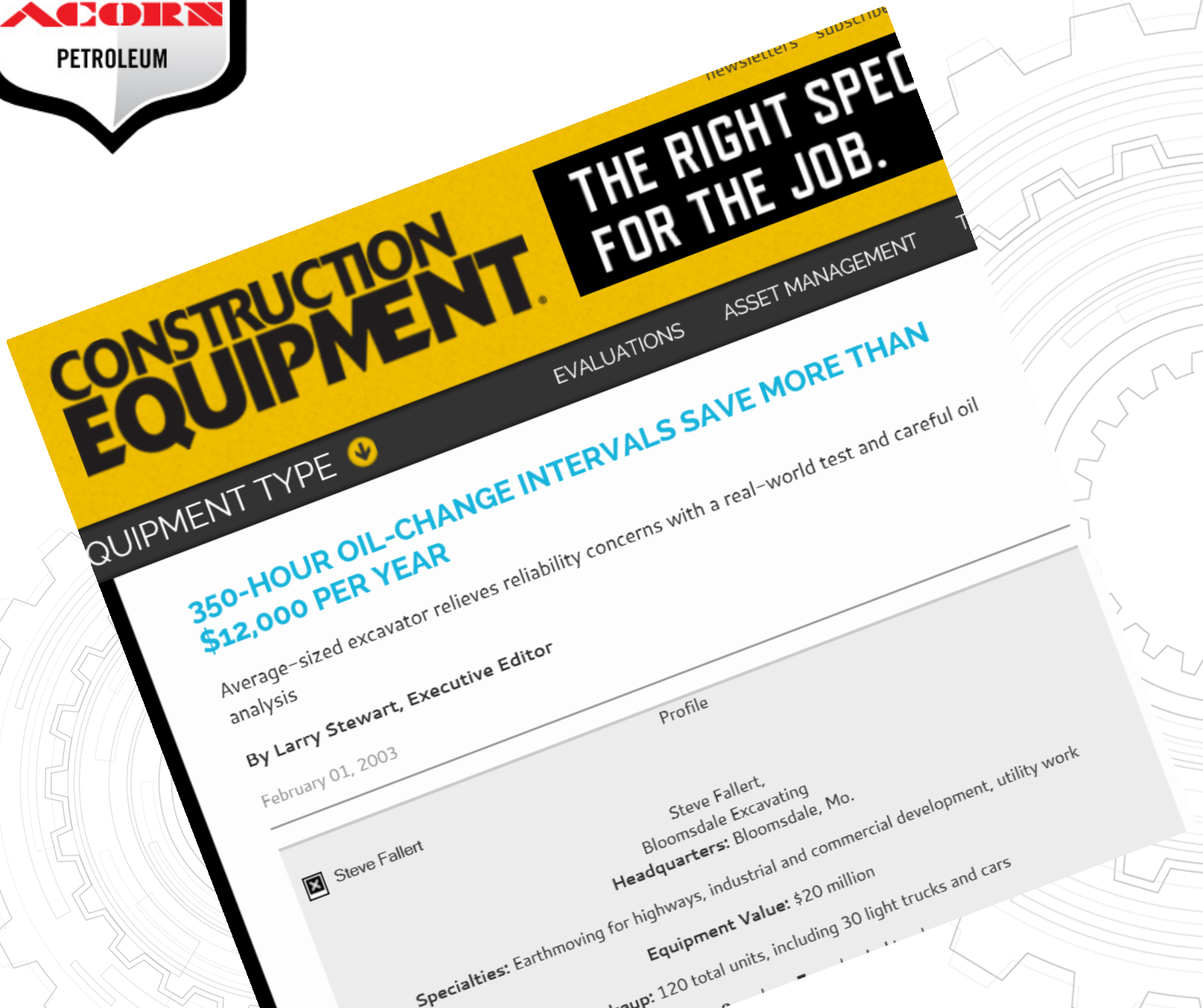


MODERN ENGINES

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

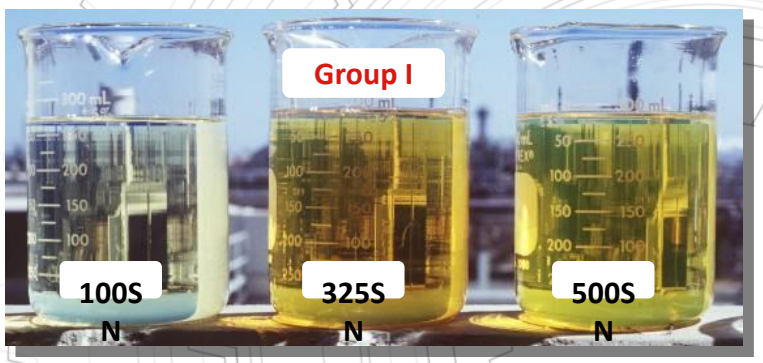
***Use Engine Oils approved against DD 93K214 – API CI-4 Plus Oils like Delo 400 Multigrade 15W-40

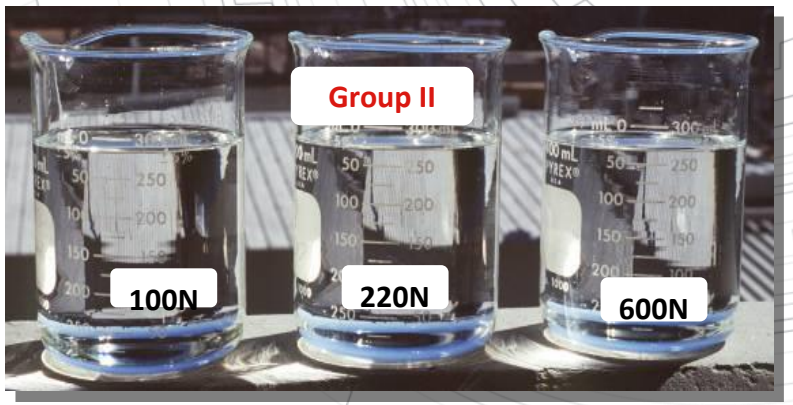
How Can We Extend Oil Drains?

- 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

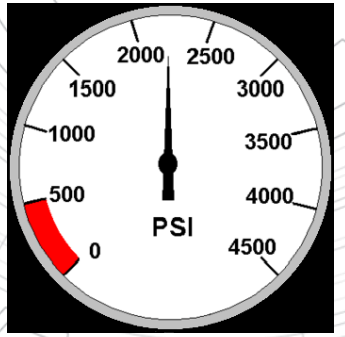
OMI

- 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



OMI

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

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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