Metalworking Fluids & Lubrication Principles

2025

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Agenda

Meet Your Trainers

Ryan McCallister

Brian Halstead

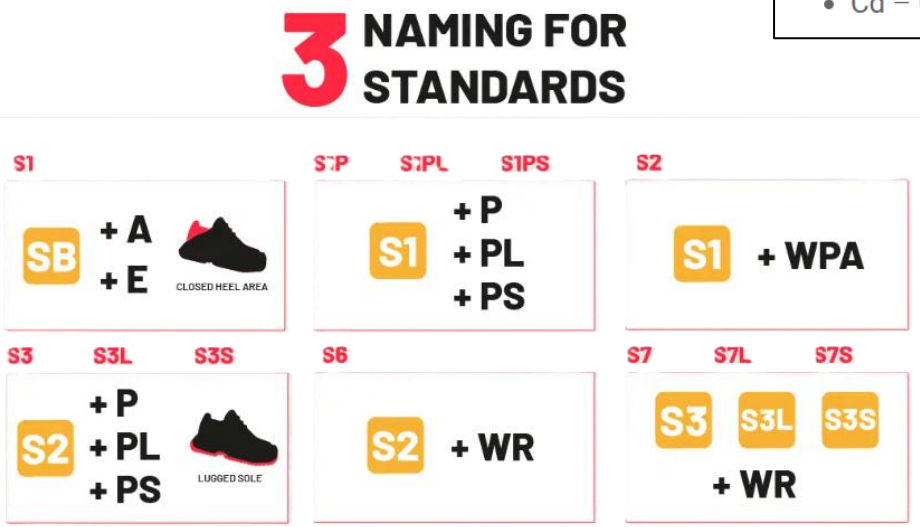
Lisa Gianino

Who enjoys spending birthdays in different countries?

Who is a big horror book & film fan?

Who heated their home only with a wood stove over 5 winters?

Safety Equipment



Q: Where can you find the ratings for safety shoes?

A: On the tongue of the shoe!

ASTM Markings

- I/75 – Impact resistance (75 ft-lb)
- C/75 – Compression resistance (2500 lbs)
- EH – Electrical hazard protection
- Mt/75 – Metatarsal protection
- PR – Puncture resistance
- SD – Static dissipative
- Cd – Conductive properties

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Principles of Metalworking

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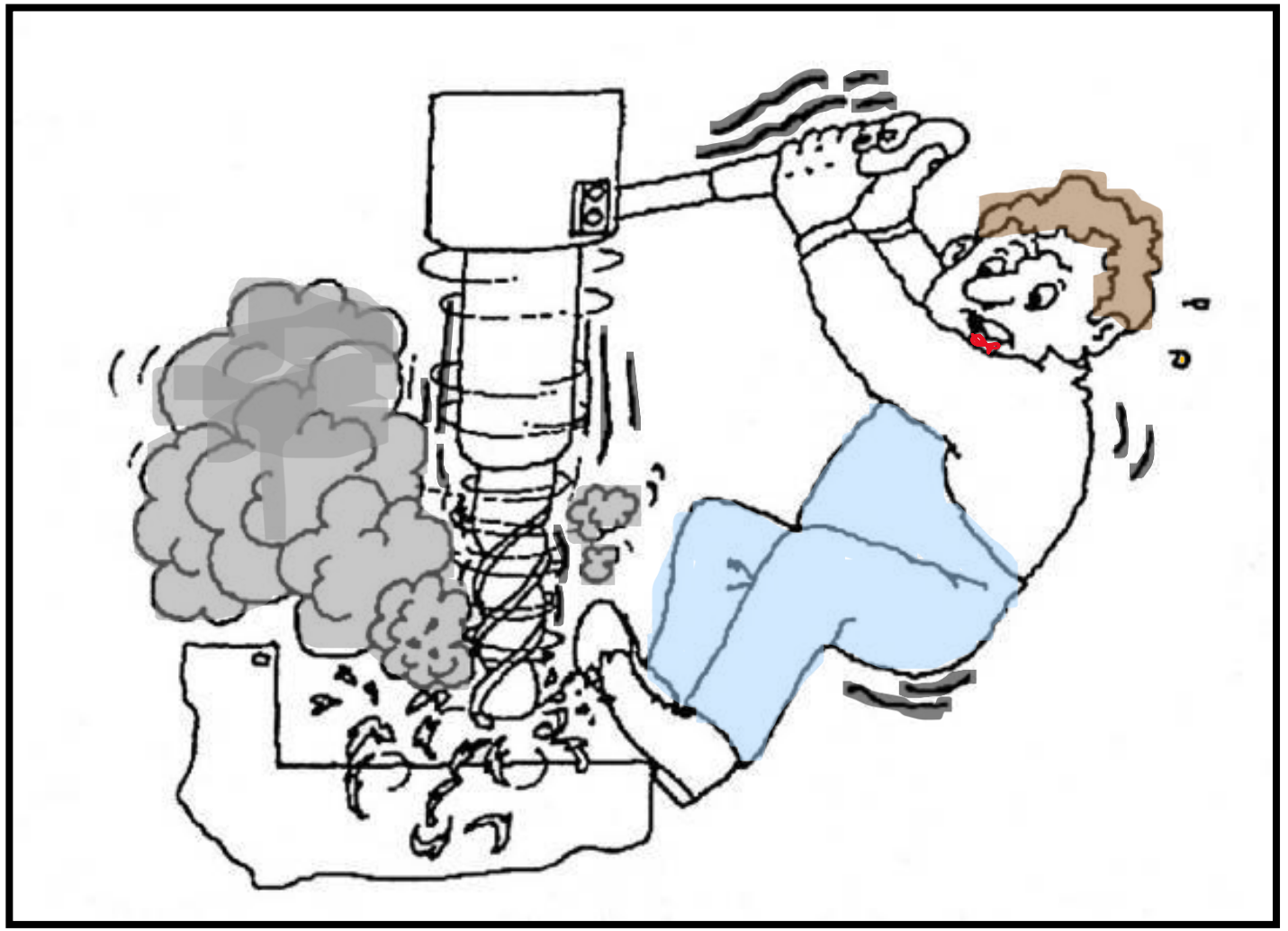
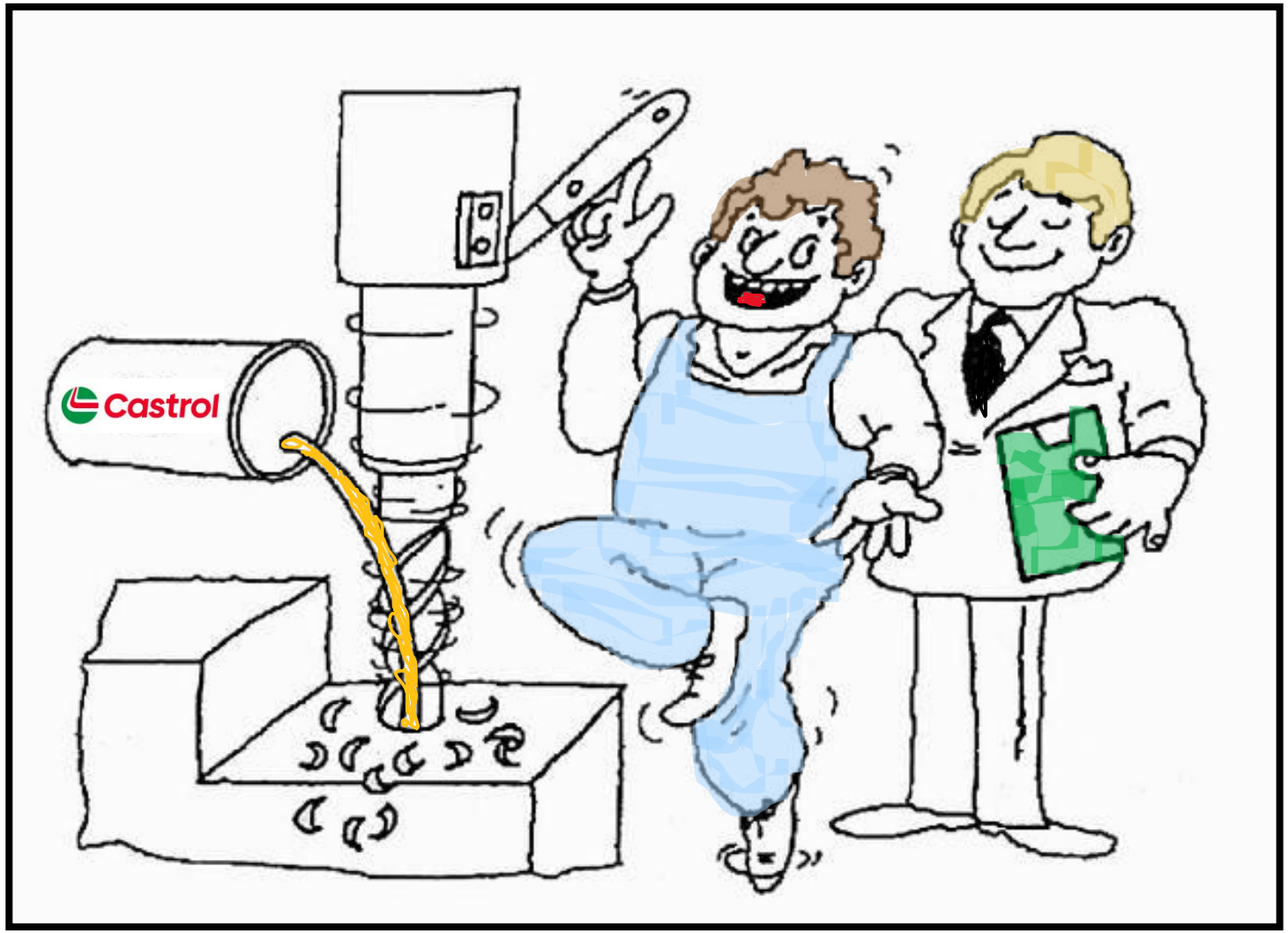
Why do we need cutting fluids?



To Make the Process More Efficient!



The Benefits of Cutting Fluids

- Increased productivity
- Improved surface finish
- Cleaner working condition
- Longer tool life
- Reduced energy requirements
- Eliminate metal dusting (can be dangerous)

What Happens When We Don't Use Cutting Fluids…???

We create friction which causes "Heat".

The results of "Heat" are:

- Expansion of work piece
- Reduced surface finish
- Rapid tool wear

Basic Role of C&G Fluids

1. Cooling
2. Lubrication
3. Tool life performance assistance
4. Wash action and chip removal from the work area
5. Corrosion protection for both machine tools and work
6. Cleanliness on machine surfaces
7. Filtration properties
8. Improve Surface Finish
9. Increase Production
10. Reduce machine energy requirements

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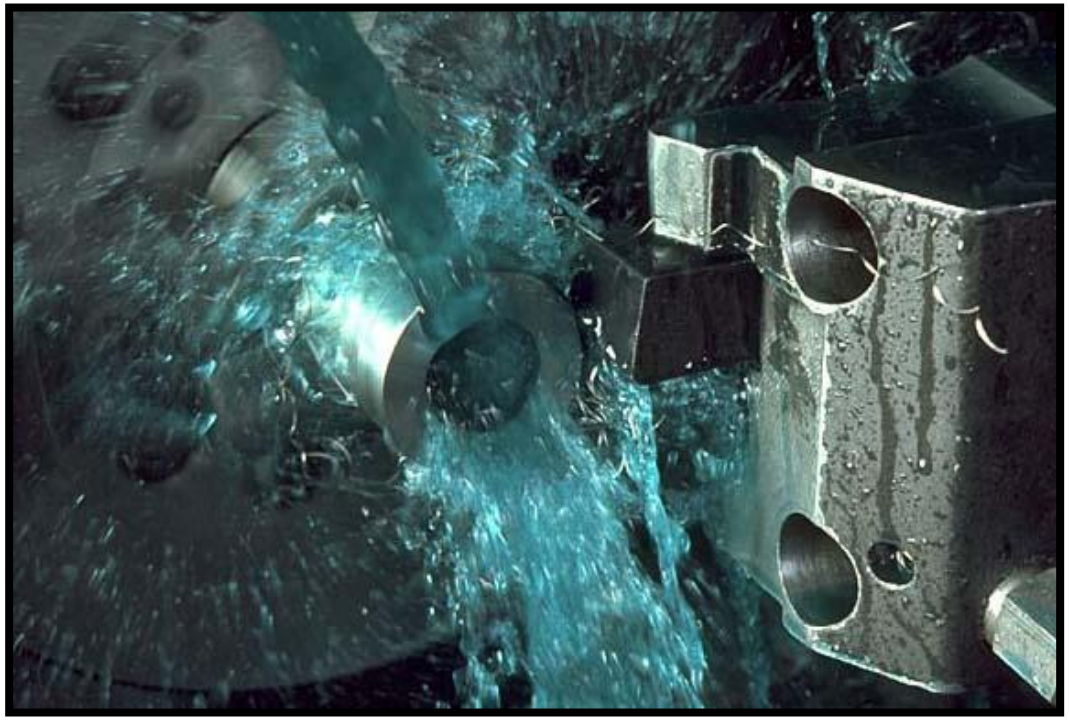
Functions at the Point of Cut

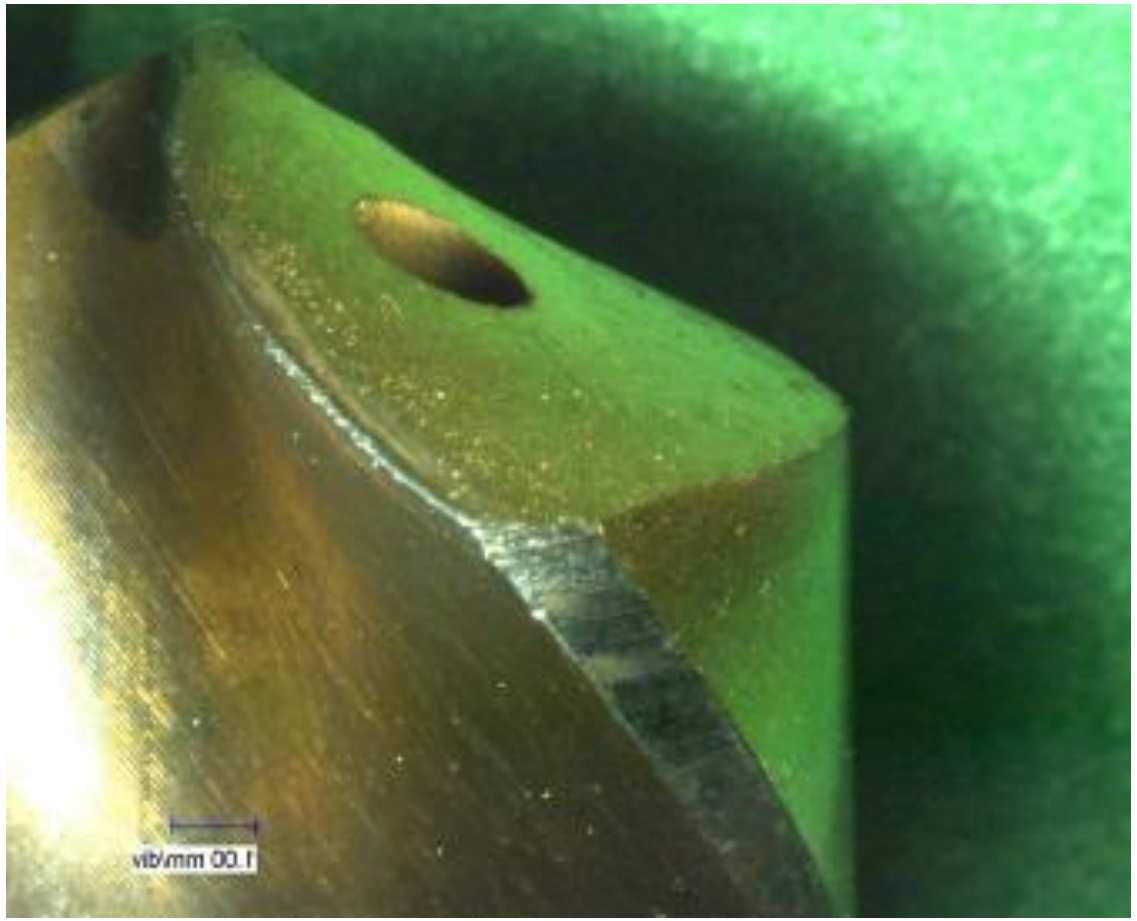
- ✓ Cooling
- ✓ Lubrication
- ✓ Flush chips and swarf from cut zone

Q: Why Would Synthetics be Featured in Cooling Discussion?



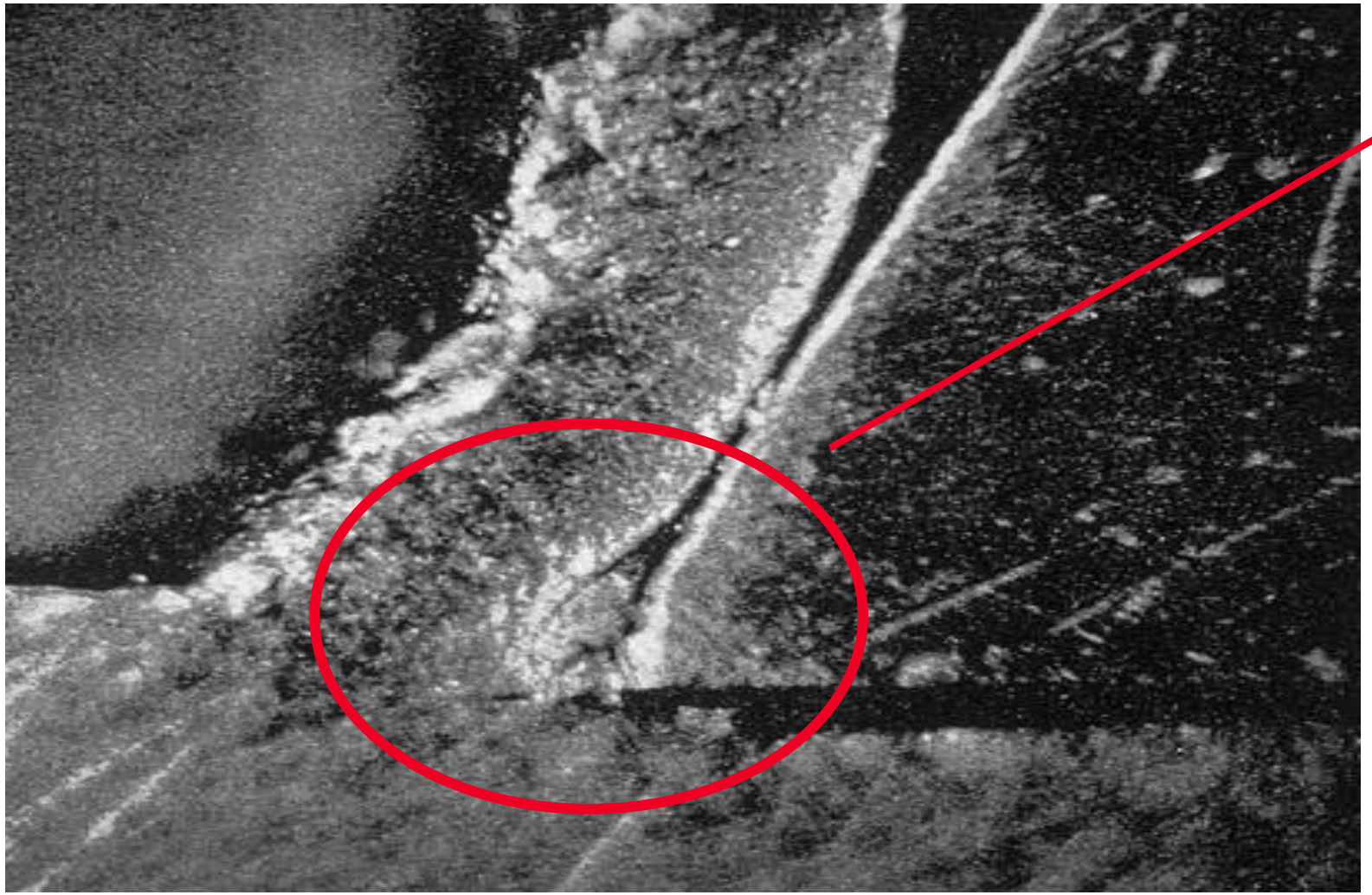
A: Because synthetic coolants offer the highest cooling capability as compared to other product categories!

Lack of Sufficient Lubrication



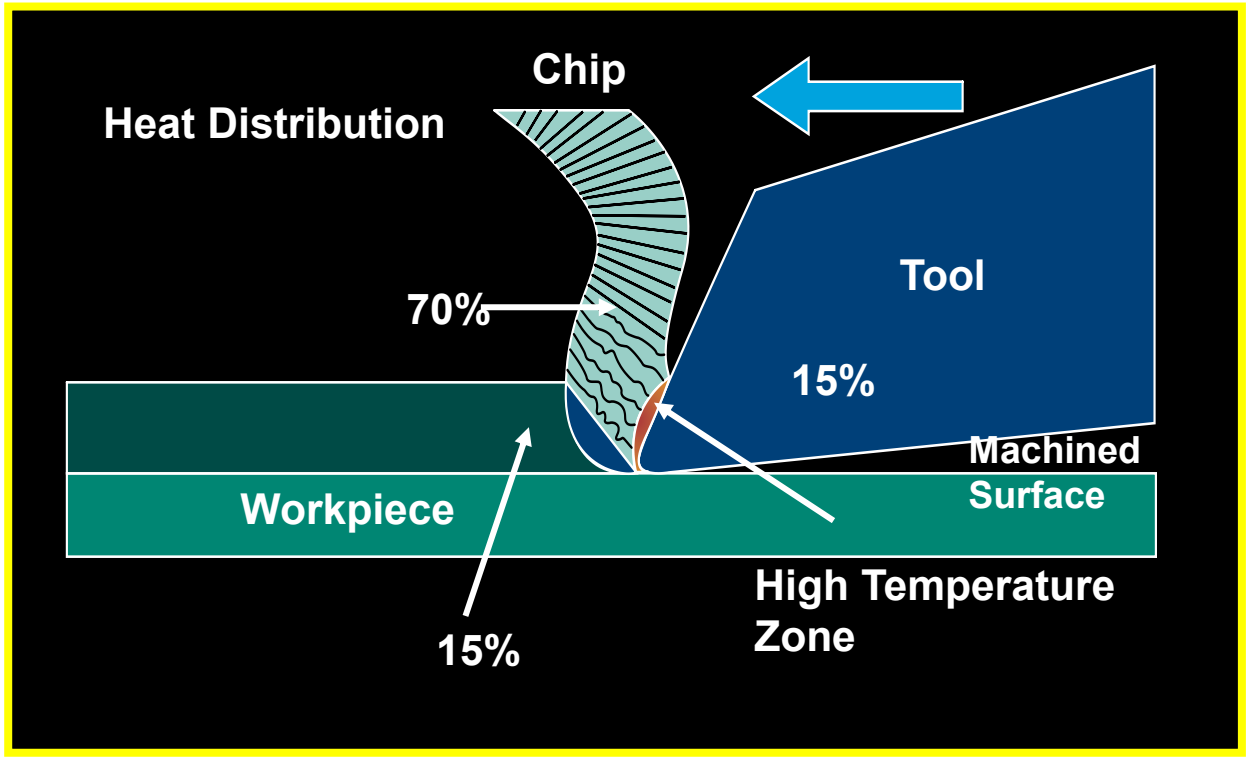
Premature tool wear can produce out of spec parts resulting in downtime to change or sharpen tools back to original geometries!

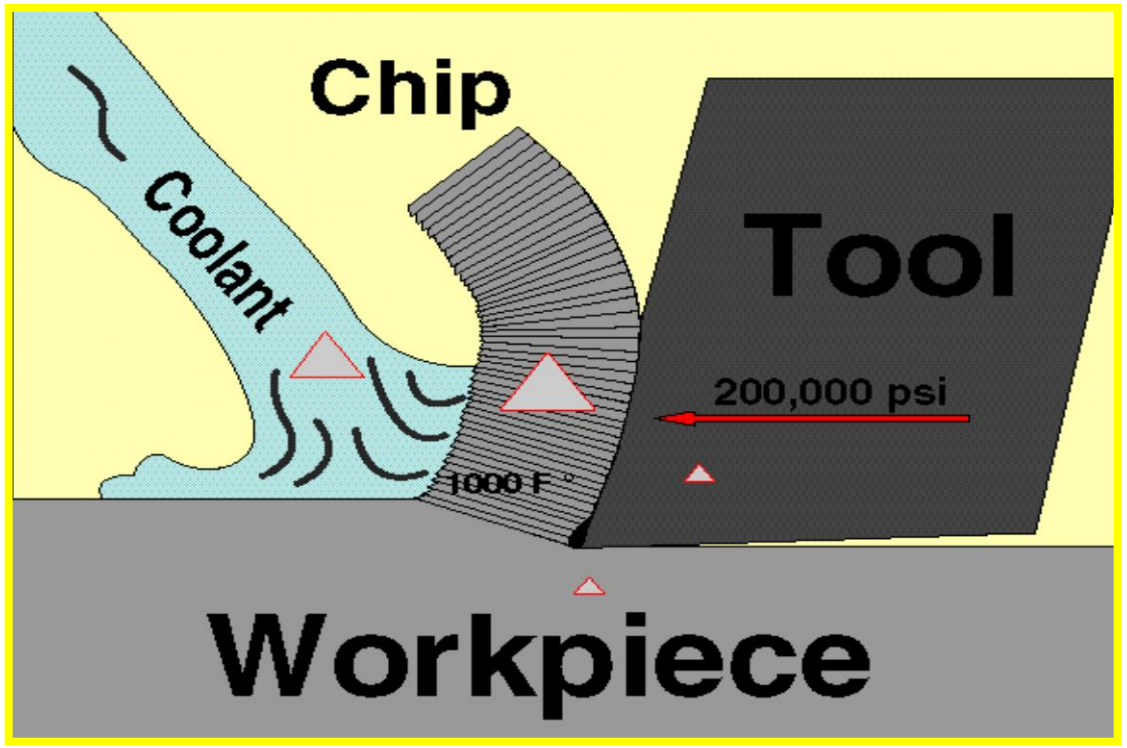
Lack of Sufficient Lubrication



BUE (Built up Edge) – a factor of force, heat, & pressure that is exerted on a cutting tool that, without sufficient lubrication, can create an environment whereby metal from a cutting face is transferred from the workpiece to the tool.

Chip Formation





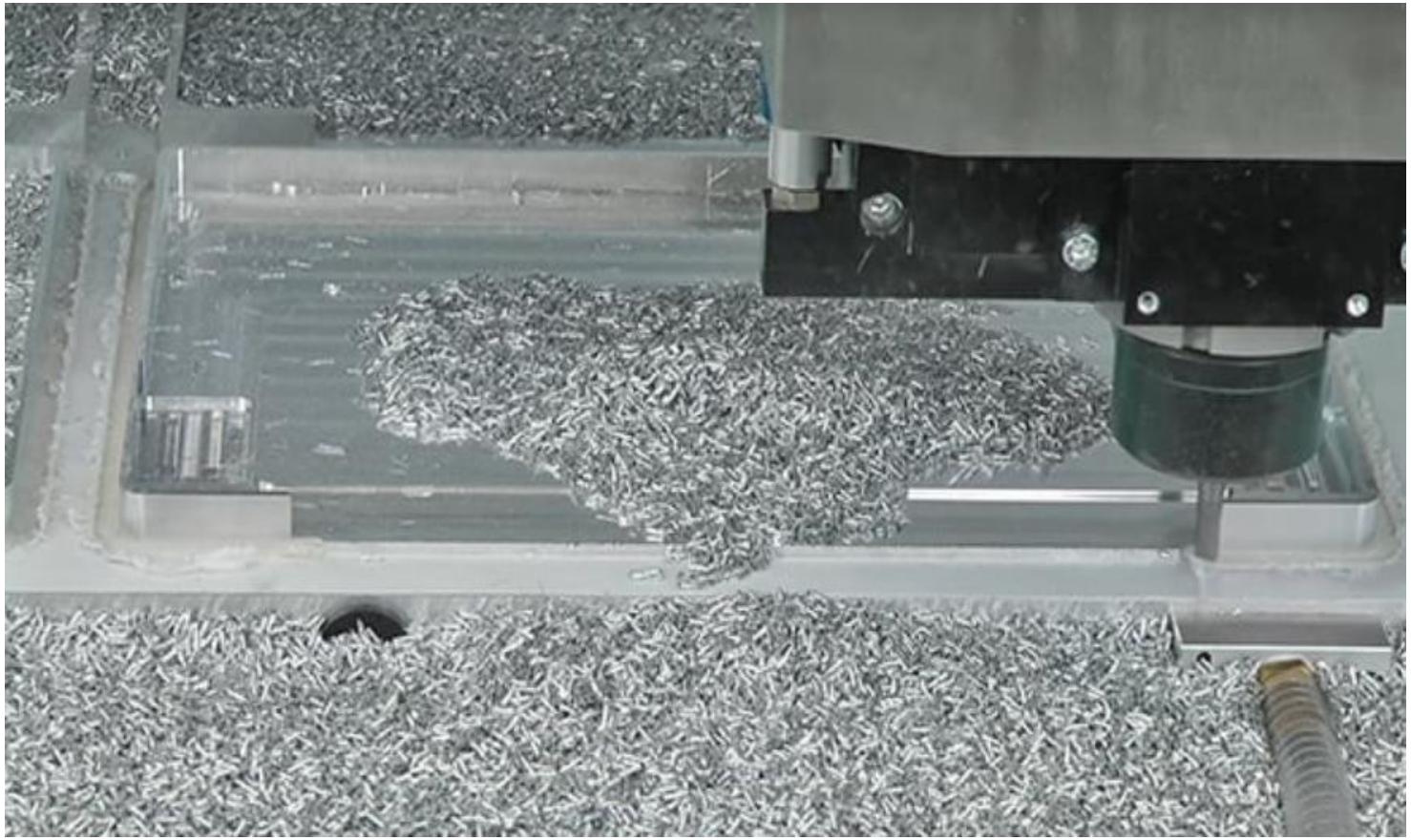
Bing Videos

There are some materials that will indicate if the majority of the heat is dissipating into the chip.

Q: What characteristic will could tell us that heat is being pulled out in the chips?

A: Color - chips will be blue in appearance

Issues related to Chip Accumulation



Q: What concerns could arise from excess chips on a machining surface?

A: Scarring of machined surfaces, impeding movement of slideways, and skin abrasions to workers who require close proximity to part movement

Effect of Lubrication on Chip Formation

- ‘’Birds nests’ in spindles can reduce efficiencies
- Clumping of chips in bins can hold on to residual coolant increasing waste

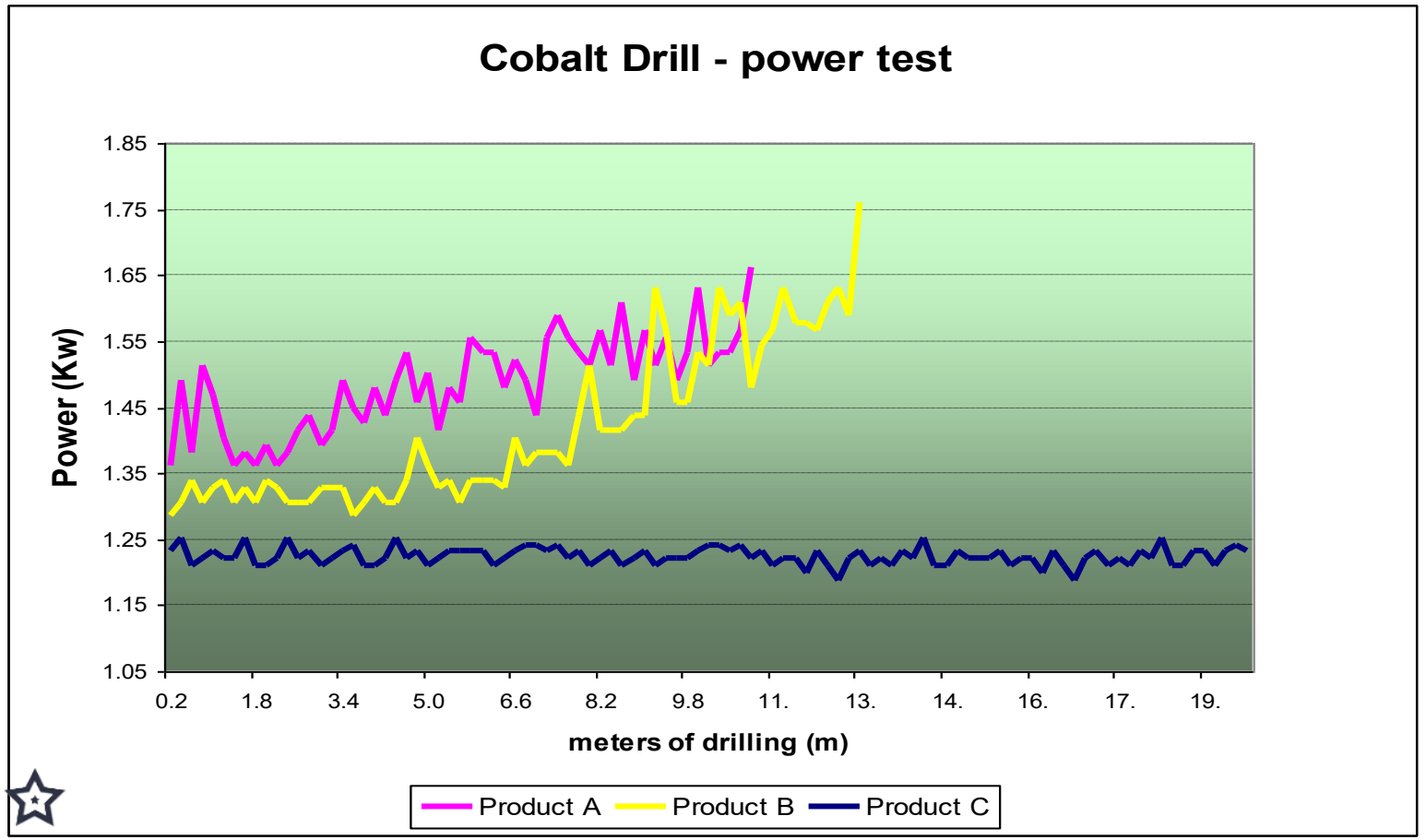
The Flushing Action Provides

- Cleanliness on machine surfaces and work piece
- Improve surface finish
- Reduce pre-mature tool wear

External

Internal

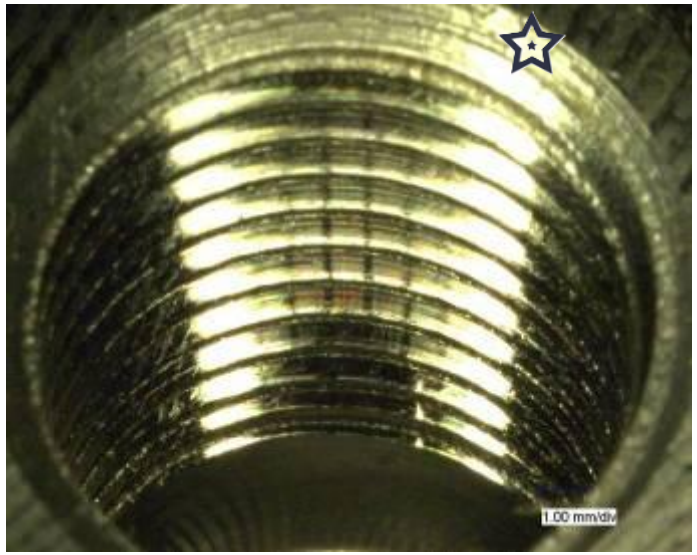
Stainless Steel Drill Test – Power Draw



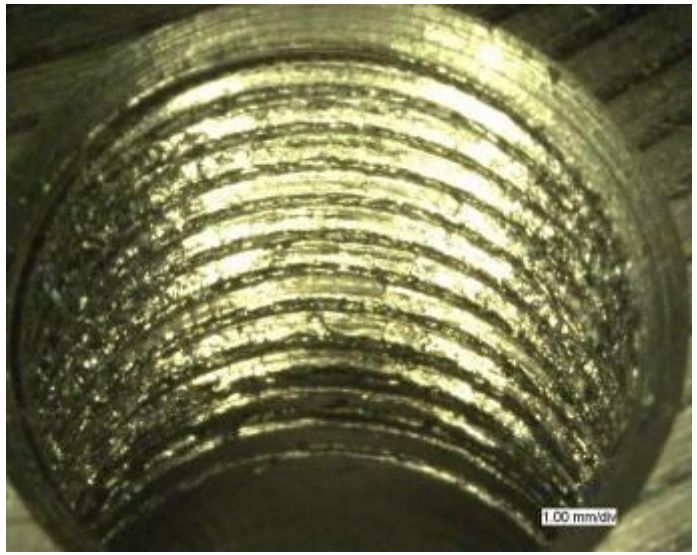
- Compare power consumption between different products performing a similar operation

Reduced power = Saved $$$

Thread Forming Test
Thread Quality



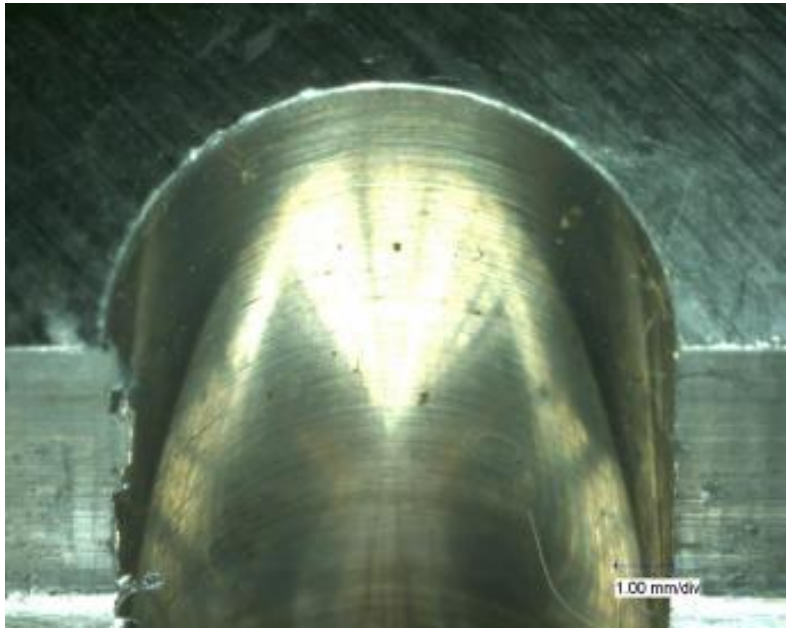
Product A

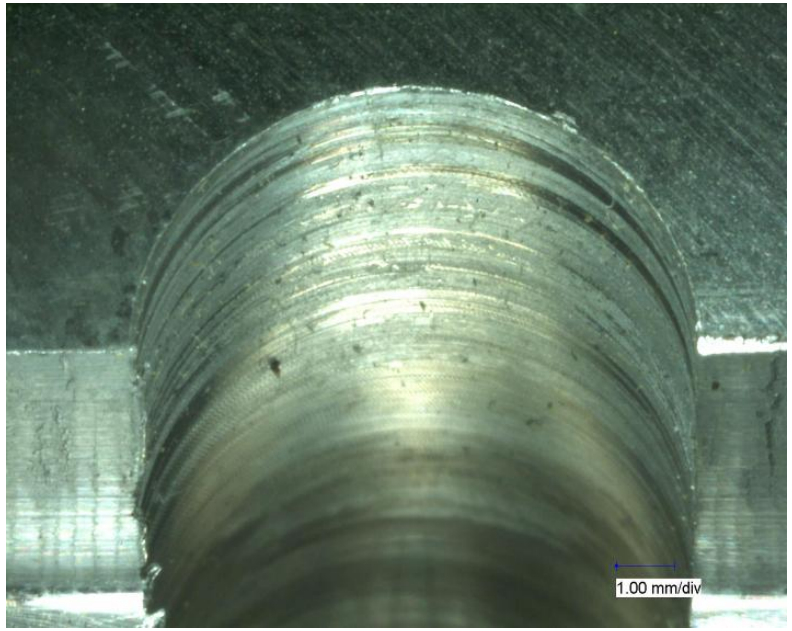


Product B

From DGP050016

Cast Aluminum Drill Test
Hole Finish





From DGP000089

Q: Do you know what this tool is called and what it is used for?

A: It is a version of a ‘go no go’ gauge that is commonly used to determine if parts are machined to specification

Fluid Types

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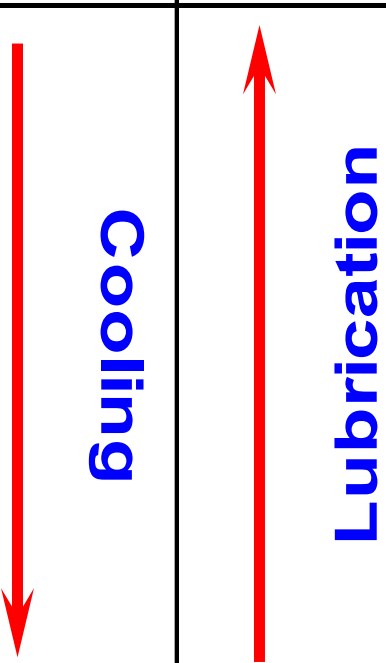
Types of Cutting and Grinding Fluids

- Straight oils – mineral
- Soluble-Oil coolants
- Semi-synthetic coolants
- Synthetic coolants
- “Green” products – Vegetable based

Cooling to Lubrication Ratio

Classification	Oil Content		
Straight Oils	100%		
Soluble Oils	40% - 80%		
Semi-Synthetics	10% - 40%		
Synthetics	0%		

Which product type would you suspect is most favored?

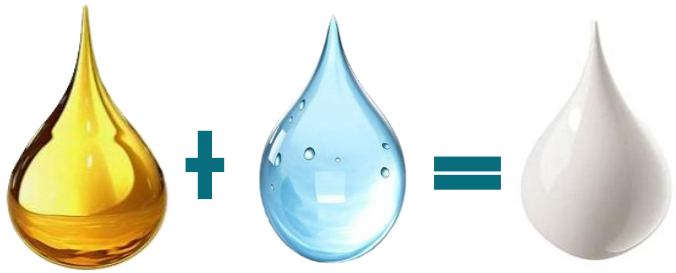
	Straight Oil	Soluble Oil	Semi-Synthetic	Synthetic
Price/gal	Very Good to Excellent	Very Good to Excellent	Good to Very Good	Fair to Good
Total Cost	Poor (run at 100%)	Fair to Good	Good to Very Good	Excellent
Usage Rate	Poor (high carry out)	Fair to Good	Good to Very Good	Excellent
Sump Life	Excellent	Poor to Good	Good to Very Good	Excellent
Maintenance	Excellent	Poor to Good	Good to Very Good	Excellent
Biostability	Excellent	Poor to Good	Good to Very Good	Excellent
Cleanliness	Good	Poor to Good	Good to Very Good	Excellent
Foam Control	Excellent	Poor to Good	Good to Very Good	Excellent
Rust Protection	Excellent	Good to Very Good	Good to Very Good	Poor to Good
Dermal Irritation	Poor to Good	Good to Very Good	Good to Very Good	Poor to Good
Seal, Paint, Plastic Compatibility	Excellent	Good to Very Good	Good to Very Good	Poor to Good
Hard Water Stability	n/a	Poor to Good	Good to Very Good	Excellent

Straight oils

- Mineral Oils
- Boundary Lubricants
  - Fats
  - Fatty Esters
- EP Lubricants
  - Chlorine
  - Sulfur
  - Phosphorus
- Anti-Mist/Anti-Foam Agents
- Odor Masking Agents

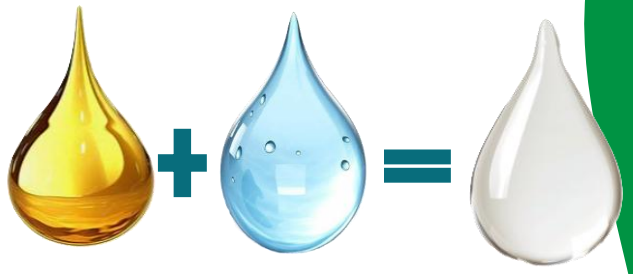
Operation	cSt @ 100°F
Honing	~17
Gun Drilling	~28
Vertical Broaching	~30
Flute Grinding	30 - 57
Swiss Automatics	~45
Screw Machines	~57
Gear Hobbing	28 - 49

Soluble Oils



- Mineral Oil
- Emulsifiers
- Coupling Agents
- Lubricant Package (EP, Boundary)
- Biocides
- Anti-foam Agents

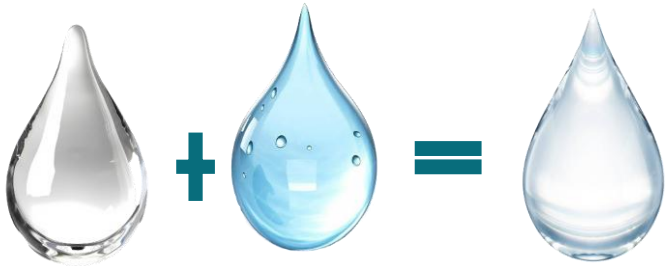
Semi-synthetics



Everything above +

- RP packages
- Buffers

Synthetics



- Coupling Agents
- Lubricant Package
- Biocides
- Anti-foam Agents
- RP packages
- Buffers

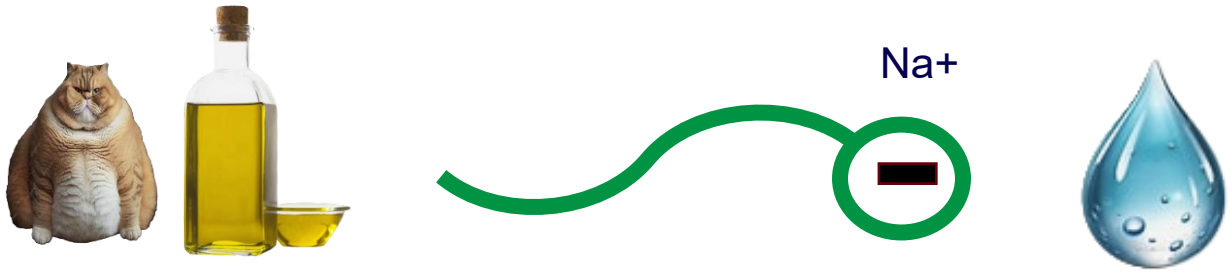
Q: What ingredient, other than mineral oil, was missing from the synthetic coolant composition that is found in both soluble oils & semi-synthetics?

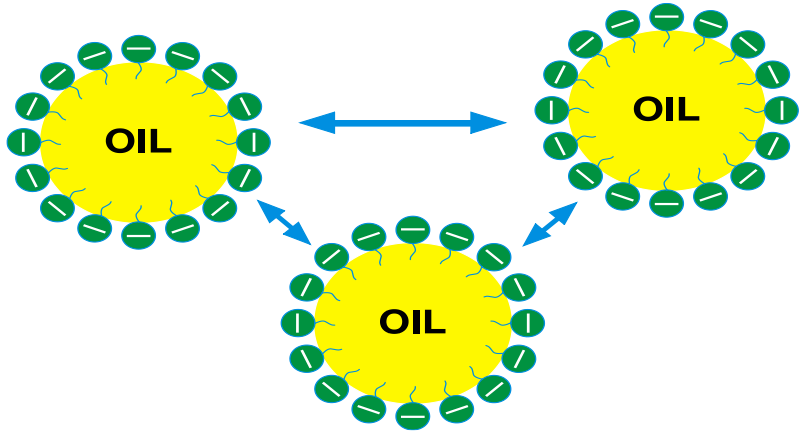
A: Emulsifiers – synthetics do not require these because there is no mineral oil present

Emulsifiers

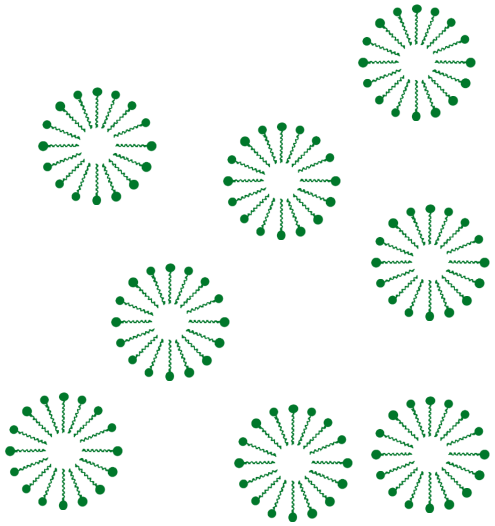
Emulsifiers are polar molecules which have a lipophilic portion and a hydrophilic portion.

The lipophilic portion attaches itself to the oil, while the hydrophilic end is in the water phase





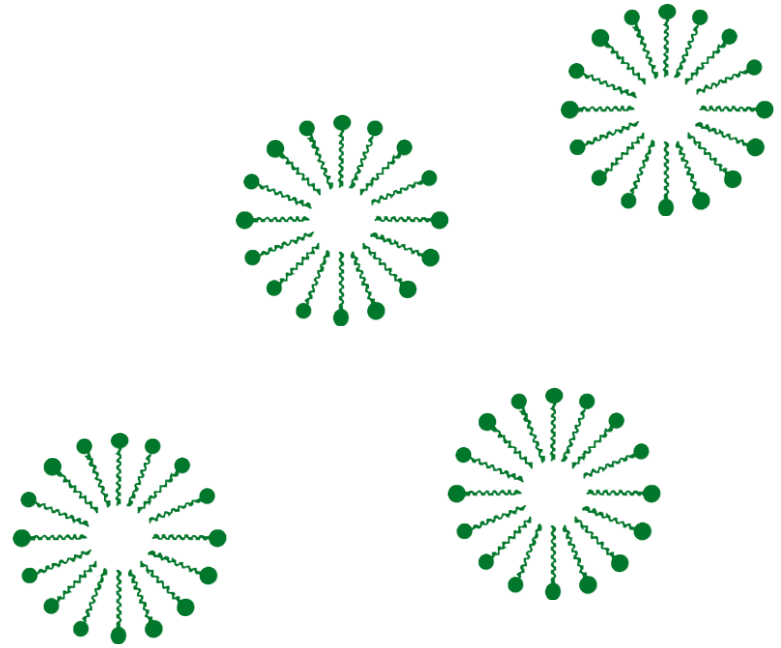
Which product is a soluble oil & which is a semi-synthetic?



Product A

Semi-synthetic : smaller oil droplet size results in a ‘tighter’ emulsion

More translucent in appearance



Product B

Soluble oil : larger oil droplet size results in a ‘looser’ emulsion

More milky in appearance

Metallurgy

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Severity of Machining

Carbon Steels
Cast & Malleable Steels
Free Machining Steels
Aluminum Alloys
Copper Alloys
Magnesium

High Machinability (Easy)

Tool Steels
Common Alloy Steels

Moderate Machinability

High Temperature Alloys
Titanium Alloys
Stainless Steels

Low Machinability (Difficult)

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Metal Types

Automotive Aluminum (300 series)

- ✓ High silicon content – more abrasion, higher tool wear
- ✓ Usually cast
- ✓ “Gumminess” – more lubrication, high speed
- ✓ Fines are light so tend to float on system – positive filtration is key
- ✓ Reaming is key operation – surface finish

Aerospace Aluminum (20XX, 60XX, 70XX)

- ✓ Staining, cracking, corrosion are key issues
- ✓ Chlorine tends to be prohibited in aerospace industry
- ✓ Corporate approvals
- ✓ Used in electronics industry applications
- ✓ Usually extruded bar stock

Metal Types

Nickel Alloys (Inconel)

- ✓ Extremely difficult to machine
- ✓ Aerospace and defense industries

Titanium

- ✓ Staining potential
- ✓ Aerospace and medical industries
- ✓ Restrictions may apply

Magnesium

- ✓ Creates Mg++; hard water soaps; splits products
- ✓ Flammability – straight oils for some customers

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Metal Types

Cast Iron

- ✓ Smut created, runs dirty
- ✓ Rust protection important
- ✓ Clinkering may occur
- ✓ Can run dry, but need fluid for dust control

Carbide

- ✓ Cobalt leaching; fluid turns purple; Inhibitor 3 needed
- ✓ Potential health issues

Plastics (Non-Metals)

- ✓ Mostly synthetics
- ✓ Many different types

Metal Cutting Operations

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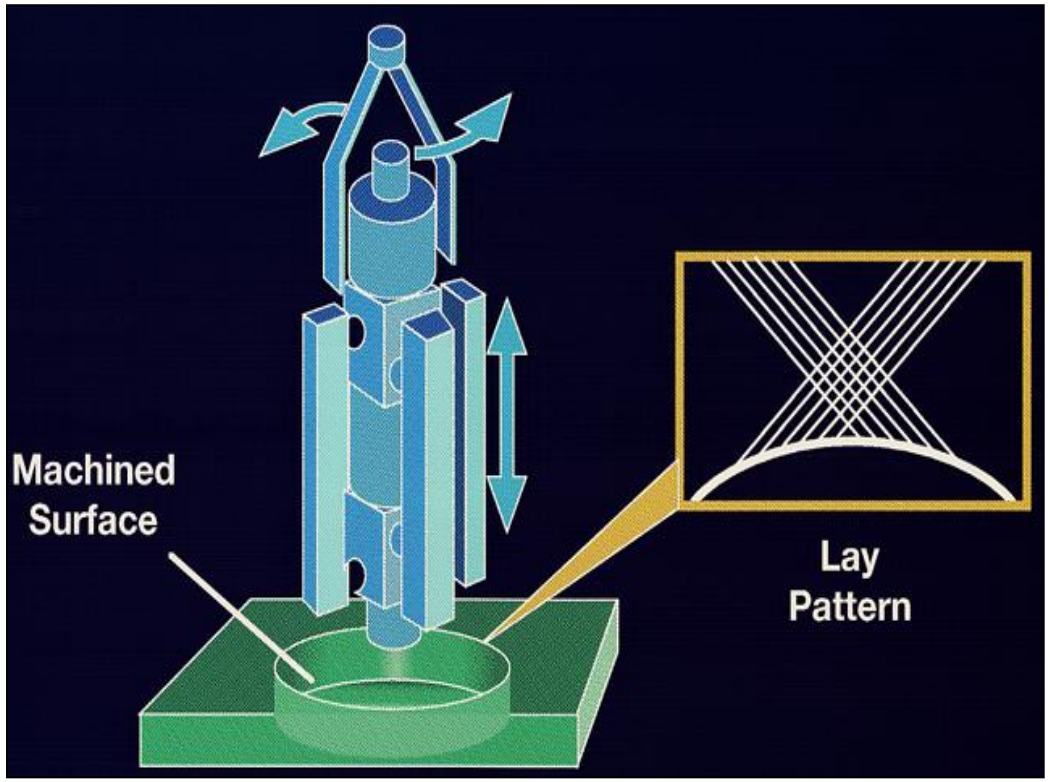
Operation vs Demand

HIGH LUBRICATION DEMAND	BROACHING	NEAT CUTTING OILS	
	TAPPING		
	GEAR HOBBING	SOLUBLE OILS	
	DRILLING		
	MILLING	SEMI-SYNTHETICS	
	TURNING		
HIGH COOLING DEMAND	SAWING	SYNTHETICS	
	HONING		
	GRINDING		

In theory, this chart is true but today almost any product type can be used in almost any application.

Honing

- Honing is a controlled, low-speed sizing and surface finishing process in which stock is removed by the shearing action to the bonded abrasive grains of a honing stone or stick.



Q: What commonly manufactured part would take advantage of the cross-hatching lay pattern?

A: Engine cylinder for a vehicle – oil adheres to the cross-hatch pattern to provide lubrication down the length of the cylinder

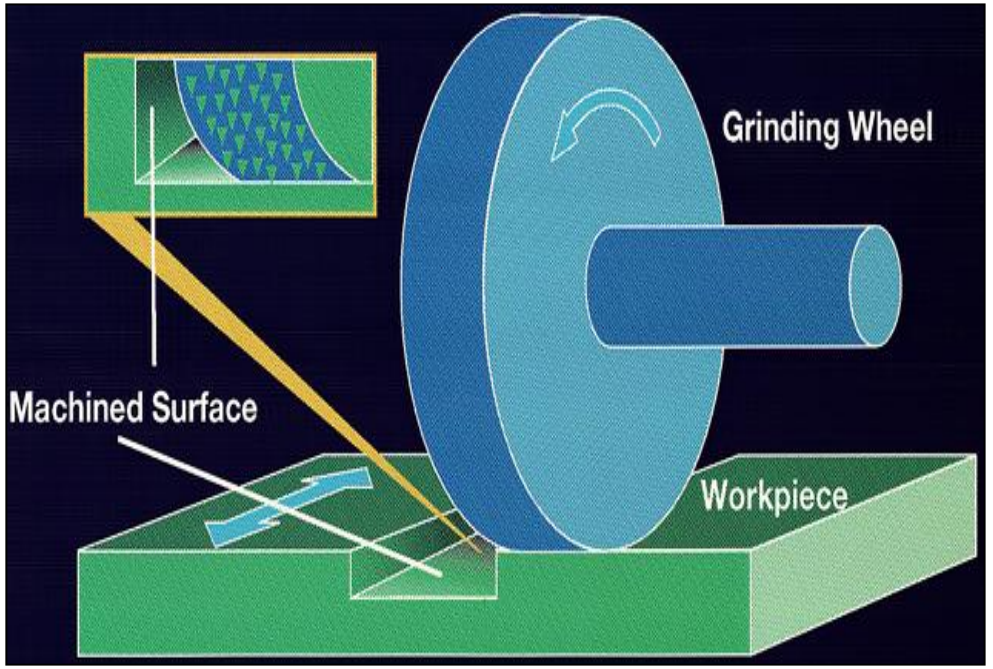
Grinding

Q: What do a sponge and grinding wheel have in common?

A: They are both porous

Q: What does it mean for a grinding wheel to be loaded?

A: The pores of the wheel are filled with metal

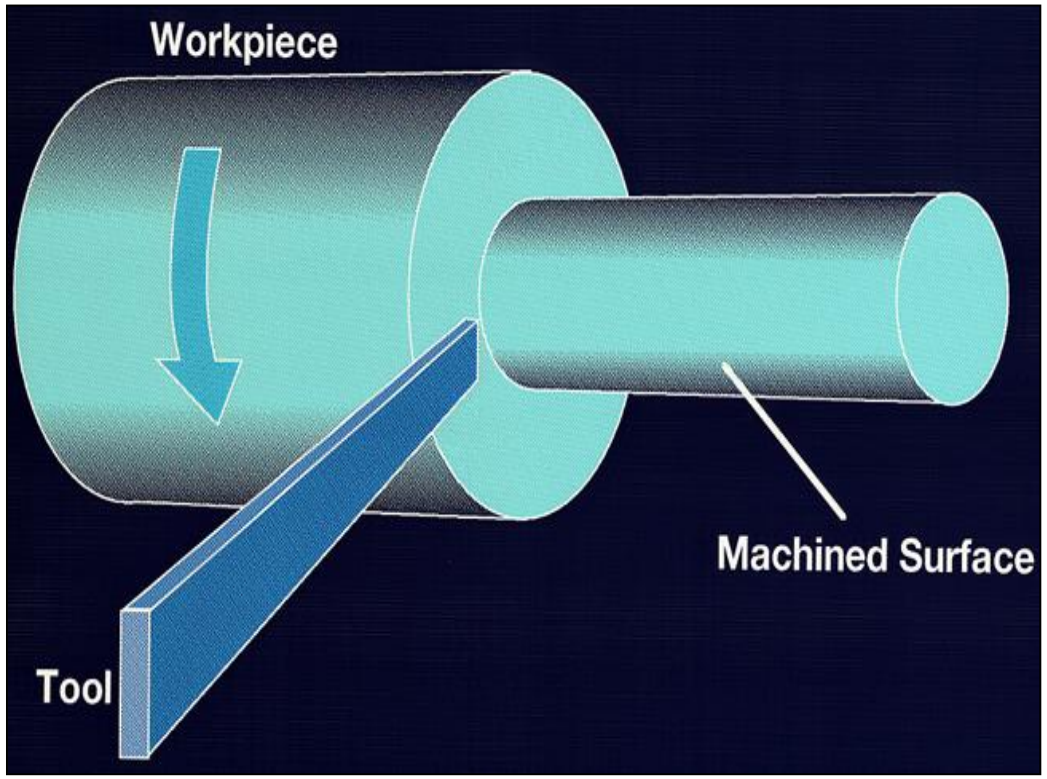


Q: What is the phrase used to clean the pores of a wheel for further machining?

A: Dressing the wheel

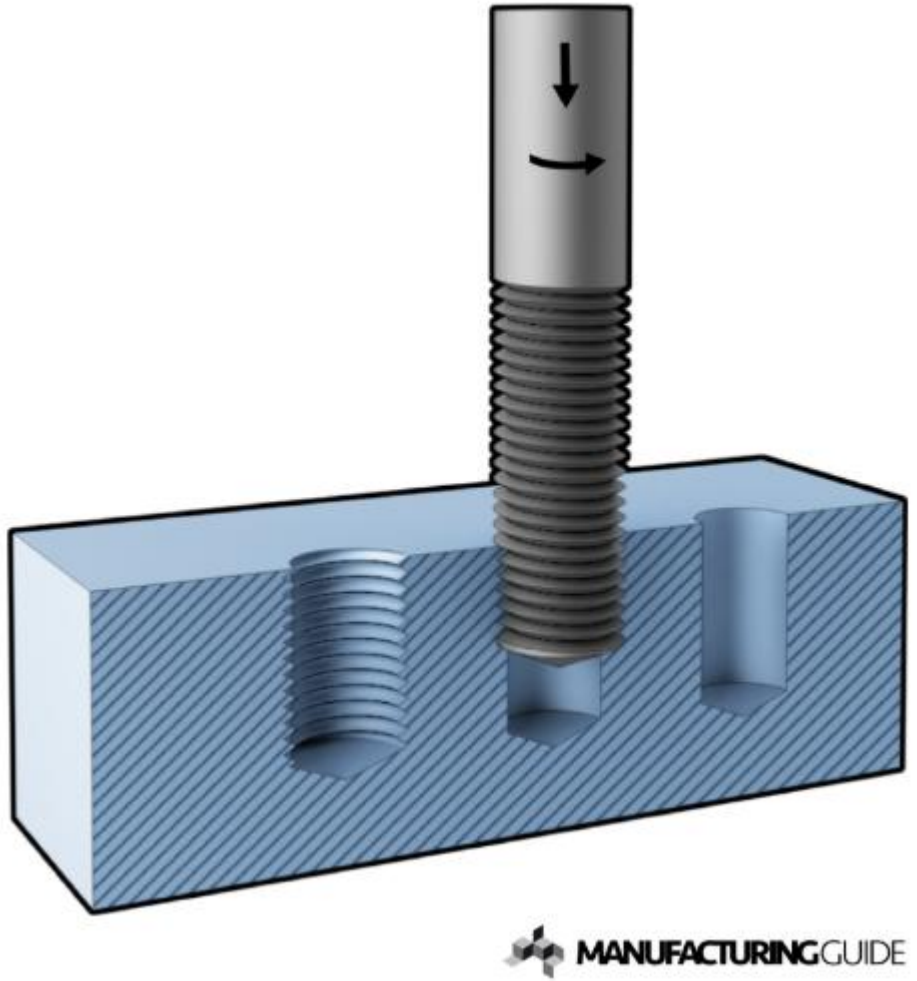
Turning

Turning is a machining process for generating external surfaces of revolution by the action of a cutting tool on a rotating workpiece, usually in a lathe.



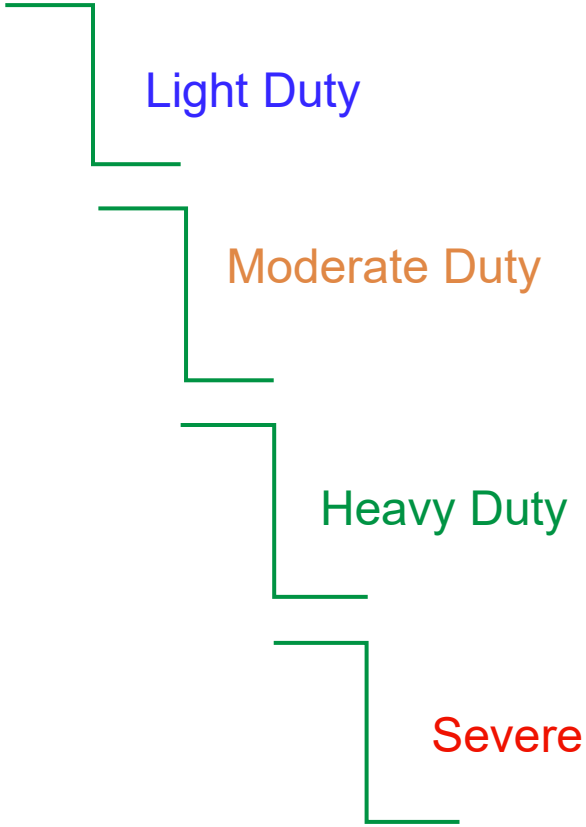
Tapping

Machining process for producing internal threads.
Combining rotary motion with axial motion, the tap cuts or forms the internal thread.



Severity of Machining Operations

1. Grinding
2. Sawing
3. Turning, Single-point Tools
4. Planing & Shaping
5. Milling
6. Drilling
7. Reaming
8. High-speed, Light-feed Screw Machining
9. Screw Machining with Form Tools
10. Boring
11. Deep-hole Drilling
12. Gear Cutting
13. Threading
14. Tapping
15. External Broaching
16. Internal Broaching



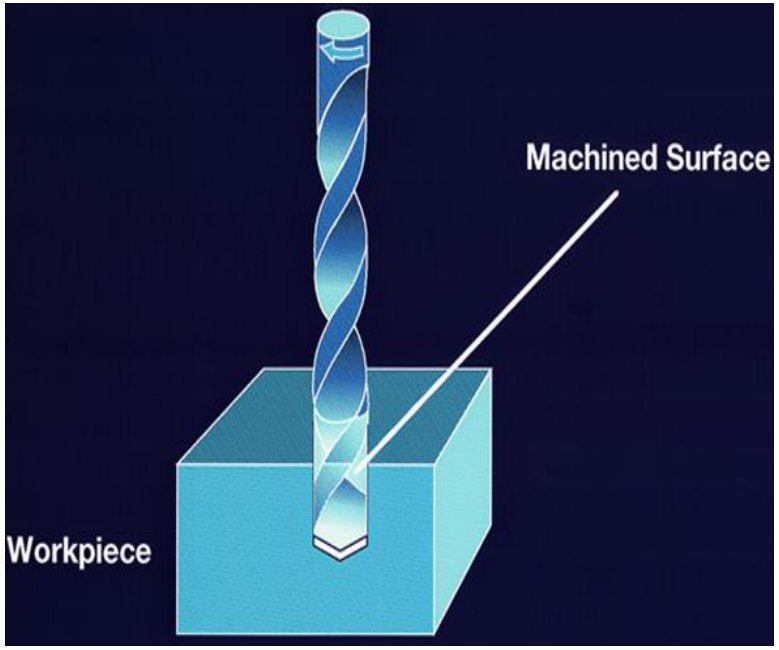
SOURCE: Machining Data Handbook, 3rd Edition; Metcut Research Associates, Inc. 1980

Milling

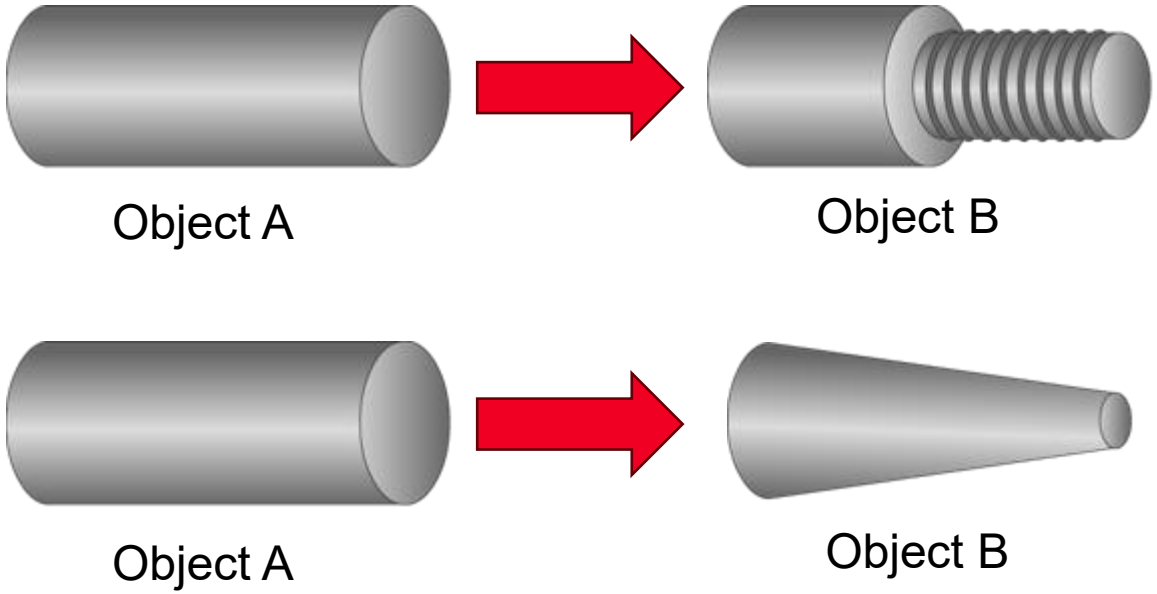
- Machining process in which metal is removed by a rotating, multiple-tooth cutter.
- Because both work piece and cutter can be moved in more than one direction at the same time, surfaces having almost any orientation can be machined
- Milling can be in a manual machine or a machining center

Drilling

- A drill for cutting metal is a rotary end cutting tool with one or more cutting lips and usually one or more flutes for the passage of chips and the admission of cutting fluids.
- Drilling is usually the most efficient and economical method of cutting a hole in solid metal.



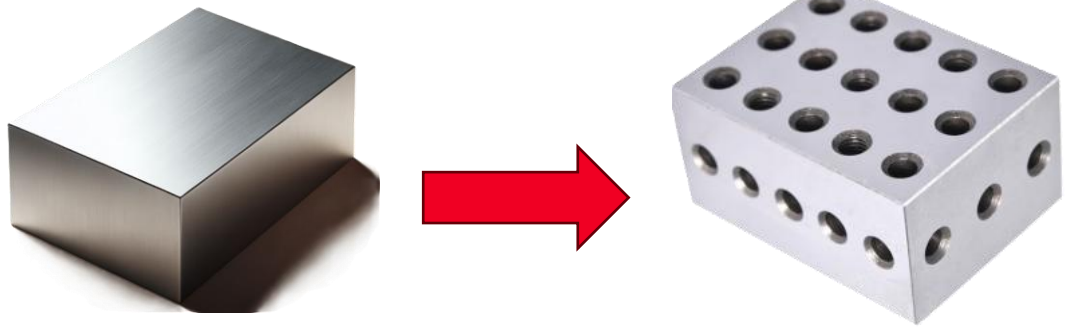
What processes are utilized?



Straight turning
+
Threading

Taper turning

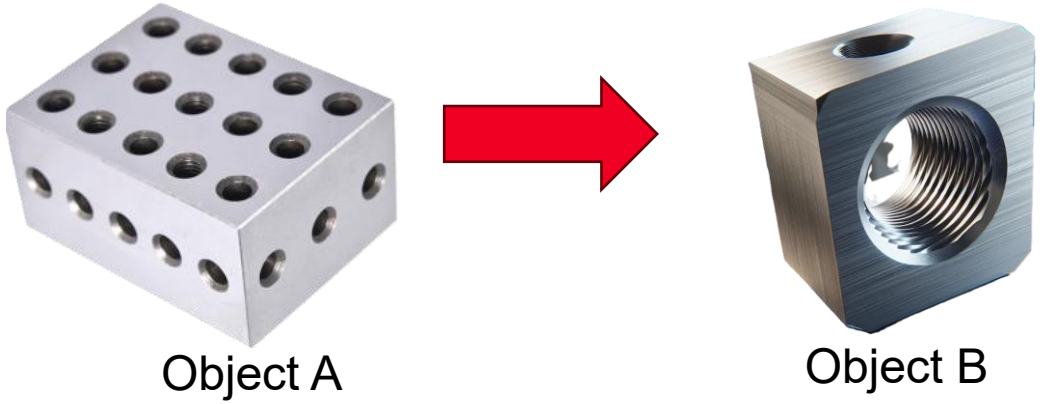
What processes are utilized?



Object A

Object B

Drilling

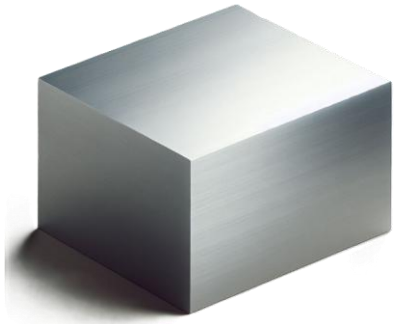


Object A

Object B

Tapping

What processes are utilized?



Object A

Object B

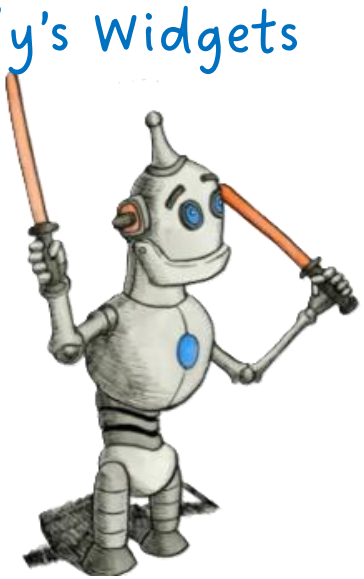
Milling

Object A

Object B

Gundrilling

Sales Scenario 1



Wally's Widgets is a job shop that manufacturers a variety of small to medium sized parts for toy companies. They have been using Ecocool 7330, a semi-synthetic, for a few years and have had mixed results.

They utilize a variety of machining applications including milling, turning, and drilling. Their CNC systems incorporate a high pressure configuration (1000psi). The primary metals being machined are steel and aluminum.

They are located in an area that has hard water (10 grain hardness).

Recently the operation manager has been commenting on unusually high corrosion both in machining centers as well as on some parts. They've also seen high levels of foam across all cells.

What considerations would you take into account when choosing what type of product category & ultimately replacement product?

1. Current product chemistry – it may make sense to stay in the same category
2. Machining operations – typically recommend to the most difficult operation
3. Metals being machined – product needs to be compatible with those metals
4. Water hardness – can contribute to product stability, foam, corrosion
5. Other issues – address corrosion with robust RP package

Hysol MB 50-semi

-Familiar product type

-very good corrosion protection

-multi-metal

-low foam in hard water

Sales Scenario 2

Allison's Air Supply is a supplier of aerospace parts to a variety of companies for the assembly of small private planes. They primarily source Titanium and Aerospace grade aluminum

Parts are machined by milling, turning, and drilling. The facility has been using Microsol 590XT, a semi-synthetic, for a few months but now are noticing a strange smell permeating through the plant. They are seeing sporadic staining on finished parts which requires additional machining.

The CNC machines operate with a moderate pressure system (500psi) and they are using local water that has very low water hardness (4 grain hardness).

What considerations would you take into account when choosing what type of product category & ultimately replacement product?

1. Current product chemistry – it may make sense to stay in the same category
2. Machining operations – typically recommend to the most difficult operation
3. Metals being machined – product needs to be compatible with those metals
4. Water hardness – low hardness can affect foam
5. Biological – choose a product that has high biostability to address growth & odors
6. Other issues – investigate whether the product requires aerospace approvals

Hysol SL 45 XBB-semi

-Familiar product type

-strong biostability

-aerospace metal compatible

Fluid Maintenance

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Q: What is Coolant Management 101?

A: Good “Housekeeping”!

2 KEYS TO SUCCESS

1. Daily Concentration Control

2. Daily Tramp oil Skimming
   #1 cause of bacterial attack

How do we do it?

- Start with a high quality, ‘forgiving’ metalworking fluid
- Good Sump Cleanouts using machine cleaner
- **Daily Refractometer Checks**
- Routine addition of make-up coolant with a pre-mix at **½ Target**
  - **Mixing Method: O-I-L = Oil In Last**
  - **Always add concentrate to water for best mixing results**
- Elimination of contaminants such as oil leaks, tapping fluids, cleaners, food, tobacco and human waste.
- **Skimming Tramp oil**

How to Mix Metalworking Fluids | Castrol USA - YouTube

Good Housekeeping: Proper make up

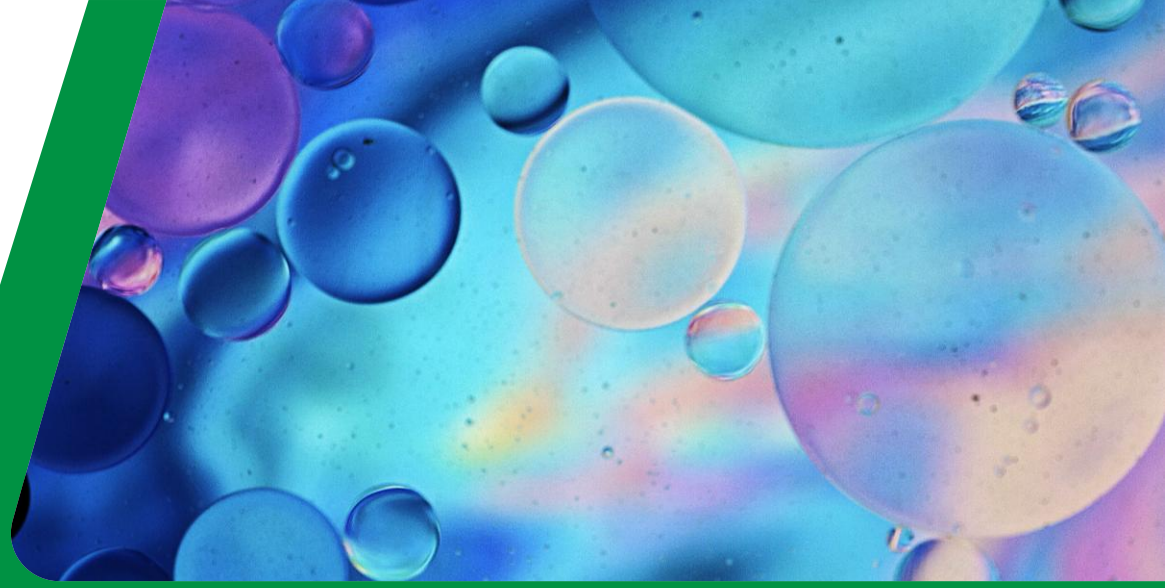
- ✓ Best way to keep sumps in line is with routine use of proportioning device
- ✓ Regular make up of **2-4 %** (or a third of your target) keeps sumps in control

Wall Mount/Dual Mix

Drum Top Type

How to Mix Metalworking Fluids | Castrol USA

Good Housekeeping - Tramp Oil



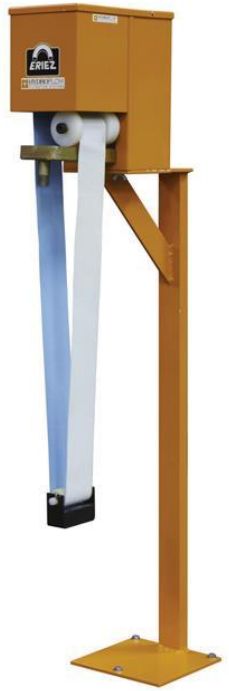
What is Tramp Oil?

Hydraulic oil, spindle oil, grease, way oil, leaks, carryover.

Excess Tramp Oil leads to:

- Poor tool life
- Bacteria
- Misting and Foaming
- Increase product usage
- Chip sticking

Tramp Oil Skimmers - Belt Type



Tramp Oil Skimmers - Disc & Rope Type

Concentration Control

- **Refractometers** are used to measure concentration by measuring the refraction of light of the fluid through a prism

- Contaminants can skew the reading or make the reading difficult, so the refractometer test will not be 100% accurate in aged or contaminated systems

How to Measure Coolant Concentration with a Refractometer | Castrol USA

Effects of Concentration Levels on Performance

Low Concentration

- ❑ Machining Issues
- ❑ Bacterial Growth
- ❑ Corrosion
- ❑ Short fluid life
- ❑ Low tool life

High Concentration

- ❑ Wastes coolant
- ❑ Staining (nonferrous materials)
- ❑ Skin irritation
- ❑ Residue buildup
- ❑ Reduces cooling
- ❑ Foam

Impact of Water on Systems

Common Water Types

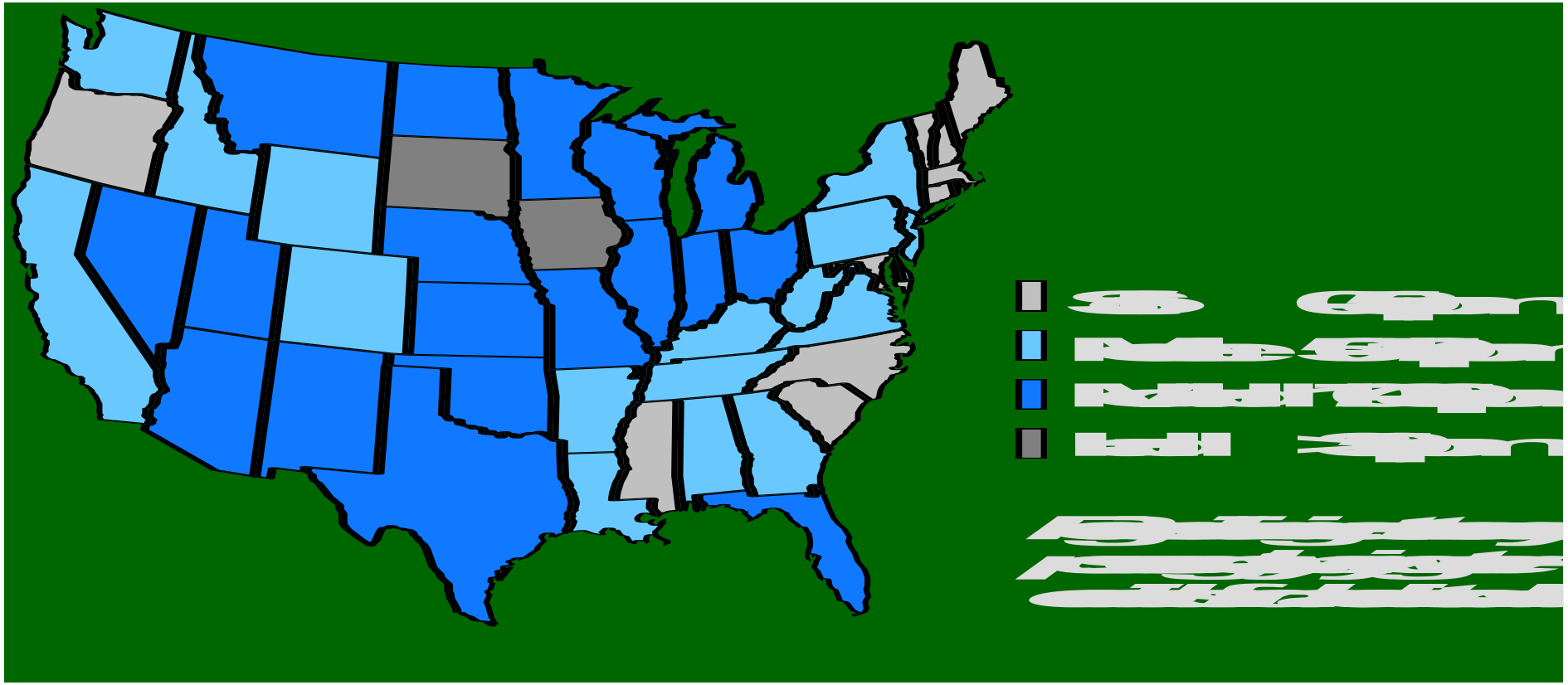
- RO Water
- DI Water
- Softened Water
- Tap Water
- Well Water

Q: Which water type would you expect to be the most likely to cause corrosion in a system? Why?

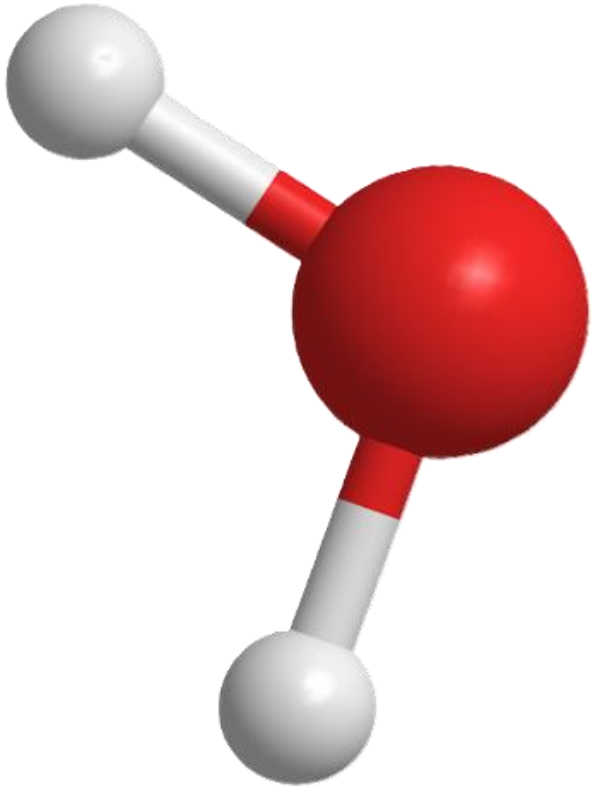
A: Softened water - salt (NaCl) is used to transfer ions leaving behind the sodium and chloride to build in the system as water evaporates

Water Quality

Water makes up 90+% of most systems, so its quality is very important!



Water Hardness



Q: How can you reduce hardness in a metalworking system?

A: There are 2 ways:

1. Fully dump and recharge the system
2. Conduct a partial dump/recharge

Effect of Water Hardness

Low Hardness (0 to 5 gpg)

- More tendency to foam and mist
- Low tendency for residues
- Good for emulsion stability

DI Water

Moderate Hardness (5 to 20 gpg)

Tap Water

- Desired range to avoid foam, mist, residues and emulsion stability

High Hardness (>20 gpg)

Well Water

- High tendency to form residues
- High tendency to split emulsions
- Low tendency for foam and mist
- Other dissolved ions
- Chlorides and sulfates – known corrosion causing ions
- Keep chlorides below 250 ppm

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Housekeeping - Contamination

Contamination Types:

- Cleaners
- Solvents
- Other Coolants or coatings on raw materials
- Floor sweepings / Airborne particulate
- Dirt or oxidation on raw materials
- Food, human waste

Metalworking Fluid Dump, Clean & Recharge | Castrol USA

Housekeeping - Contamination

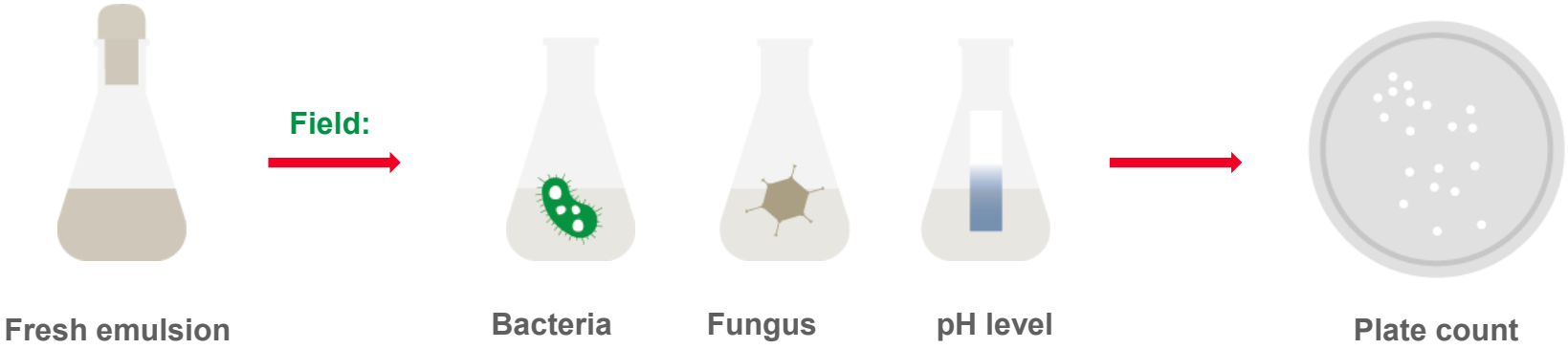
ALL OF THOSE MAY LEAD TO:

- Bacteria Growth
- Foam
- Odor
- Shorten Fluid Life

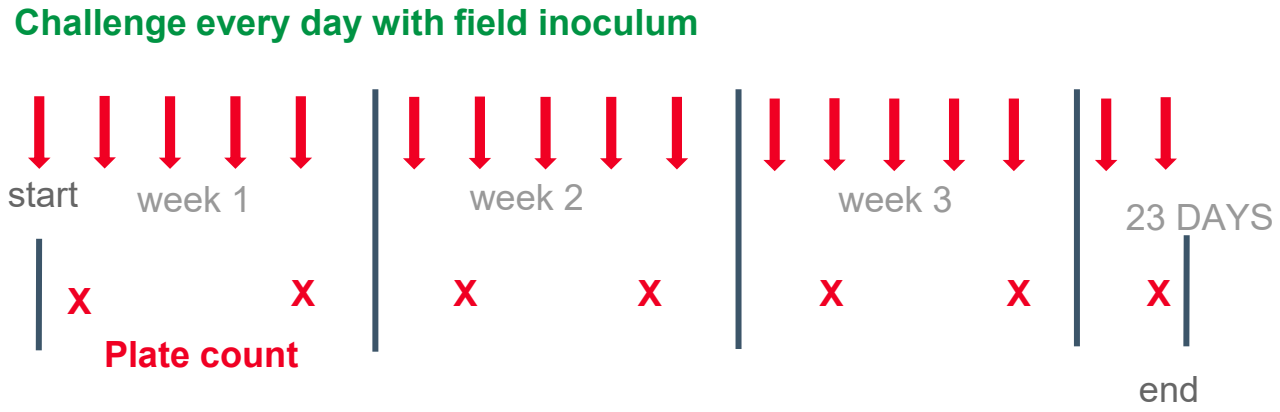
Machine down time and maintenance costs

Putting our Fluids to the Test

Microbiology Challenge Test



23 DAYS long!



Microbiology Results

Overall performance represented by stoplight indicators

Product	Inoculum	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Hysol 11 FF	Bacteria	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+05	1.00E+04
Hysol 33 FF	Bacteria	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+05	1.00E+04
Hysol 11 FF	Fungi	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hysol 33 FF	Fungi	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Note: Field samples can be tested using Dip Slides to determine current biological status

Biocontamination

Would you rather???

A. Have bacteria in your machine system?

B. Have fungus in your machine system?

Why did you make this choice?

Personal Hygiene

1. Minimize contact with any chemicals

2. Wash Hands regularly

3. Change clothes daily

4. Should not eat or drink while working

5. Follow proper PPE

6. Notify your EHS staff with any concerns

Fundamentals of Lubrication

Understanding the basics of Friction, Wear, and Lubricants

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Tribology

Tribology is the study of Friction, wear, lubrication; the science of interacting surfaces relative to motion.

Friction	Wear	Lubrication
Resistance to motion	Material loss from contact	Reduces friction and wear

“Think of tribology as the science behind why your bike chain squeaks—and how to stop it.”

Tribology -

What is friction? Resistance to motion

Higher Resistance = More Friction

Less Resistance = Less Friction

Tribology -

Two primary forms of friction

Dry Friction

Fluid Friction

Tribology -

Tribology = The study of:

Friction | Wear | Lubrication

Dry Friction

Fluid Friction

From a distance, the surface of the earth appears smoother than that of a bowling ball

When you look closer, you can see the roughness of the terrain

Tribology -

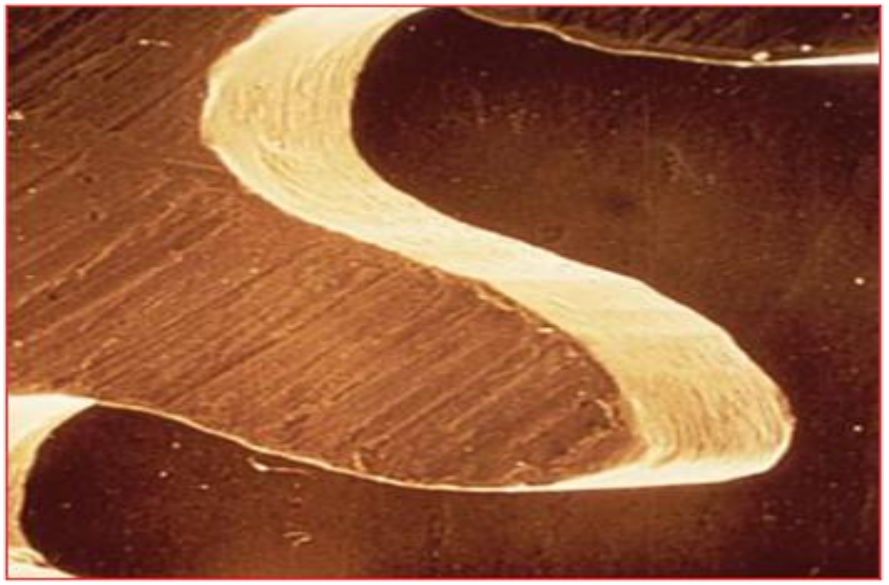
Tribology = The study of:

Friction | Wear | Lubrication

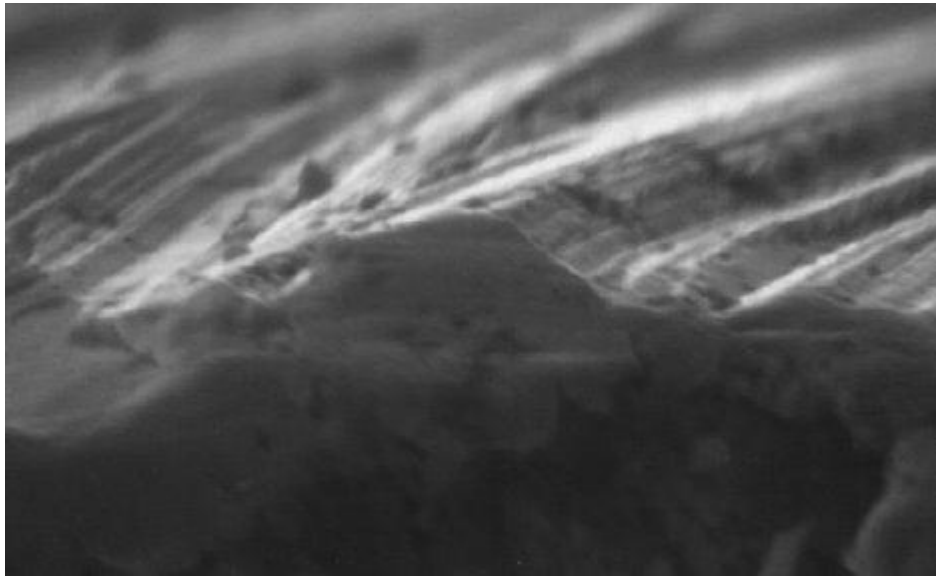
Dry Friction

Fluid Friction

(Under a Microscope)



Precision Gear From a Watch under magnification



2000 times magnification of a highly machined surface

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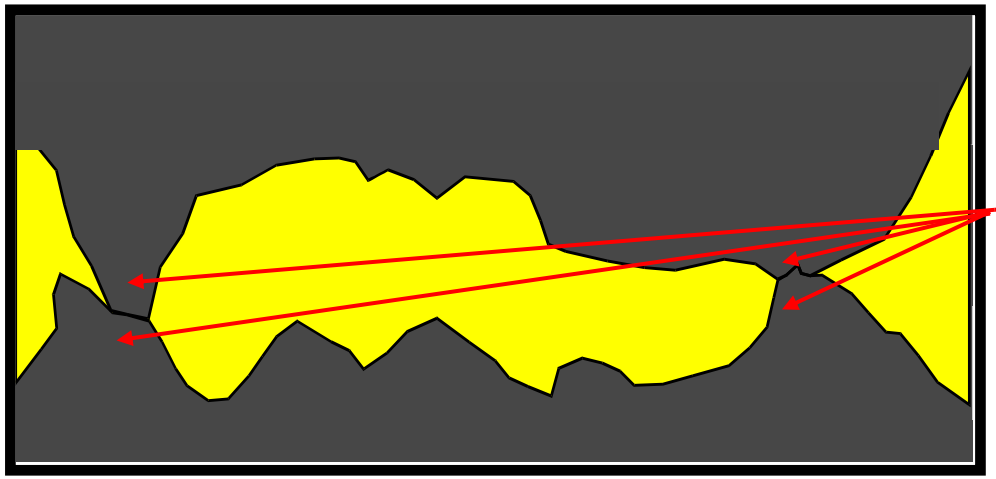
Tribology -

Tribology = The study of:

Friction | Wear | Lubrication

Dry Friction

Fluid Friction



Surfaces are rough and have peaks called **asperities** which pass and "bump" into each other

As surfaces move over each other, they will block movement and a force is required to move the asperities over or through one another.

This force is called the frictional force.

Tribology -

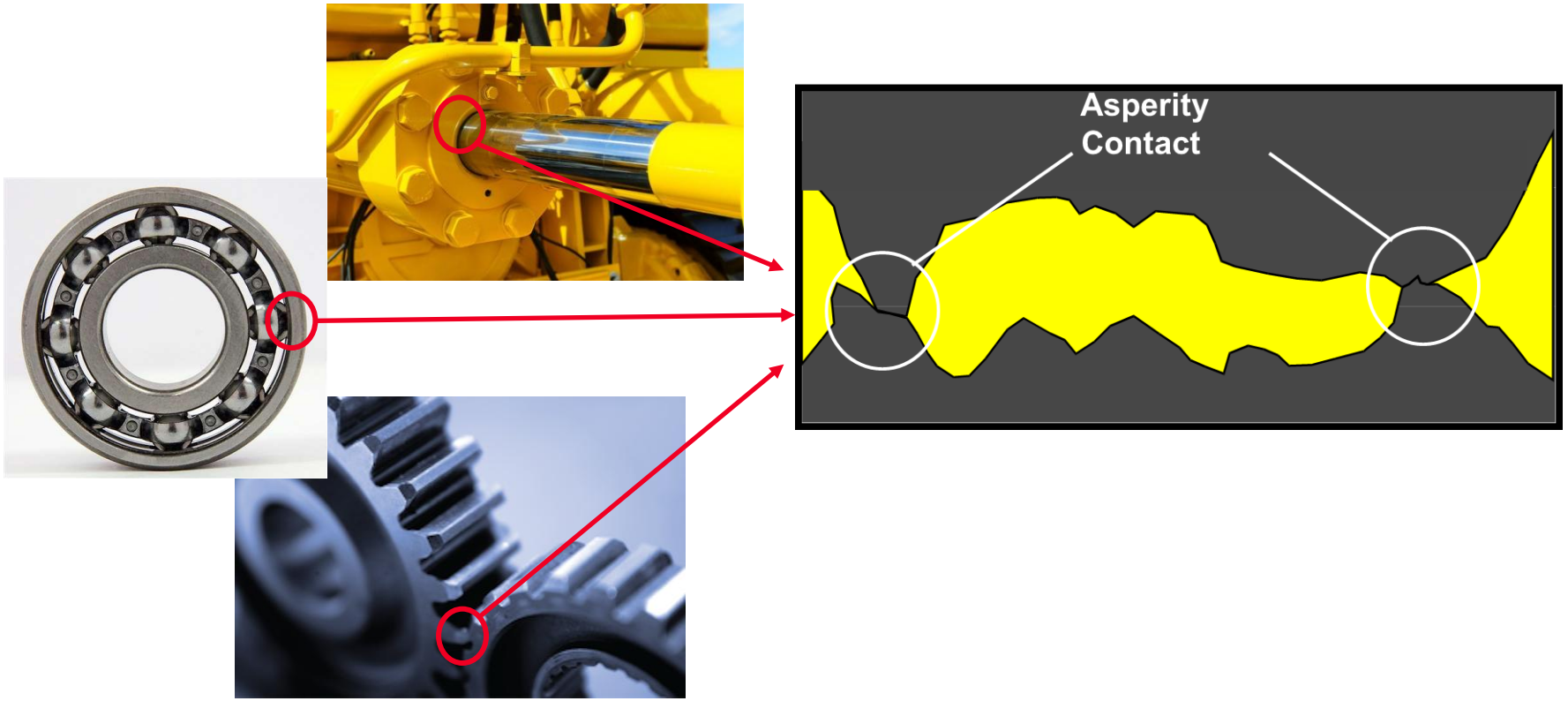
Tribology = The study of:

Friction | Wear | Lubrication

Dry Friction

Fluid Friction

Where does dry friction occur?



Tribology -

What are the two modes (i.e. different forms) of friction?

Sliding (or rubbing)

Rolling

Tribology -

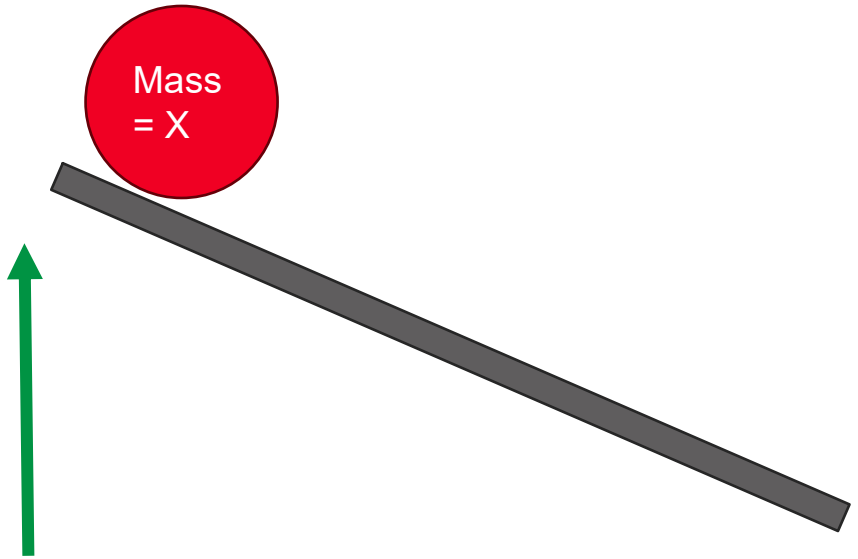
Tribology = The study of:

Friction | Wear | Lubrication

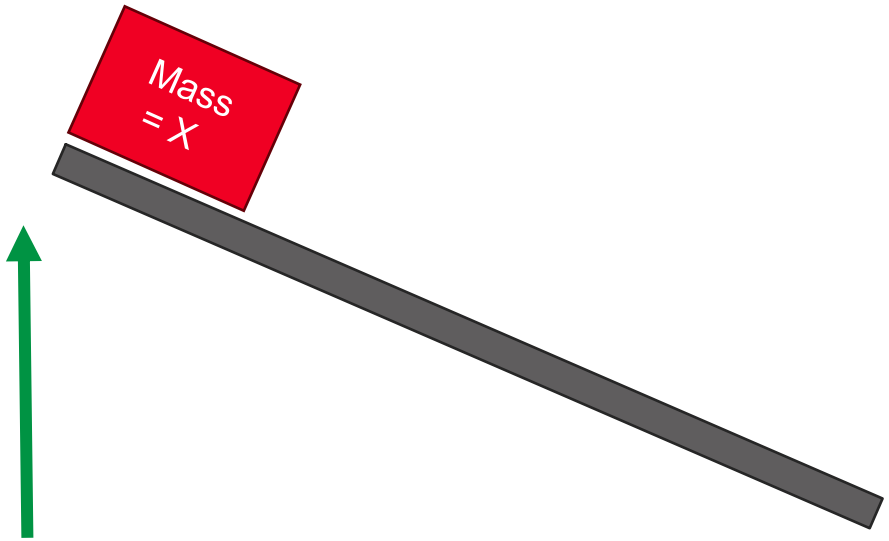
Dry Friction

Fluid Friction

Q: Which object moves FIRST as the platforms are raised and why?



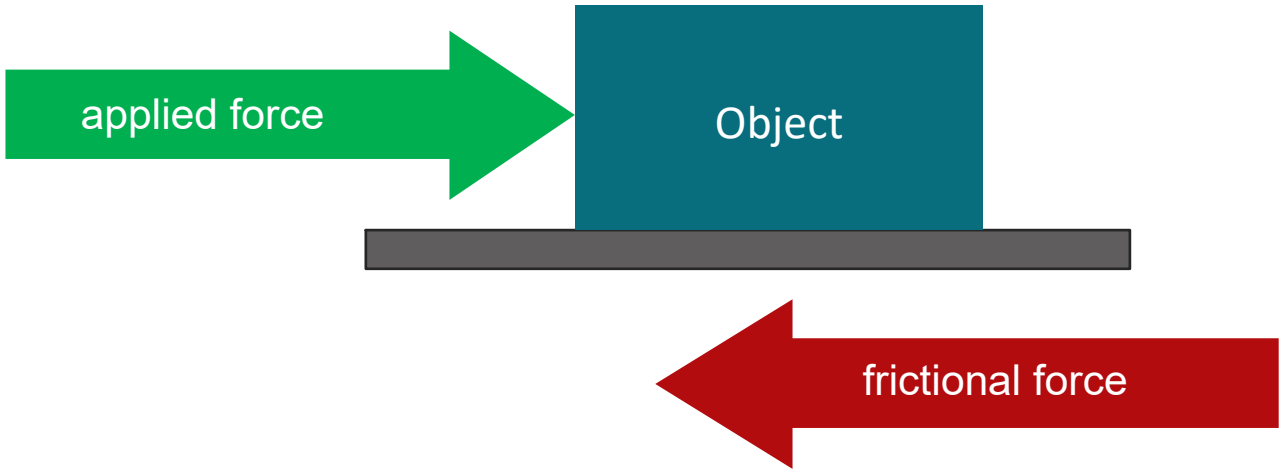
Object A



Object B

Tribology -

Sliding Friction is the force that resists sliding motion



Applied force must be GREATER than frictional force for motion to occur!

Tribology -

Tribology = The study of:

Friction | Wear | Lubrication

Dry Friction

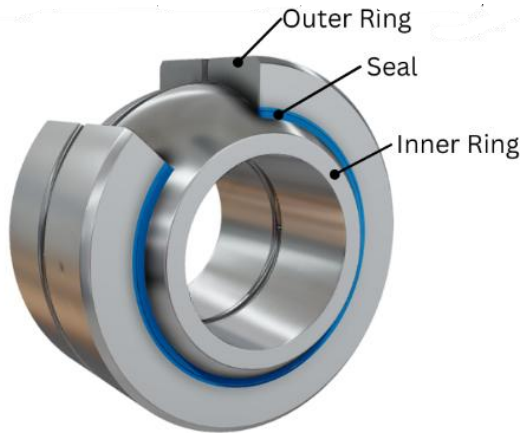
Fluid Friction

Applications with sliding friction

Slideways

Screw threads

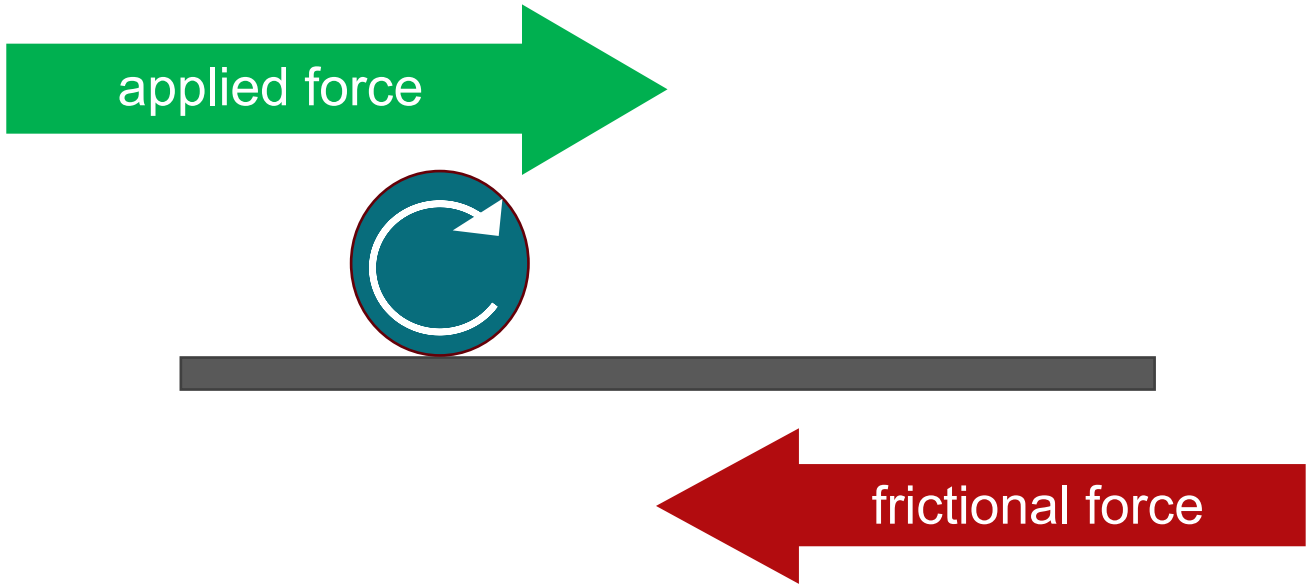
Worm gears



Plain journal bearings

Tribology -

Rolling Friction is the force that resists rolling motion



Applied Force must be GREATER than Frictional Force for motion to occur!

Tribology -

Applications with rolling friction

Roller / Ball Bearings

Gears – slide & roll

Tribology - Friction

Two primary forms of friction

Dry Friction

Fluid Friction

Tribology -

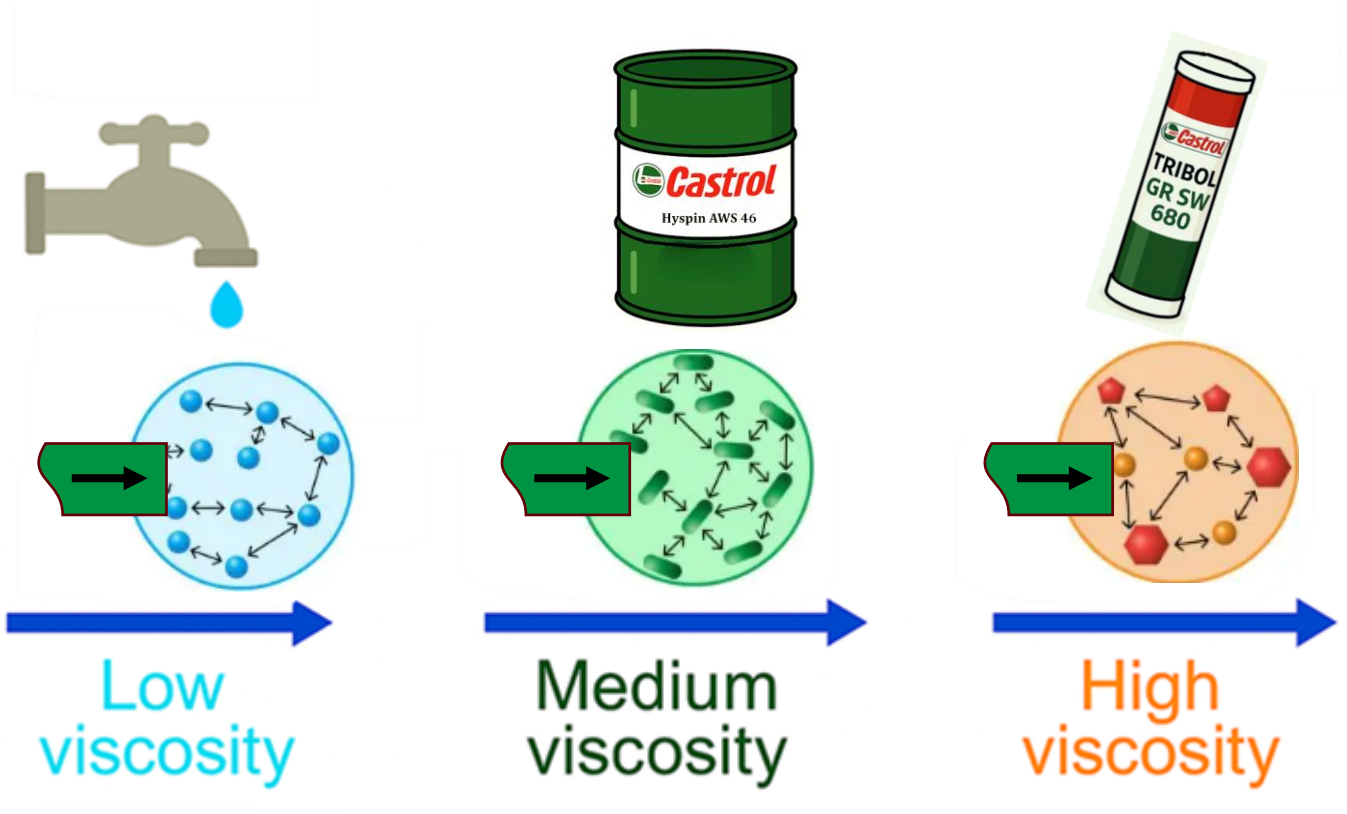
Tribology = The study of:

Friction | Wear | Lubrication

Dry Friction

Fluid Friction

Fluid Friction - Resistance created within the fluid film when the molecules collide



Tribology -

Tribology = The study of:

Friction | Wear | Lubrication

Dry Friction

Fluid Friction

Fluid Friction - Resistance created within the fluid film when the molecules collide

GROUP QUESTION:

What could happen if you over-lubricate?

What could happen if you use the wrong viscosity?

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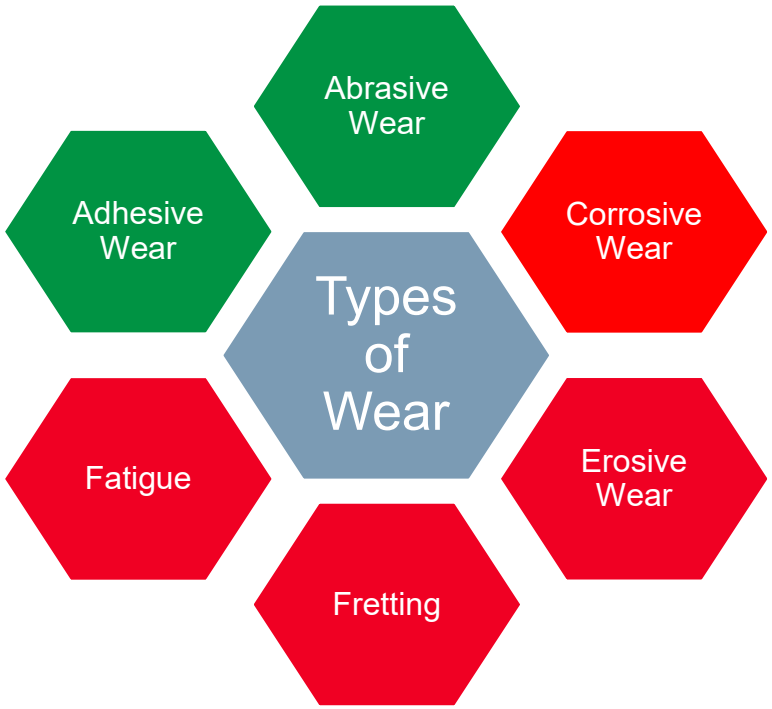
Tribology -

WEAR = the removal or transfer of material.



By reducing wear, equipment life is extended and the quality of production maintained longer

Tribology -

Why Controlling Wear Is Critical

Wear = Cost

- Increased downtime
- Higher maintenance costs
- Reduced equipment life
- Lower product quality

Real-world examples:

- A bearing failure due to abrasive wear leading to unplanned shutdown
- Mis-alignment creates concentrated stress and fatigue failure leading to gear tooth breakage.
- Too low viscosity allows metal surfaces to contact and create excessive wear and heat leading to lubricant failure and component damage.

Tribology -

Lubrication ⟶ The science & art of controlling friction and wear

Sales Take Away:

- The common missing piece in reliability is the person paid well enough to focus on the science and art of lubrication within the facility day to day.

- You do not have to be the artist to sell art; but speak the language and know the value.
- We must not focus on just replacing the competitor but find the missing piece.

Tribology -

Friction = Energy Loss

- Up to 30% of industrial energy is consumed overcoming friction.
- Reducing friction means reducing energy demand, heat generation, and wear.

Lubrication is the solution

- Proper lubrication minimizes friction and wear.
- But not all lubricants are created equal — selecting the right one matters.

“Let’s explore what lubricants are, what they do, and how to choose the right one for your application.”

Sales Scenario – Why Lubrication Matters

Scenario: *A prospect says, "We buy oil from Larry's Lube down the road— what would be the difference of buying from you?'"*

Talking points:

- Lubrication is a system, not just a product. If you will allow me to gather a little more information, I can see how our product and service will best benefit you.
- A complete lubrication system reduces downtime, improves performance, and saves money.

Ask:

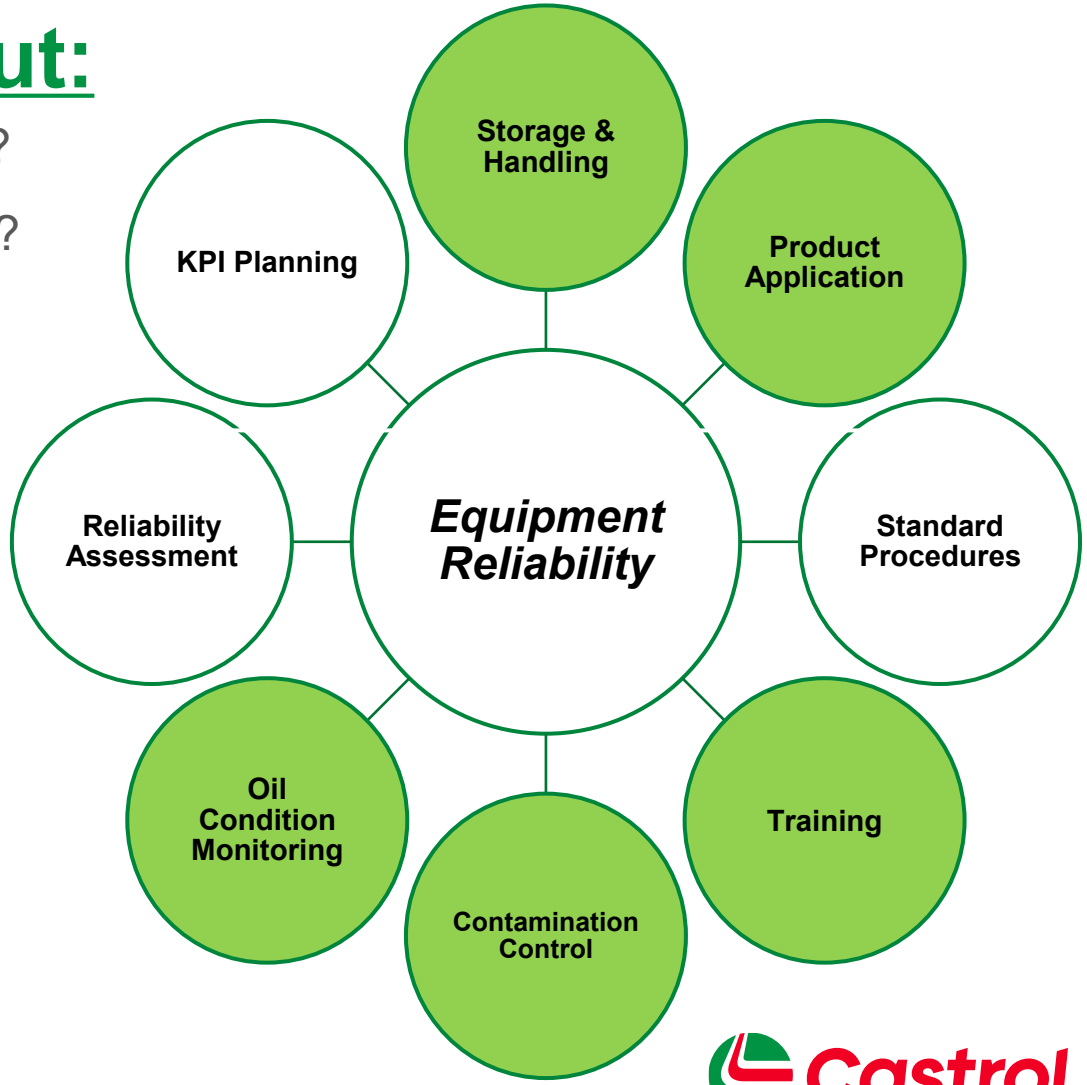
- Can you show me where you store your lubricants?
- How do you apply, and monitor your lubricants?

Lubrication Strategy for Equipment Reliability

Let's talk about:

What has been done well?

What needs improvement?



Areas of support:

- Ensure proper lubricants are used for all applications
- Consolidation of products
- Standardized product application guide
- Application training for mechanics/lubricators
- Maximize oil analysis program
- Contamination control support
- Improve lubrication storage & dispensing practices
- Correct all identified safety & environmental issues
- Critical gear inspections
- Product usage reductions

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Lubrication Strategy for Equipment Reliability

RELIABILITY PROGRAM SELF-ASSESSMENT

1- Not Doing or Considered
2- Considered but not doing
3- Discussed with team, not doing
4- Started but not well implemented
5- Going through the motions for years but needs improvement
6- New process working on improvements
7- Performing and find it useful
8- Performing and and has prevented failures
9- Performing, Documented, Trained, and Savings Attributed
10- Fully optimized, could write the book

		Rate Current Performance (1-10)	Currently Working on Improvements (Y/N)	Top 3 Areas for Supplier Support (1 ,2, 3)	Comments / Blockers
1	Overall Reliability Program Goals/Metrics				
2	Routine Lubrication Program/Goal Review (Internal/Supplier)				
3	Lubrication Consolidation				
4	Lubrication Training and Certification				
5	Used Oil Analysis Program				
6	Sampling Techniques/Locations				
7	Contamination Control				
8	Lubrication Storage and Handling Improvements				
9	Lubrication/Relubrication Practice Improvements				
10	Documented Lubrication Procedures/Routes				
11	Lubrication Safety Practices (Using lubrication equipment to reduce risk)				
12	Lubrication Continuous Improvement Meetings				
	TOTAL				

Best Practices:	100 - 120
Good Practices:	80 - 100
Fair Practices:	60 - 80
Poor Practices:	<60

What is a Lubricant?

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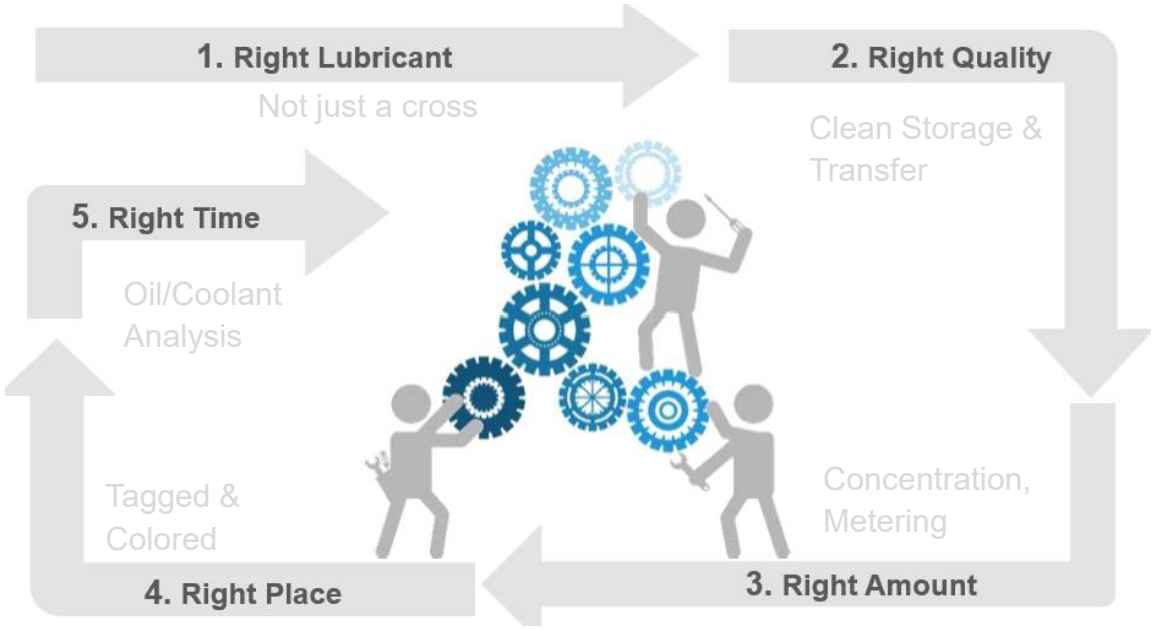
Tribology - Lubricant vs Lubrication

Refresh: ……Tribology is the study of Friction, wear, lubrication;

Lubrication → The science & art of controlling friction and wear

Lubricant → A substance that controls friction and wear



The correct lubricant is only **ONE** piece of the lubrication puzzle!

What do lubricants do? (besides the obvious)

What else do lubricants do?

Tribology - Lubricant History _ Past

17th Century BC – Egyptians used olive oil to move stones and other objects

14th Century BC – Tallow being used to lubricate wheels/chariots

Early 1900's – Mineral oil-based lubricants start being used in industry

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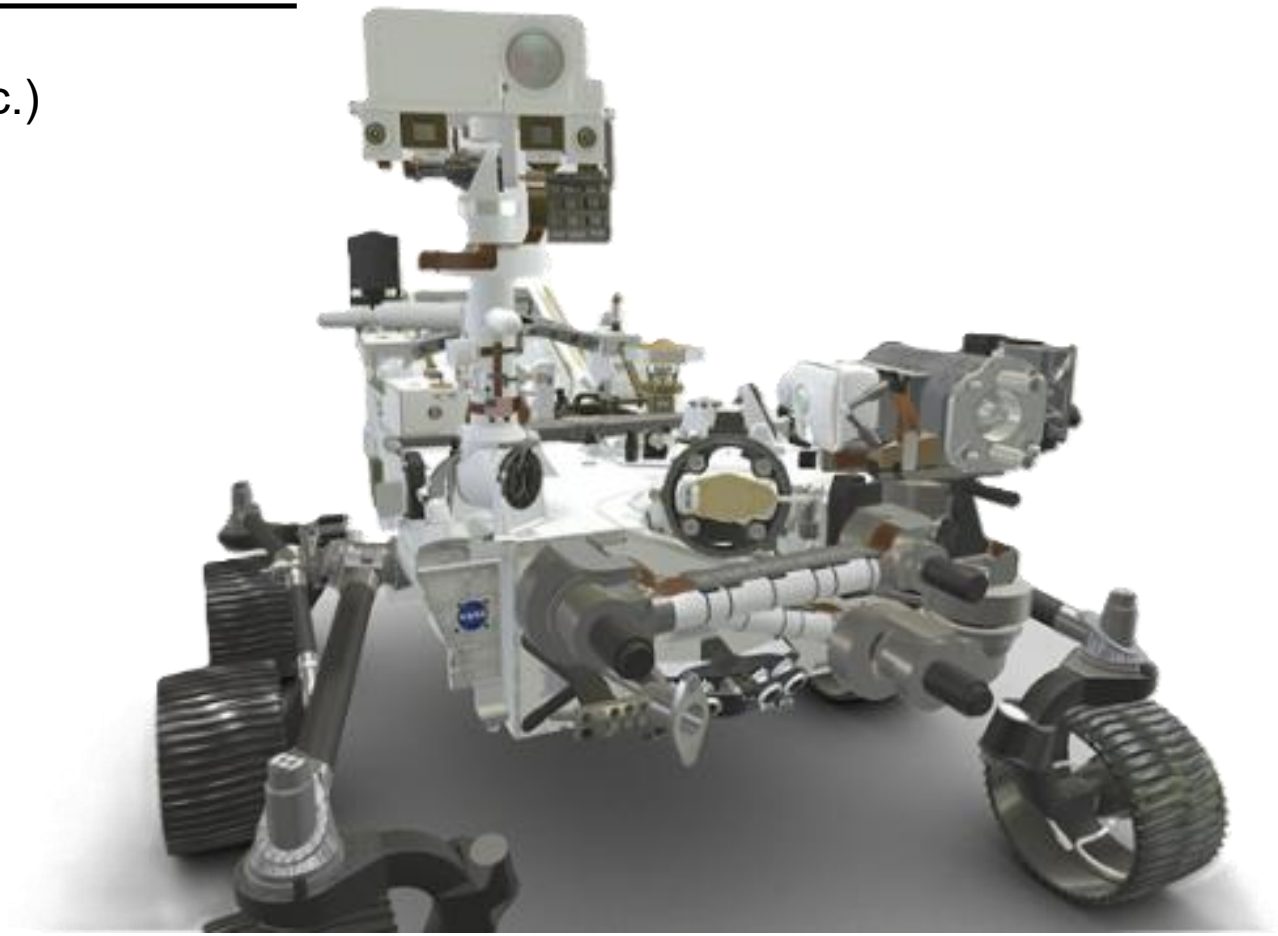
Tribology - Lubricant History _ Present

Lubricants are now used in many facets of our lives:

- Sporting equipment (skateboards, etc.)
- Bikes
- Cars
- Construction equipment
- Airplanes
- Robots
- Elevators
- SPACE



Tribology - Examples of Lubricants

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What are some unique lubricants?

Graphite to lubricate guitar nut

Air as a cushion to allow puck to move freely

Lubricant Characteristics

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Lubricant Characteristics

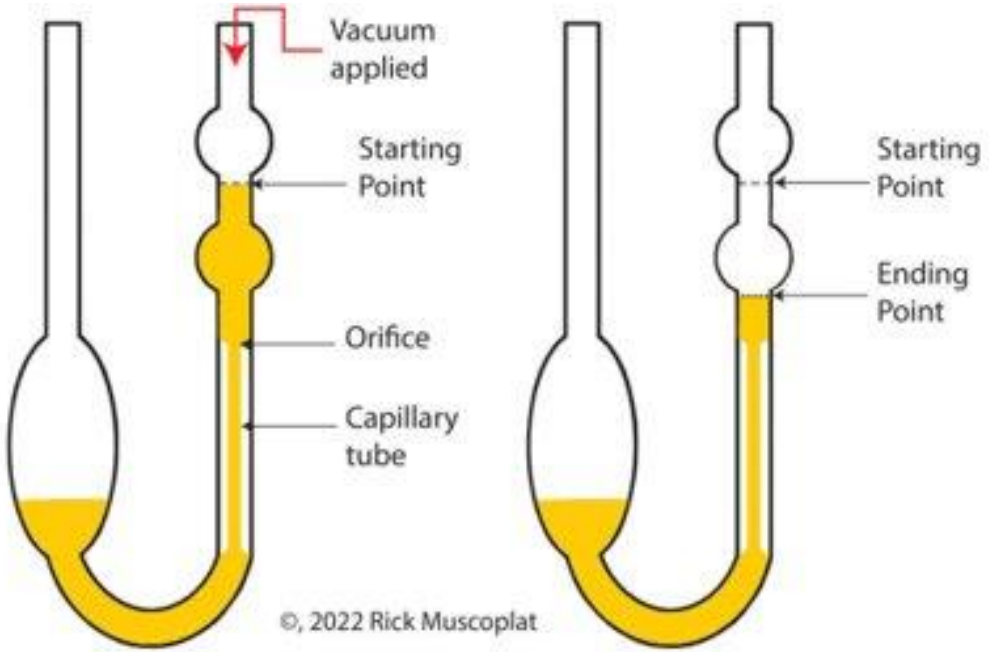
What is the most important characteristic of an oil?

Viscosity!

What is Viscosity?

VISCOSITY= Fluid's Resistance to Flow

Lubricant Characteristics- Viscosity



Capillary Tubes

Kinematic viscosity (ASTM D445, done in temp. controlled water bath)

Lubricant Characteristics- Viscosity

ISO: (International Standards Organization)

- Centistokes (cSt at 40°C)
  - ex: ISO 32 Hydraulic Oil

AGMA: (American Gear Manufacturers Association)

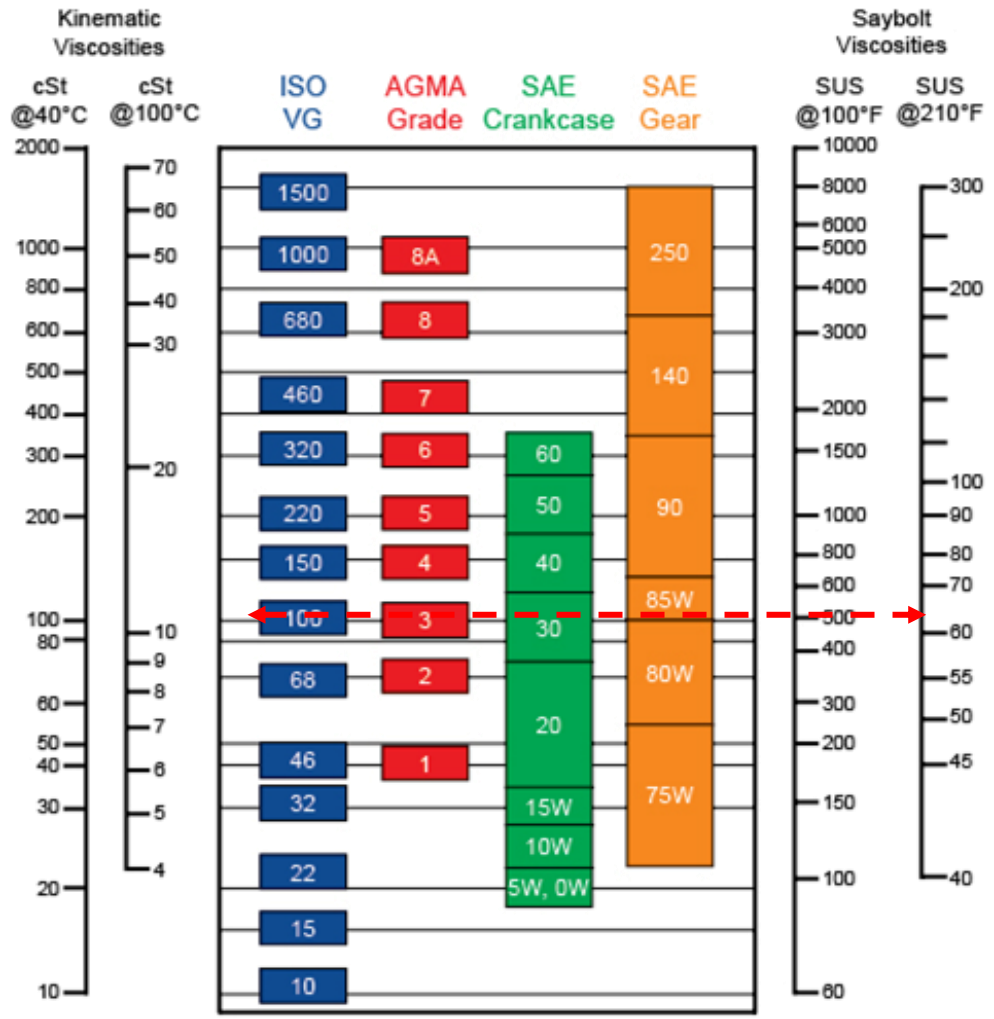
- ex: AGMA 6 Gear Oil

SAE: (Society of Automotive Engineers)

- Single grades/multi-grades
  - ex: SAE 10W-30 Motor Oil

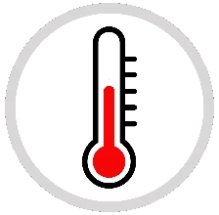
SUS or SSU: (Seybold Universal Second)

- ex: 500 SUS oil

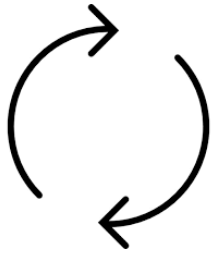


Lubricant Characteristics- Viscosity

- **Load**
  - Lighter Load = Lower Viscosity
  - High Load = Higher Viscosity



- **Temperature**
  - Lower Temperature = Lower Viscosity
  - Higher Temperature = Higher Viscosity



- **Speed**
  - Faster Speed = Lower Viscosity
  - Slower Speed = Higher Viscosity

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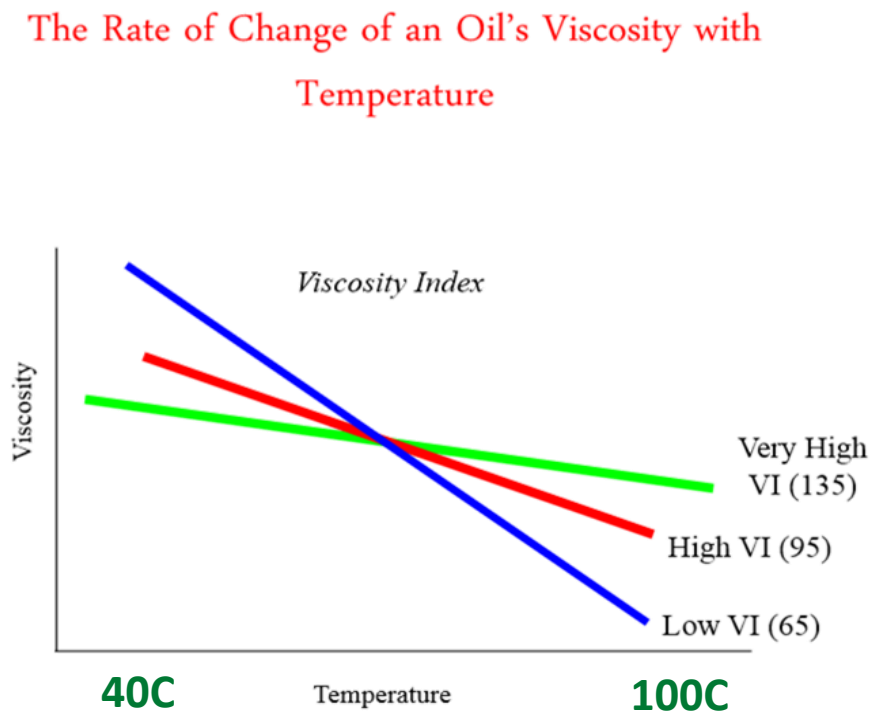
Lubricant Characteristics- VI

Viscosity Index (VI)

The relationship of a fluid lubricant's viscosity to temperature

A high Viscosity Index will allow an oil to retain it's intended viscosity in the presence of increasing temperatures!



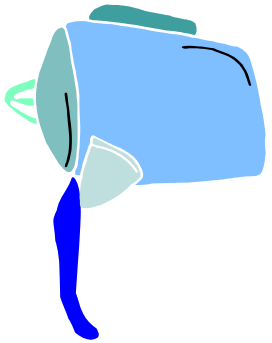
Why is this important?

It allows the oil to lubricate as intended rather than thin out and circulate out of the system.

Lubricant Characteristics- Pour Point

The depressed temperature at which a fluid no longer flows

100 F

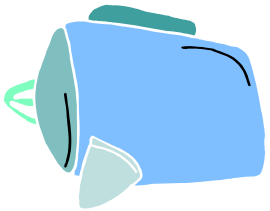


Fluid Flow

20 F

Slow Flow

-10 F



No Flow
(Pour Point)

Rule of Thumb The lowest useful temperature of a fluid lubricant is a minimum 15 F to 20 F above its pour point, at system startup.

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Lubricant Characteristics- Flash and Fire Points

Flash Point

The temperature at which a fluid lubricant will ignite but not continue to burn for more than five seconds.

Fire Point

The temperature at which a fluid lubricant ignites and continues to burn for more than five seconds.

Lubricant Characteristics- Additives

Understanding the properties that drive performance and selection.

ADDITIVES

- EP additives
- Detergents
- Dispersants
- Demulsifiers
- VI Improvers
- Anti-foam Agents
- Antioxidants
- Corrosion inhibitors
- Oiliness agents
- Anti-wear agents

Lubricant Characteristics- Compatibility

✓ = Compatible

✗ = Incompatible (detailed flush needed)

	Mineral Oil	PAO	Water Glycol	Polyol/ Diester	Phos Ester	Veg Oil	Poly Glycol
Mineral Oil	-	✓	✗	✓	✓	✓	✗
PAO	✓	-	✗	✓	✗	✓	✗
Water Glycol	✗	✗	-	✗	✗	✗	✗
Polyol & Diester	✓	✓	✗	-	✓	✓	✗
Phosphate Ester	✓	✗	✗	✓	-	✓	✗
Vegetable Oils	✓	✓	✗	✓	✓	-	✗
Polyglycol (PAG)	✗	✗	✗	✗	✗	✗	-

These are only guidelines! Lab compatibility testing is recommended!

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Lubricant Characteristics- Synthetic Base Oil

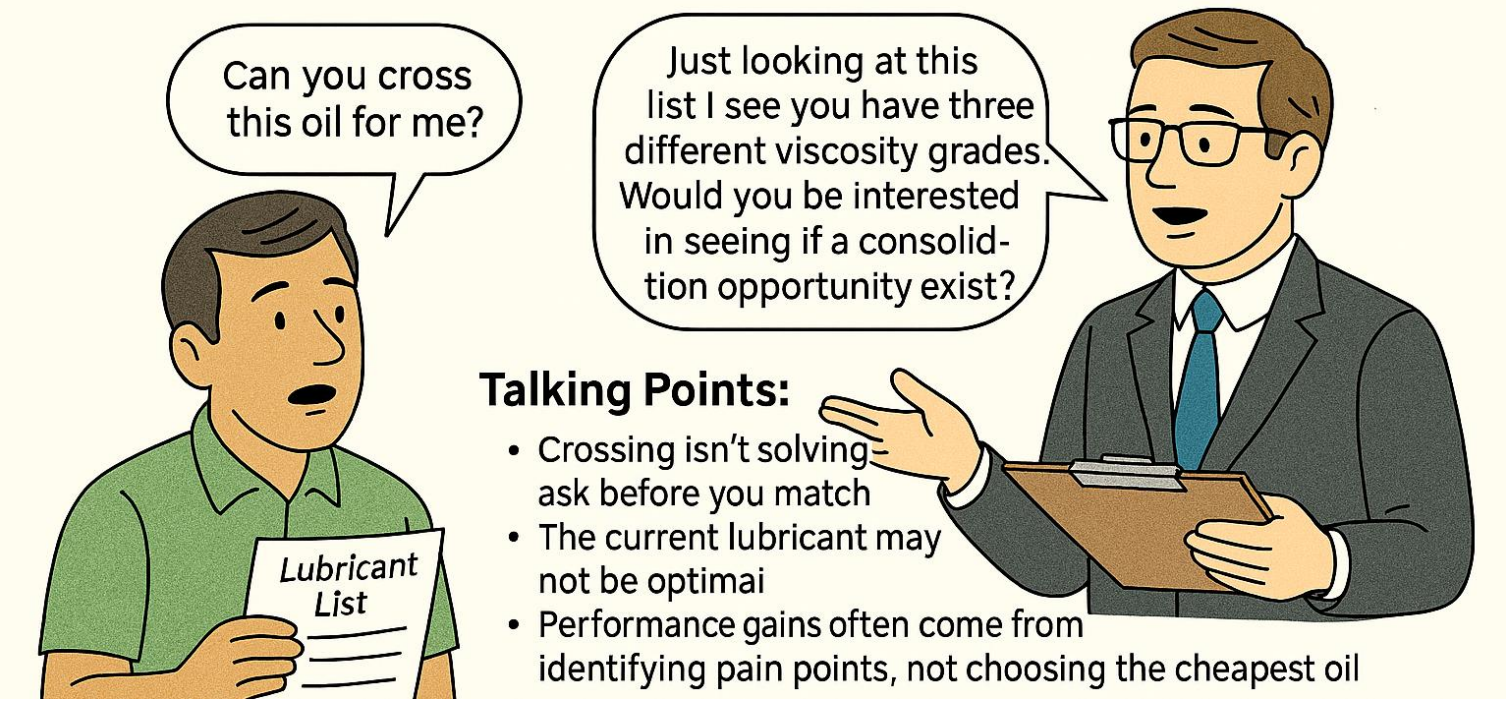
BENEFITS

- Greater oxidative stability (long life) in most cases
- Wider operating temp range
- Lower pour point
- Higher flash & fire points
- Reduced deposit formation
- Improved film strength
- Lower volatility

DRAWBACKS

- Higher purchase cost
- Potential incompatibility with seals
- Potential incompatibility with other products
- Potential misuse or product mixing
- Possible storage & handling problems
- Possible higher disposal cost of used lubricant

Sales Scenario – Oil is Oil?



Ask:

- What's the **application** (bearing, gear, hydraulic, etc.)?
- What are the **operating temperatures**?
- How often are you **changing the lubricant** and what is this based on?
- What are the **environmental conditions** (humidity, dust, washdown)?
- What issues are you currently facing— **downtime, wear, contamination, noise**?

Lubricant Categories

Common lubricant terms

Term	What Does it Mean?
Viscosity index	Fluid's ability to resist viscosity change with temperature
Total Acid Number (TAN)	Measures the acid number as precursor to oxidation
ISO cleanliness	Indicates how clean the oil is based on dirt particle size
Particle counts	The size and quantity of the dirt particles in µm (micrometer)
Carbon and varnish	Build up in the system from oil oxidation.
Group base oils	The higher the group, the more refined the oil is
Oxidation	Causes viscosity to rise, varnish, & possibly TAN increase
Dual purpose (eg Magna SW D-32 combined hydraulic/way oil fluid)	An oil that can be used in hydraulic & way oil applications

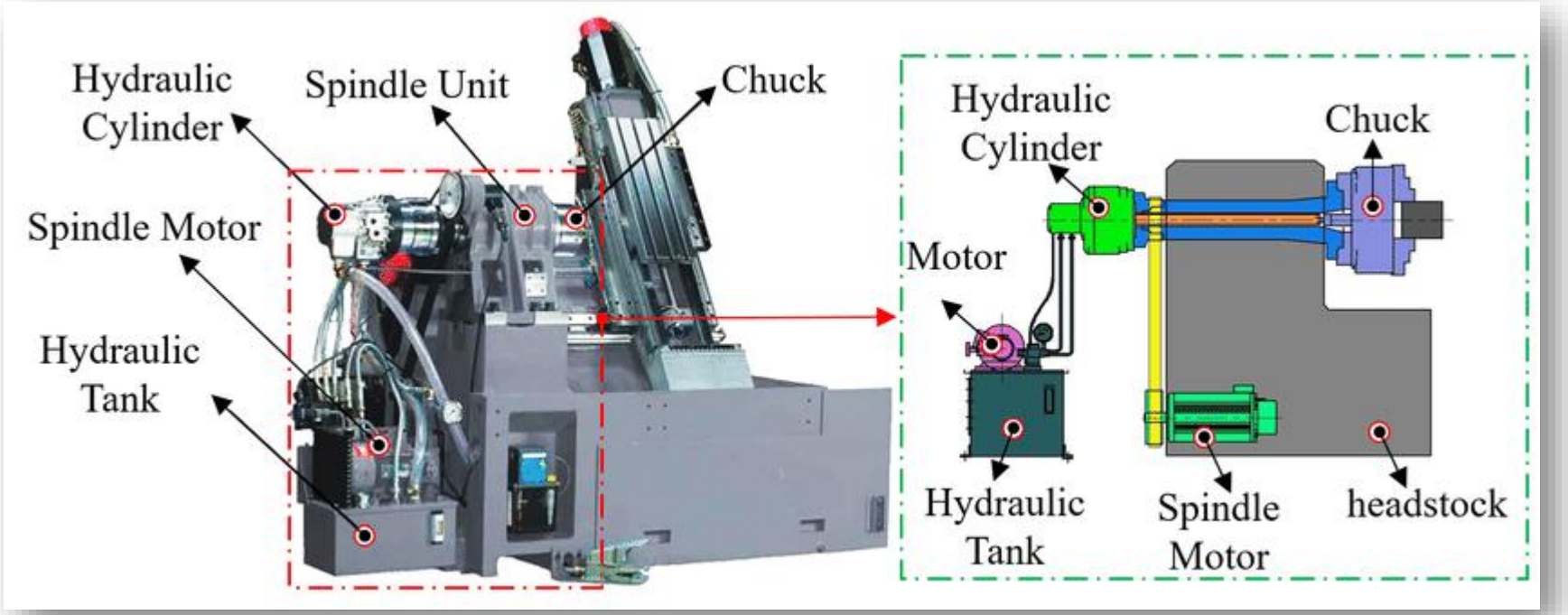
Hydraulic Oils

Base Oils:

- Mineral
- PAO
- POE
- Water Glycol

Additives:

- AW & EP
- R&O
- Anti-foam
- Demulsifier



Common Viscosity Grades: ISO 32-100

Way Oil

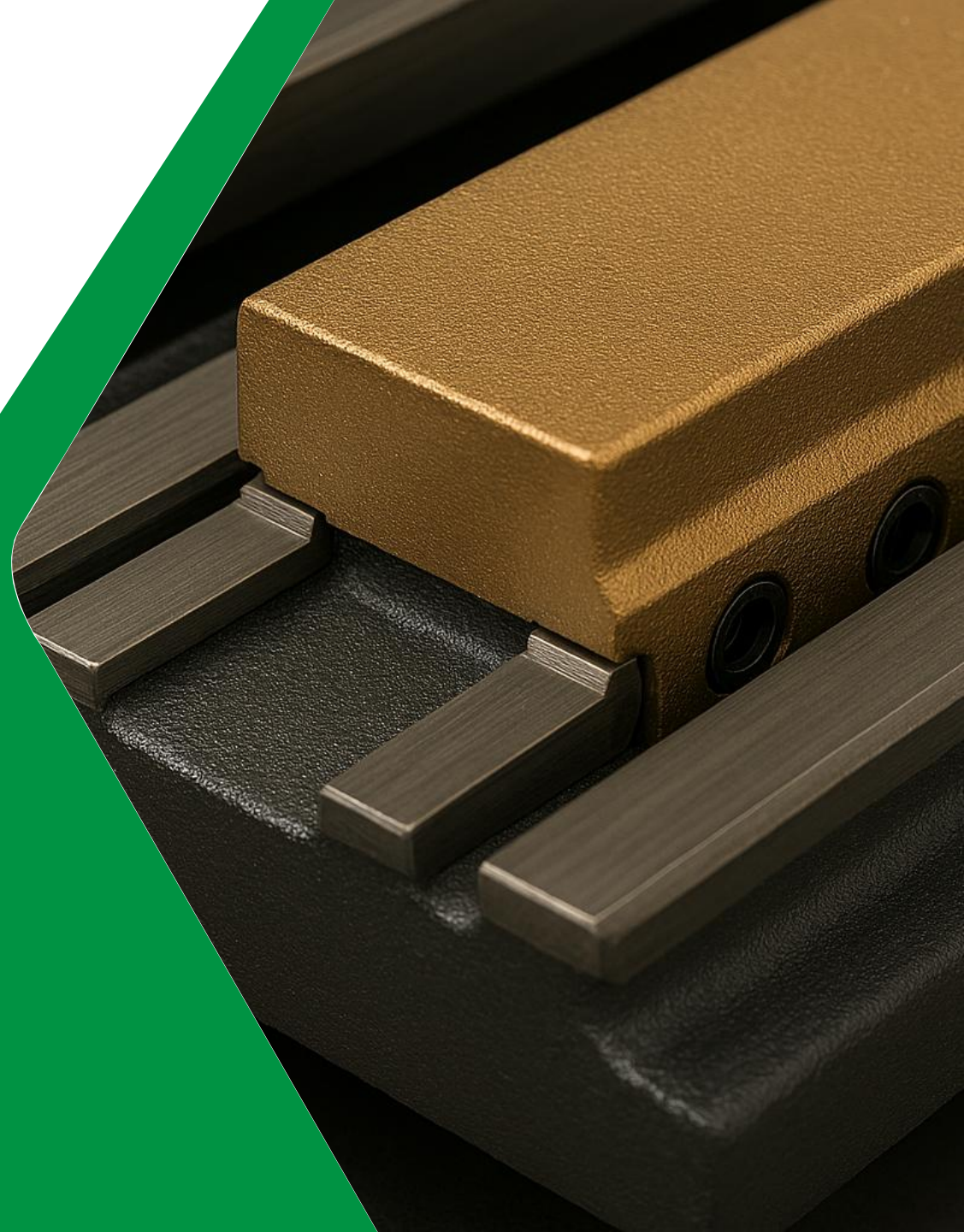
Base Oils:

- Mineral,
- PAO
- Ester

Additives:

- EP
- AW
- R&O
- Friction Modifiers
- Demulsifier
- Solids

Common Viscosity Grades: ISO 32,68,220



Spindle Oil

Base Oils:

- **Mineral**
- PAO
- Ester

Additives:

- **R&O**
- AW
- Foam Inhibitors
- Demulsifier

Viscosity Grades: ISO 2-32

Common Viscosity Grades: ISO **2,10**, 22

Gear Oil

Base Oils:

- Mineral,
- PAO
- PAG

Additives:

- EP
- AW
- R&O
- Friction Modifiers
- Demulsifier
- Solids

Common Viscosity Grades: ISO 68-680

Common Additive Types

Examples

EP = Extreme Pressure → Chlorine, Sulfur, Phosphorus

AW = Anti-wear → Zinc

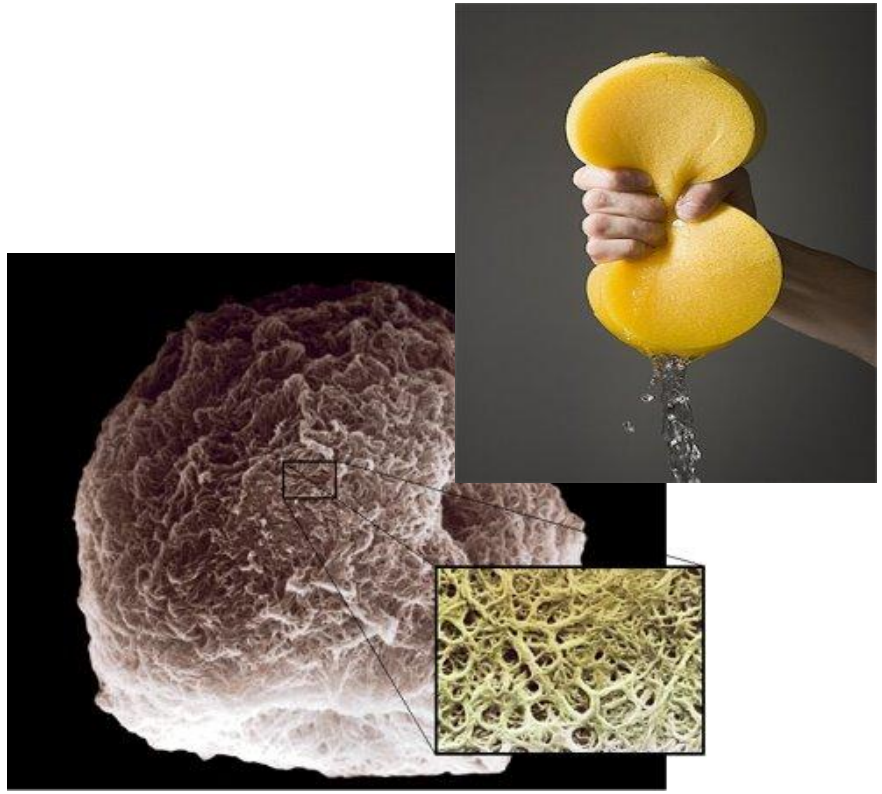
R&O = Rust & Oxidation → Various additives

Greases

Castrol

Grease - What is a grease thickener?

+



Grease - What is in a grease?

Base Oil

- Mineral
- Synthetic

Thickener

- Soap
- Non-soap

Additive

- EP
- AW
- R&O
- Solids

Grease - **Why Use Grease?**

- To Seal out Contaminants
- To Reduce Lubricant Consumption & Waste
- An Oil will not work Effectively
- Simplifies Bearing Housing Design

Grease - **Where?**

- Where Oils Drip or Run Out
- High Loads Squeeze Oil Out
- Centrifugal Force Throws Oil Out
- Water Washes Oil Out
- In Hard to Reach Areas

Grease

Characteristics Unique to Greases:

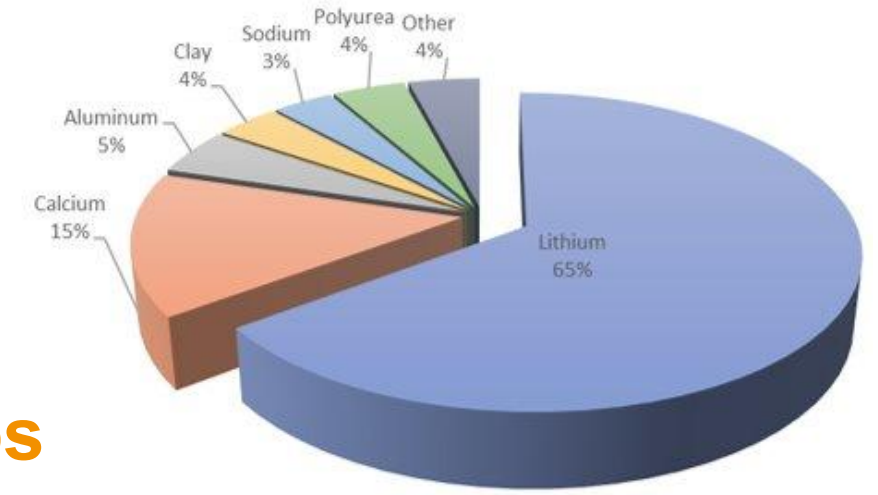
- Thickener type
- Consistency - NLGI no.
- Dropping Point
- Water wash out
- “Worked” / Shear stability

Typical Characteristics

Name	Method	Units	100-00 PD	100-0 PD	100-1 PD	100-2 PD
Appearance	Visual	-	Brown			
Thickener type	-	-	Lithium			
Base oil	-	-	Mineral oil			
Consistency	ISO 2137/ ASTM D217	NLGI Grade	00	0	1	2
Density @ 20 °C/68 °F	inhouse method	kg/m³	910	890	890	890
Worked Penetration (60 strokes @ 25 °C/77 °F)	ISO 2137/ ASTM D217	0.1 mm	400 - 430	355 - 385	310 - 340	265 - 295
Worked Penetration (100,000 strokes @ 25 °C/77 °F) - change from 60 strokes	ISO 2137/ ASTM D217	0.1 mm	-	-	<20	<20
Dropping point	ISO 2176/ ASTM D566	°C/°F	-	-	190/374	200/392
Base Oil Viscosity @ 40 °C/104 °F	ISO 3104/ ASTM D445	mm²/s	130	130	95	95
Copper Corrosion (24 hrs,100 °C/ 212 °F)	ASTM D4048	Rating	1b			
SRV Friction and Wear test (400N/ 2h/50 °C)	ASTM D5707	coeff. of friction/ wear scar diam (mm)	0.08/0.65	0.07/0.65	0.07/0.65	0.07/0.65
Flow pressure @ -35 °C/-31 °F	DIN 51805	hPa	500	1000	1100	1200
Water Resistance	DIN 51807-1	Rating	-		1 - 90	
DIN Classification	DIN 51502	-	KP 00 N-40	KP 0 N-40	KP 1 N-30	KP 2 N-30
ISO Classification	ISO 6743/9	-	L-XDDHB-00	LXDDHB-0	LXCDHB-1	LXCDHB-2

Subject to usual manufacturing tolerances.

Grease Thickeners



Metallic Soaps

(90% of all greases)

- ✓ Lithium 12 / Lithium Complex
- ✓ Calcium / Ca Complex (Sulfonate)
- ✓ Sodium
- ✓ Aluminum / Al Complex

Economical - Good Lubricity

Non-Soaps

(10%)

- ✓ Polyurea - Long lasting
- ✓ Bentone (clay) (Microgel) - Do not melt
- ✓ Fumed Silica - Used in gear compounds
- ✓ Carbon Black - 400-1000F temp range

Generally, more costly than soaps but they have certain characteristics that make them beneficial

Note: Complex version of a soap has 100-150 F higher useful temperature range.

Grease Compatibility

Important Rules to Follow:

1: Don’t mix incompatible lubricants.

2: When in doubt, assume that two lubricants, when mixed, will be incompatible and will exhibit adverse side effects.

Grease Compatibility

B/L=Borderline (Sample) C=Compatible I=Incompatible	Aluminum Complex	Barium	Calcium	Calcium 12 Hydroxy	Calcium Complex	Clay	Lithium	Lithium 12 Hydroxy	Lithium Complex	Polyurea
Aluminum Complex	X	I	I	C	I	I	I	I	C	I
Barium	I	X	I	C	I	I	I	I	I	I
Calcium	I	I	X	C	I	C	C	B/L	C	I
Calcium 12 Hydroxy	C	C	C	X	B/L	C	C	C	C	I
Calcium Complex	I	I	I	B/L	X	I	I	I	C	C
Clay	I	I	C	C	I	X	I	I	I	I
Lithium	I	I	C	C	I	I	X	C	C	I
Lithium 12 Hydroxy	I	I	B/L	C	I	I	C	X	C	I
Lithium Complex	C	I	I	C	C	I	C	C	X	I
Polyurea	I	I	I	I	C	I	I	I	I	X

Grease Consistency

NLGI – National Lubricating Grease Institute

Serves all key stakeholders in the grease industry

Image courtesy of JAX Inc

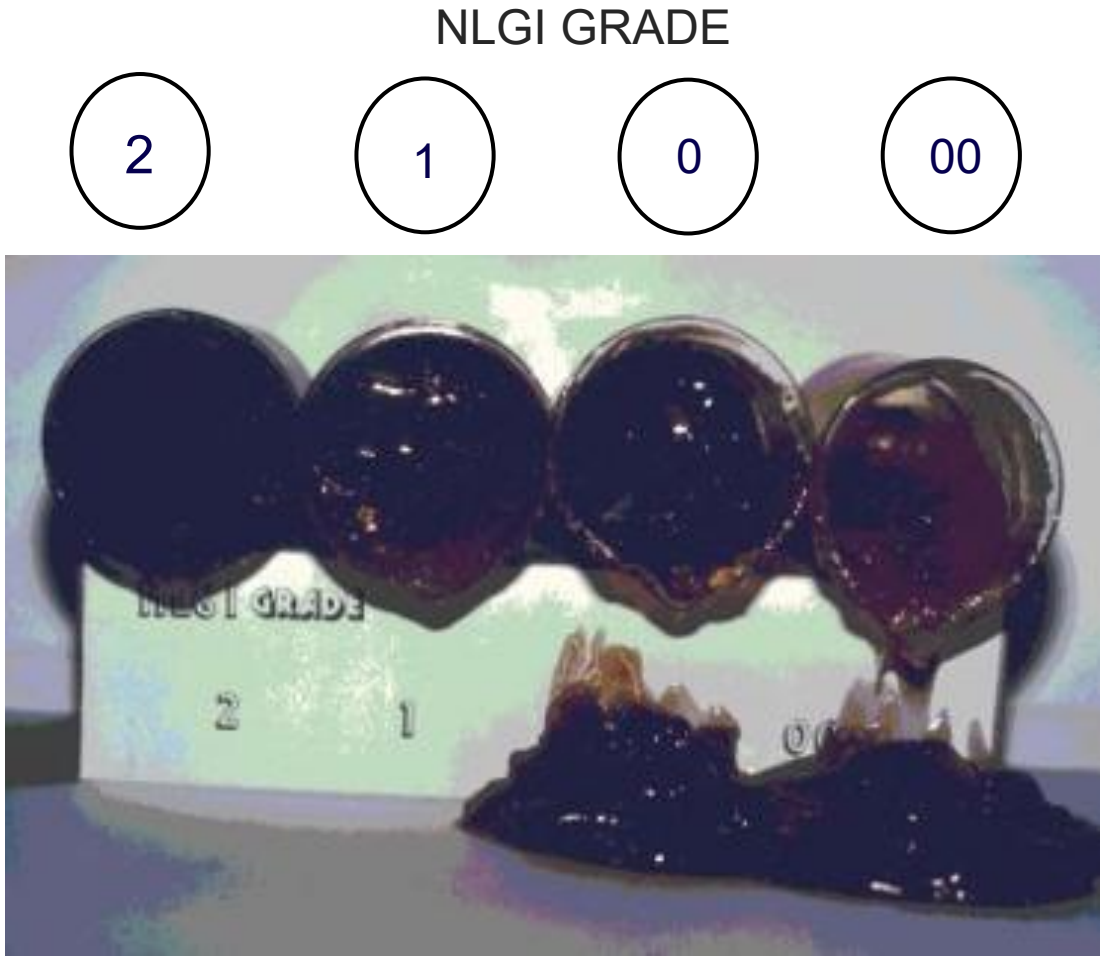
Grease Consistency

Q: Which grease is softer?

A: The one on the far right – Grade 00

Q: Which grease has higher penetration?

A: The one on the far right – Grade 00



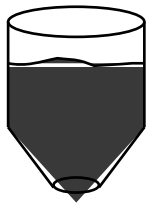
Penetration: Is the consistency or hardness of a grease.

Penetration is to a grease what viscosity is to an oil.

Grease Characteristics - Dropping Point

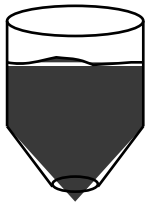
Dropping point is the temperature at which grease passes from semi-solid to a fluid state.

300 F



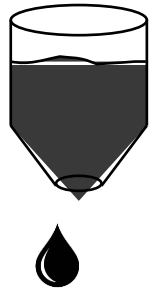
No Drip

400 F



No Drip

500 F



First Drop
(Dropping Pt)

Rule of Thumb: The highest useful temperature of a grease is **100 F to 125 F below** its dropping point

Grease - Shear Stability

Is the measure of a grease's ability to withstand repeated working (shearing) with minimum change in its structure and consistency.

Determined by working the grease repeatedly and checking its consistency.

Grease - Water Washout and Pumpability

Water Washout

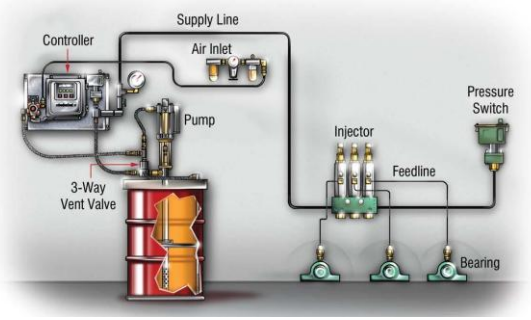
Determines how well a grease will stay in place in a wet environment

Determined as a percentage of grease washed off

Includes 2 tests:
Water Wash -- Flow of water over surface
Water Spray-Off -- Direct spray onto surface

Grease Pumpability

Is the ability of a grease to be pumped through lubricating system especially centralized automatic system.

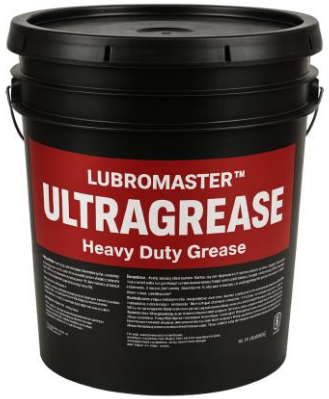


Grease – Sales Scenario

You will be playing the role Application Engineer Arnold

From: Enduser, Earl <enduserearl@makinstuff.com>
To: Distributor, Dan <distributor.dan@greatoil.com>
Subject: Grease Cross?

Hi Dan, do you have a grease to replace this?

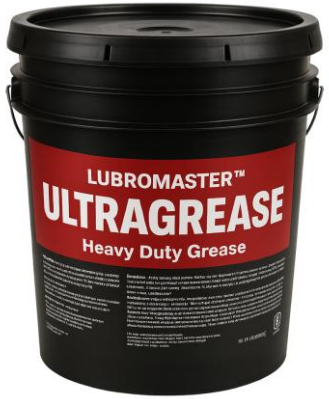


Thanks, Earl

→

From: Distributor, Dan <distributor.dan@greatoil.com>
To: Appeng, Arnold < appeng.arnold@greatoil.com>
Subject: Grease Cross?

Hi **Arnold**, can you cross this please?



Thank you, Dan

→ ?

Grease – Sales Scenario

Technical Data – Using Product Guide find the best alternative?

Product Name	Thickener	Base Oil Type	Base Oil Viscosity	Additives (EP, Moly)	NLGI Grade
Ultragrease Heavy Duty	Aluminum Complex	Mineral	~130 cSt @ 40°C	EP, Molybdenum Disulfide , Graphite	0

Questions:

- What is the application and equipment?
- What are the operating temperatures, loads, and speeds?
- Is the environment wet, dusty, or exposed to chemicals?
- Are solid additives (moly, graphite) required?
- Why is NLGI 0 specified?
- How is the grease applied and how often?
- Why is the customer seeking an alternative?
- Have other greases been tried and failed?
- What package sizes are needed?
- Will the new grease be mixed with the old? Any compatibility concerns?

Grease – Sales Scenario

Product Name	Thickener	Base Oil Type	Base Oil Viscosity	Additives (EP, Moly)	NLGI Grade
Ultragrease Heavy Duty	Aluminum Complex	Mineral	~130 cSt @ 40°C	EP, Molybdenum Disulfide , Graphite	0
Castrol Pyroplex Gold	Aluminum Complex	Mineral	~134 cSt @ 40°C	EP, Molybdenum Disulfide	1
Molub-Alloy 860/220-0 ES	Lithium Complex	Mineral	~220 cSt @ 40°C	EP, Molub-Alloy solids	0
Contractor Special	Lithium Complex	Mineral	~150 cSt @ 40°C	EP, 3% Molybdenum Disulfide	1
Tribol GR CLS 000	Lithium-Calcium	Mineral	~100 cSt @ 40°C	Water-resistant, corrosion inhibitors	000
Optileb GR 823	Aluminum Complex	Food-grade mineral	~192 cSt @ 40°C	Food-grade, EP, anti-wear,	0

Storage, Handling,& Contamination Control

Castrol

Q: Why is storage and handling of lubricants important?

A: Contamination Control

~30-40% of Gear & Bearing Failures are Due to Contamination

~70-80% of Hydraulic Failures are Due to Contamination

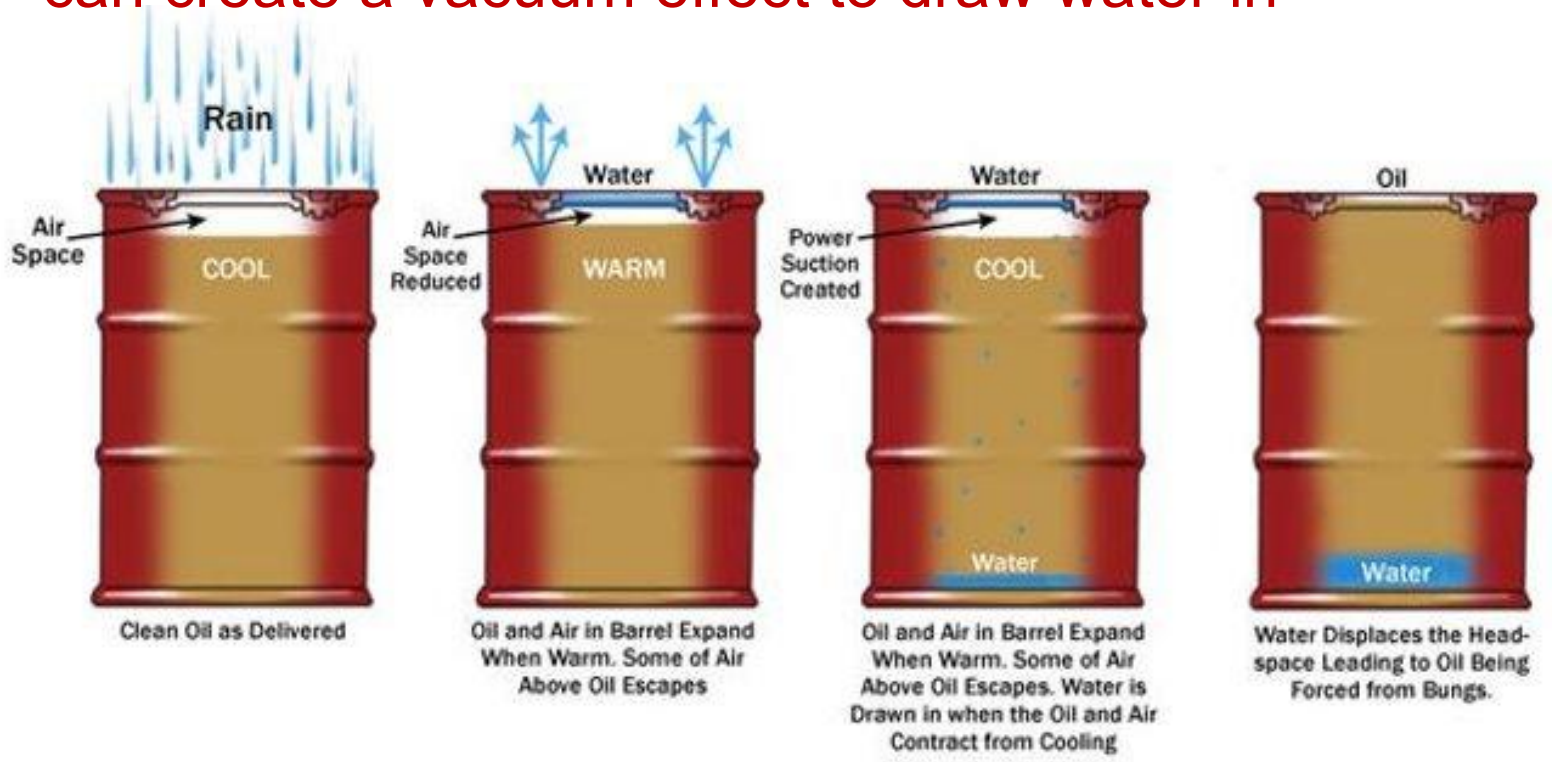
These are your clues to opportunity!

- **Lubricant is the Life Blood of the Equipment!**

- **Storage and Handling**
- Clear Debris
- Monitor Temperatures
- Check Breathers
- Broken and Dirty Grease Zerks
- Water Wash Down

Q: How would water get into a sealed or unopened drum?

A: Changes in temperature and exposure to moisture can create a vacuum effect to draw water in



Q: What is Wrong Here?

A:

1. Breather is spent & needs to be changed to optimize its purpose

2. Tank is open to water ingress and contamination

3. Contaminants can easily enter the drum

1

2

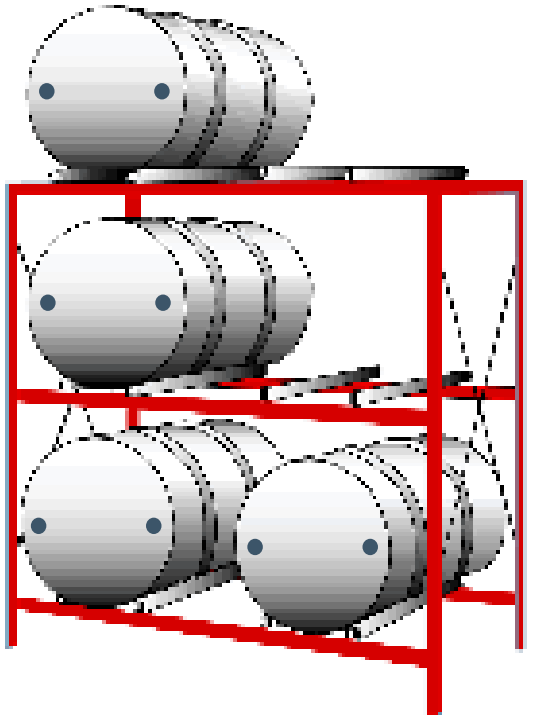
3

Poor Example of Storage

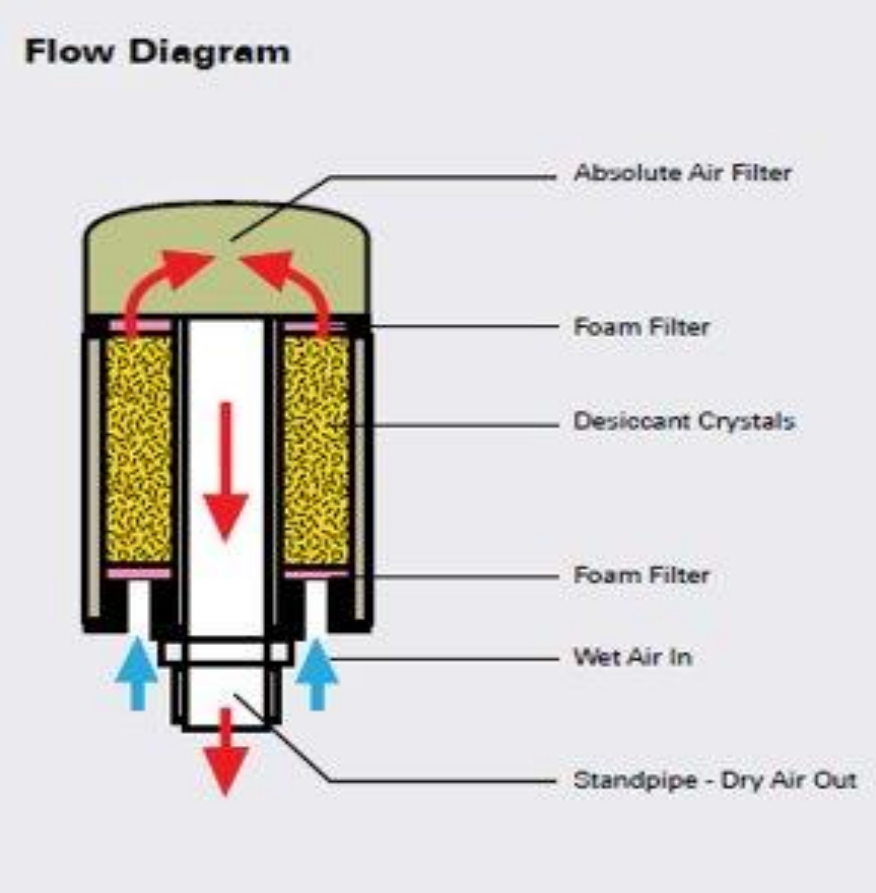
Proper Way to Store Drums

Before you expect your lubricant to perform at it's best……

you must store and handle it APPROPRIATELY!!



Proper Bulk Tank Maintenance



Storage & Handling- Dedicated Storage

Storage & Handling- Transferring Lubricants

Funnels should NEVER BE USED for new lubricants

- If you currently must use a funnel, you don't have the right tools.
- Funnels can be a leading cause of contamination. When not being used they attract dirt and debris.

Storage & Handling- Transferring Lubricants

Transfer Containers

Q: What problem could be an outcome of using the containers shown to the right?

A: **8%** of the population are colorblind. If a person falls into this population, they may not see the difference between the bottle colors - thus the importance of labelling and using shapes.

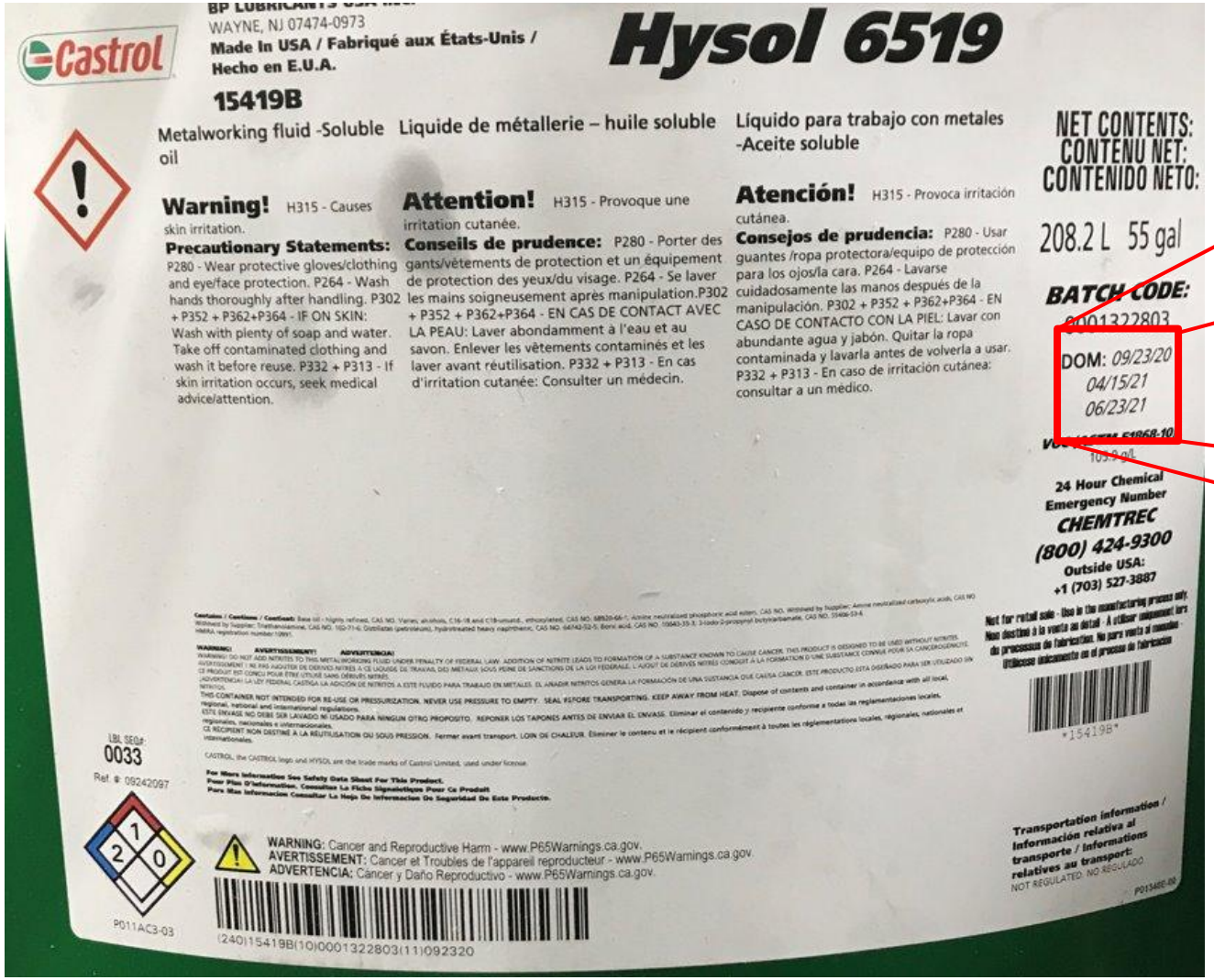
Transfer Containers

Lube & Grease Storage Cabinet

- Dedicated location for grease guns to be returned after each shift
- Colored & labeled OilSafe containers will keep clean oil ready for use.

Colored zerk caps match grease gun color

Storage and Handling- Best-By Date



Forms of Contamination

Solids

- Metal chips, sand, dirt
- Weld splatter, slag
- Gasket Sealing material

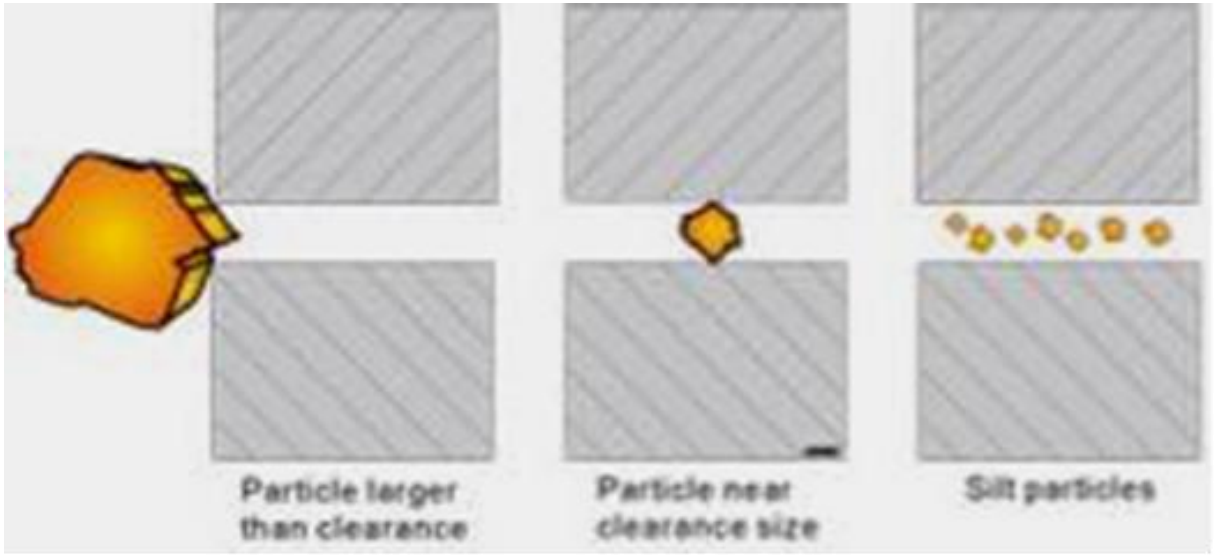
Liquid

- Water (free, dispersed, & dissolved)
- Chemicals

Gas

- Air (free & entrained)

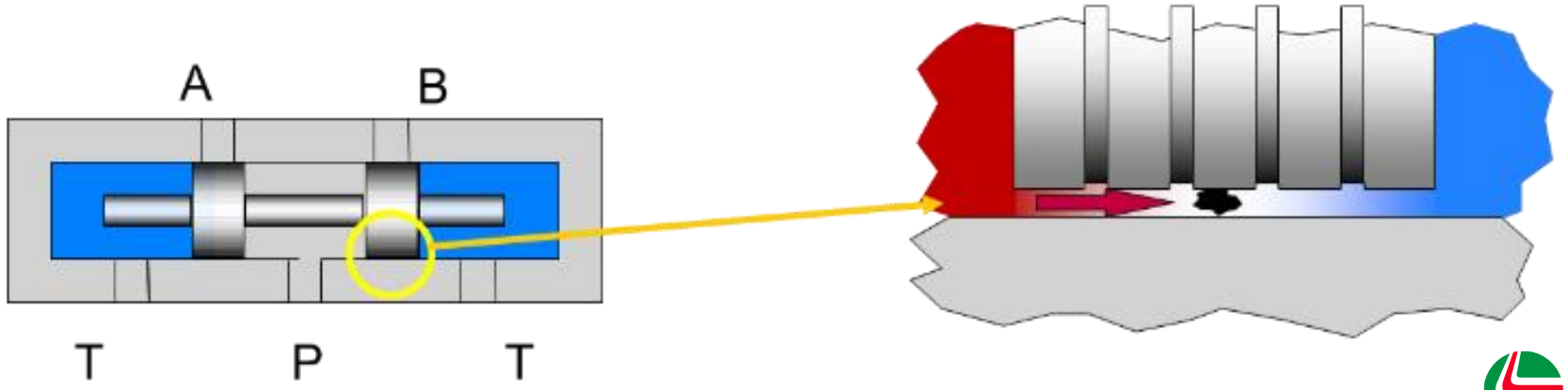
Particle Size Matters



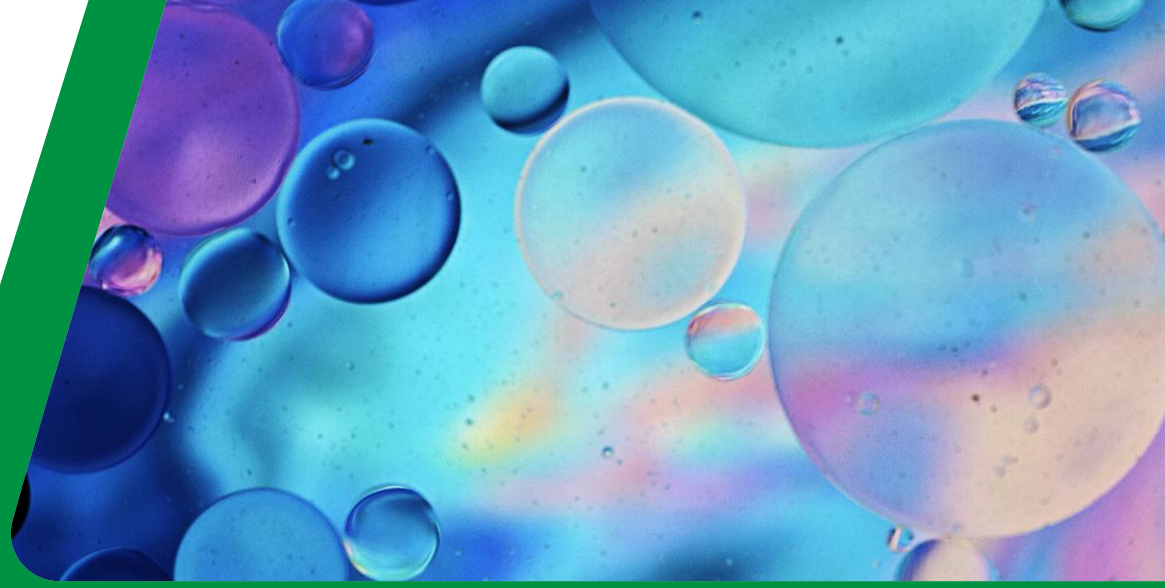
Typical valve dynamic clearances

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

Reference: ASME Wear Handbook

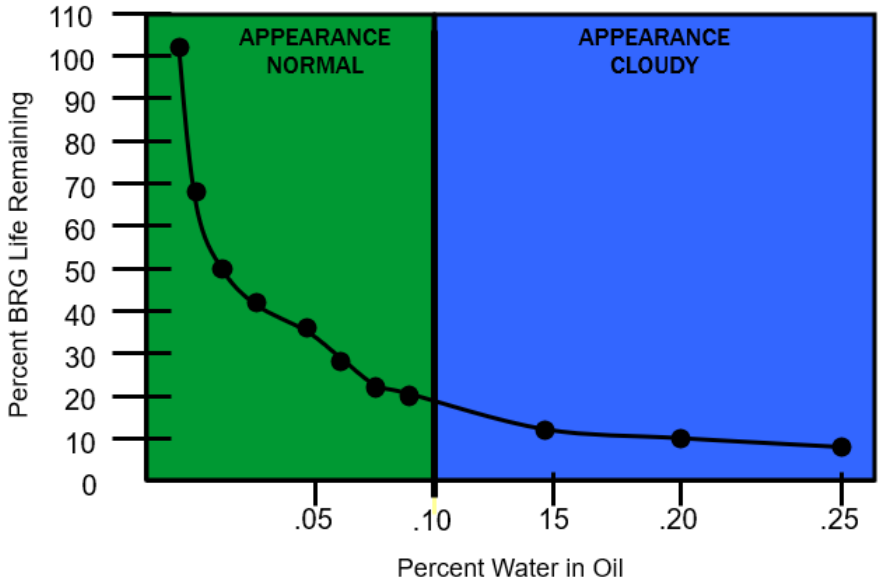


Water Ingress



Sources of water contamination:

- ✓ Heat exchanger leaks
- ✓ Seal leaks
- ✓ Condensation of humid air
- ✓ Inadequate reservoir covers
- ✓ Temperature drops: dissolved water to free water



Used Oil Analysis

Castrol

Sales Scenario:

Sales scenario – Acme Manufacturing uses a low-cost hydraulic oil and changes it every 6 months, as recommended by their previous supplier. The maintenance manager believes this is “good enough” and is reluctant to pay more for premium oil.

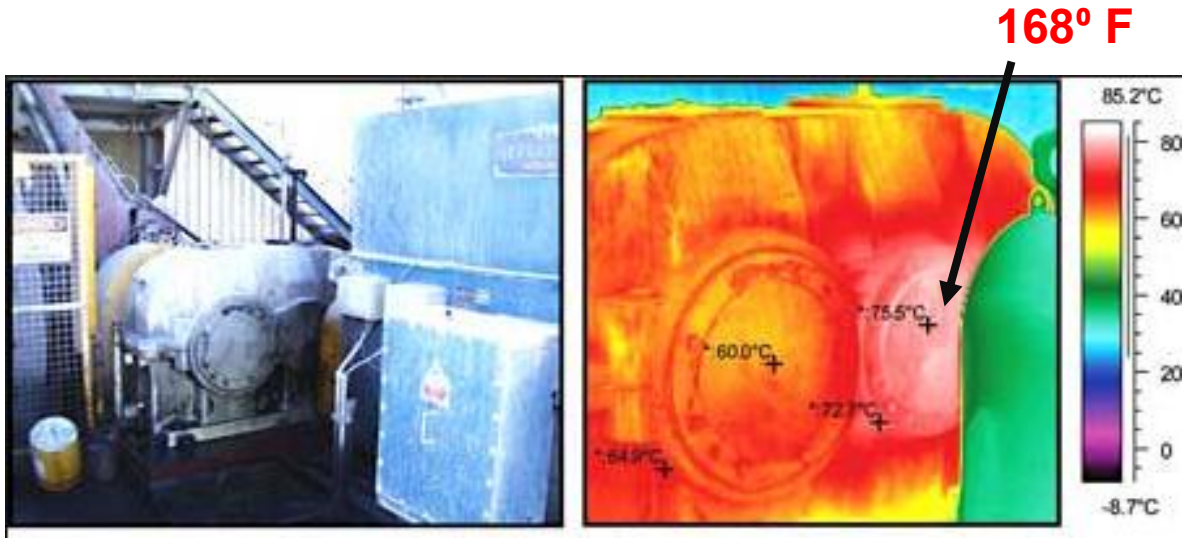
- **Ask:**
  - “How do you determine when it’s time to change your oil?”
  - “Have you ever had a failure or downtime between scheduled changes?”
  - “Do you monitor oil cleanliness or condition, or just change it by the calendar?”
  - “Would you be interested in a program that could reduce oil changes, lower downtime, and save money—even if the oil itself costs a bit more?”

- **Value Proposition:**
  - “By switching to a higher-quality oil and implementing oil analysis, you could safely extend drain intervals, reduce maintenance costs, and improve equipment reliability.”
  - “Let’s review your current oil analysis reports (if any), or I can help you set up a baseline test to show the difference.”

Lubricant Degradation

- **Contamination**
  - Particulates (Dirt, Wood, Metal, etc.)
  - Water
- **Oxidation / Thermal Breakdown**
  - Over Extended Change Interval
  - Heat
    - Over/Under Lubrication
    - Debris
    - Incorrect Lubricant
    - Mechanical
  - Increases acidity and viscosity
    - Sludge and Varnish
- **Additive Depletion**

- **For every 18° over ~140°F-160°F, oxidation rate doubles**
  - **Localized heat sources can be overlooked**
  - **Point of contact temperature can be ~10° - 20° higher than sump temperature.**



Machinery Lubrication (3/2004)

Oil Sampling and Analysis

Why Oil Analysis

- To Monitor changes in lubricant properties
- To identify contamination and its effect on lubricant properties
- To determine type and severity of wear occurring

Oil Sampling and Analysis

Systems should be prioritized by:

- Criticality (A, B & C)
- Size
- Degree of contamination/known problems

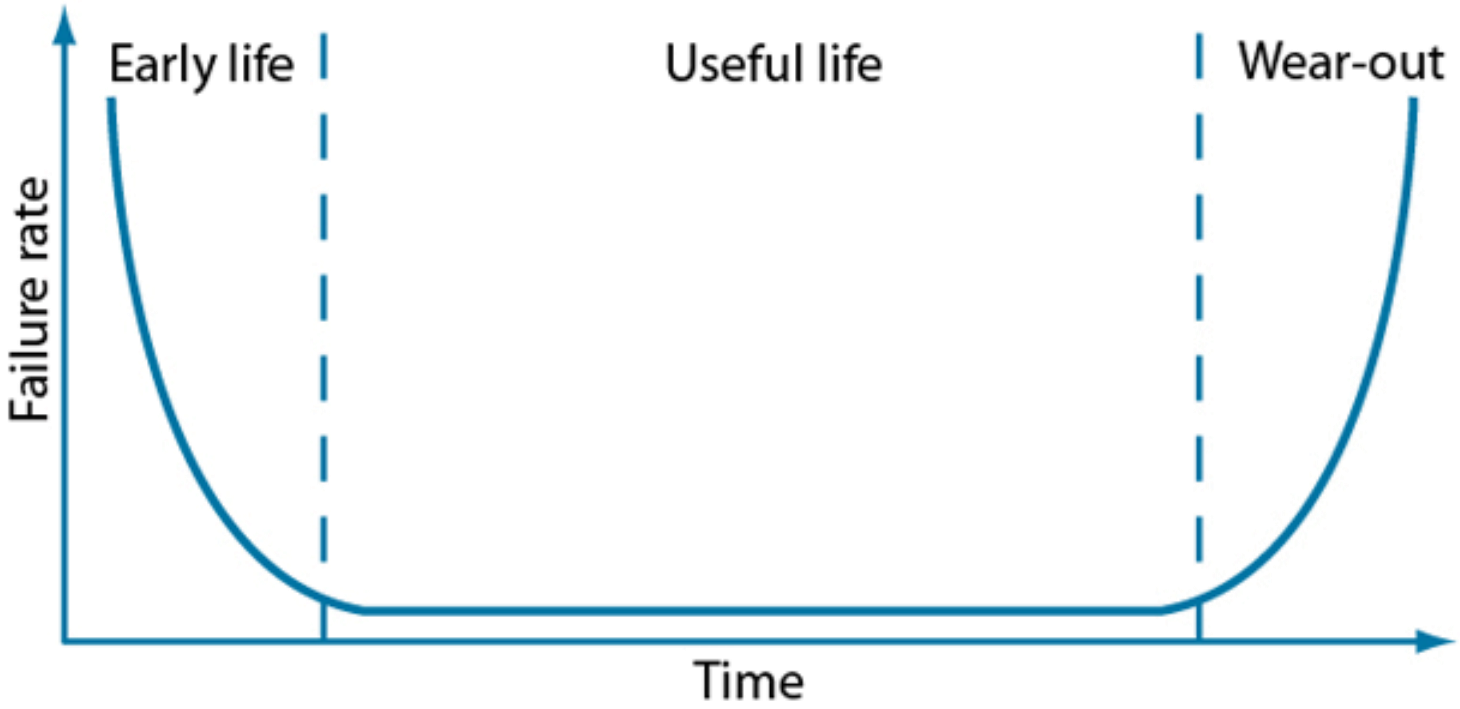
How Often?	
Critical Equip, Trouble Equip, Large Reservoirs	More Often
	
Non-critical Equip, Trouble-free Equip, Small reservoirs	Less Often or Change

Small, non-critical systems:

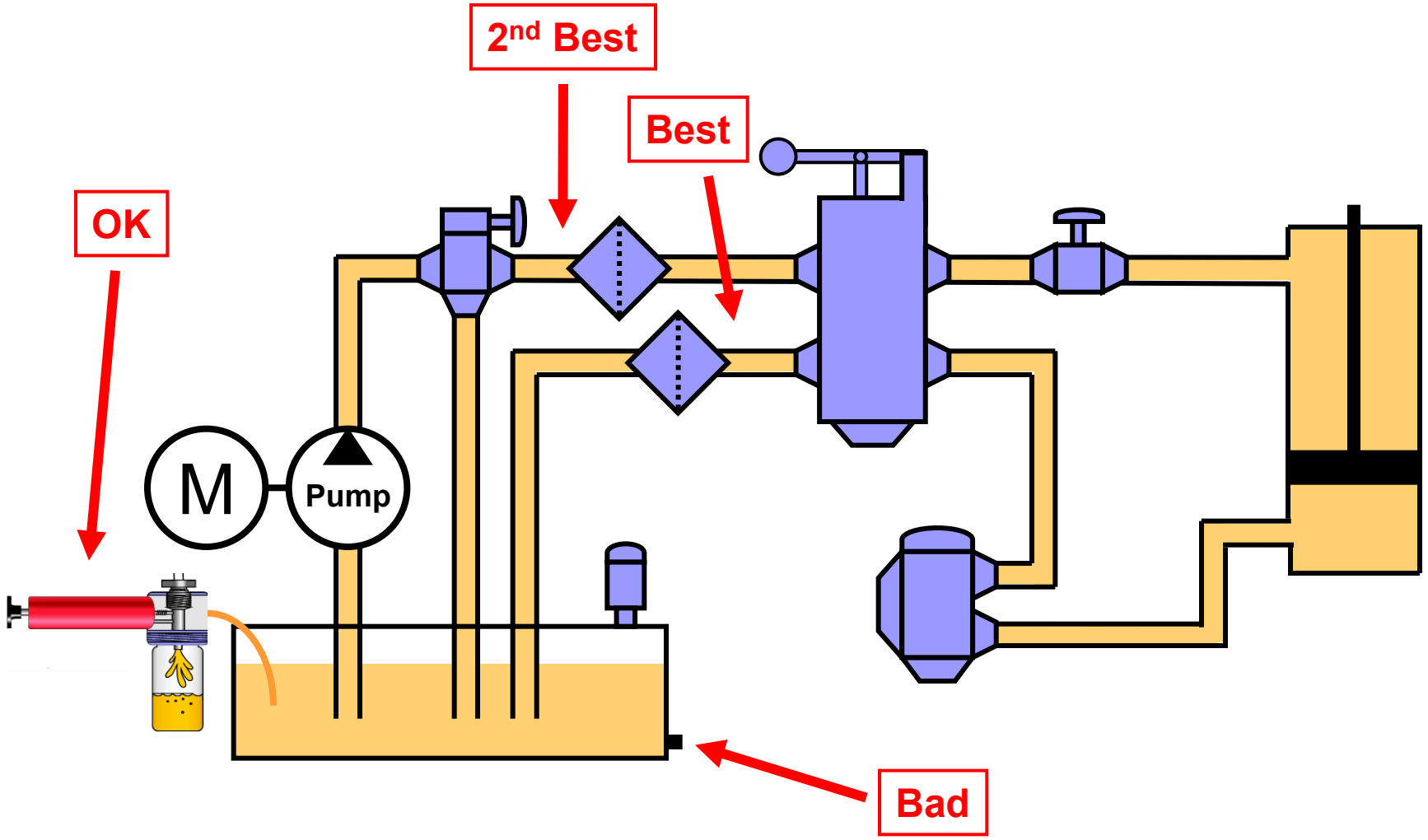
- should not be sampled
- should be scheduled for changeout on a time basis

Oil Sampling and Analysis

- Infant mortality
- Contamination
- Incorrect Lubricant
- Insufficient Lubricant



Sampling Points and Methods



Sampling Points and Methods

ESTABLISH SAMPLING POINT:

- Circulated with Unrestricted Flow
- Sampling valve or petcock
- Vacuum Pump with Drop-tube
- Drain Port

REPRESENTATIVE SAMPLE:

- While Operating or within 30 Minutes

CONSISTENT SAMPLING :

- Same Method Each Sample

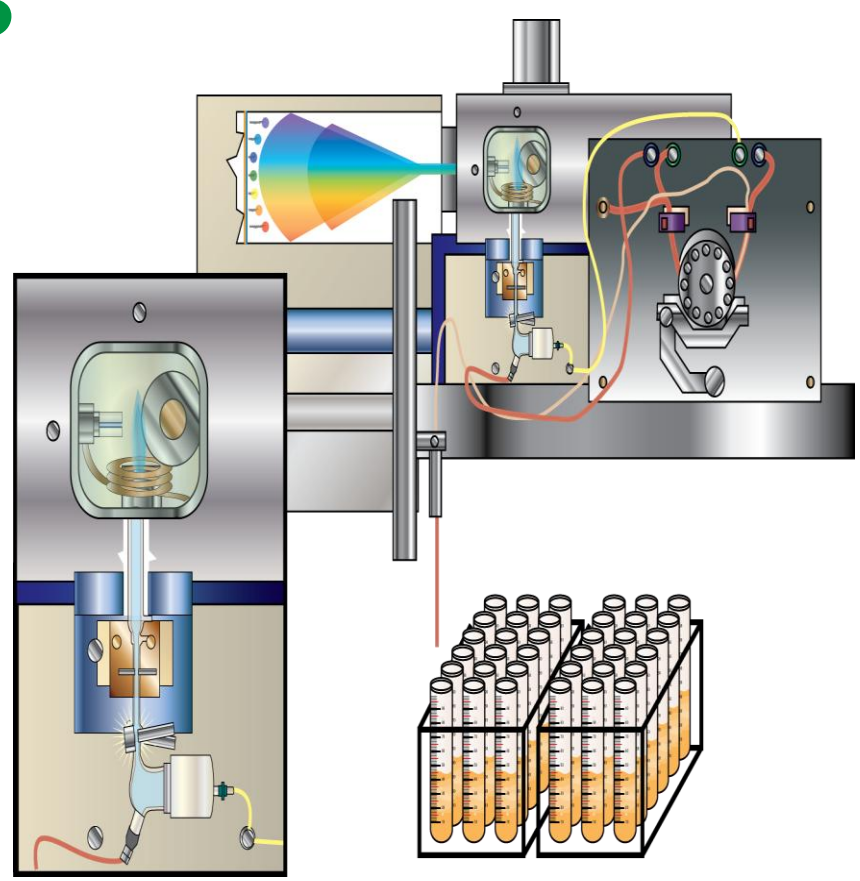
Used Oil Analysis Testing

ICP and Particle Count

Castrol

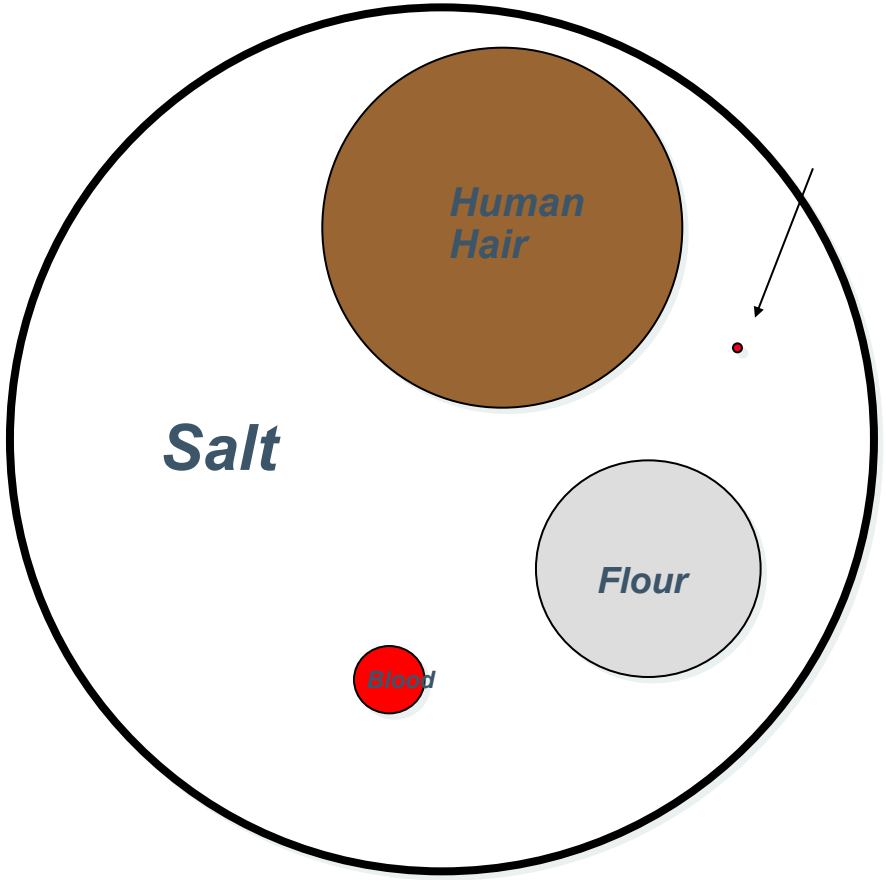
Oil Sampling and Analysis

- **Inductively Coupled Plasma (ICP)**
  - A diluted oil sample is pulverized by inert gas (argon) to form a mist, then introduced to a flame (plasma @ 9000°C/12000°F) and vaporized
  - Light emitted by vaporized sample is separated into frequencies (color)
  - Each color represents an element (i.e. iron, nickel, copper, etc.)
  - Light concentrations are then converted to parts per million (ppm) of 24 elements present in the sample
  - LIMIT 8-10 Microns



Particle Size Matters

- **Grain of table salt**
  - 100 microns
- **Human hair** (Limit of Sight)
  - 40 microns
- **Milled flour**
  - 25 microns
- **Red blood cells**
  - 8 microns



Particle Size Matters

Q: What does this symbol mean - µ

A: µ = Micron or mircometer or 1/1000th of a millimeter

- Expressed as: x/x/x
- Example: 16/14/11
  - 16 - ≥ 4µ
  - 14 - ≥ 6µ
  - 11 - ≥ 14µ

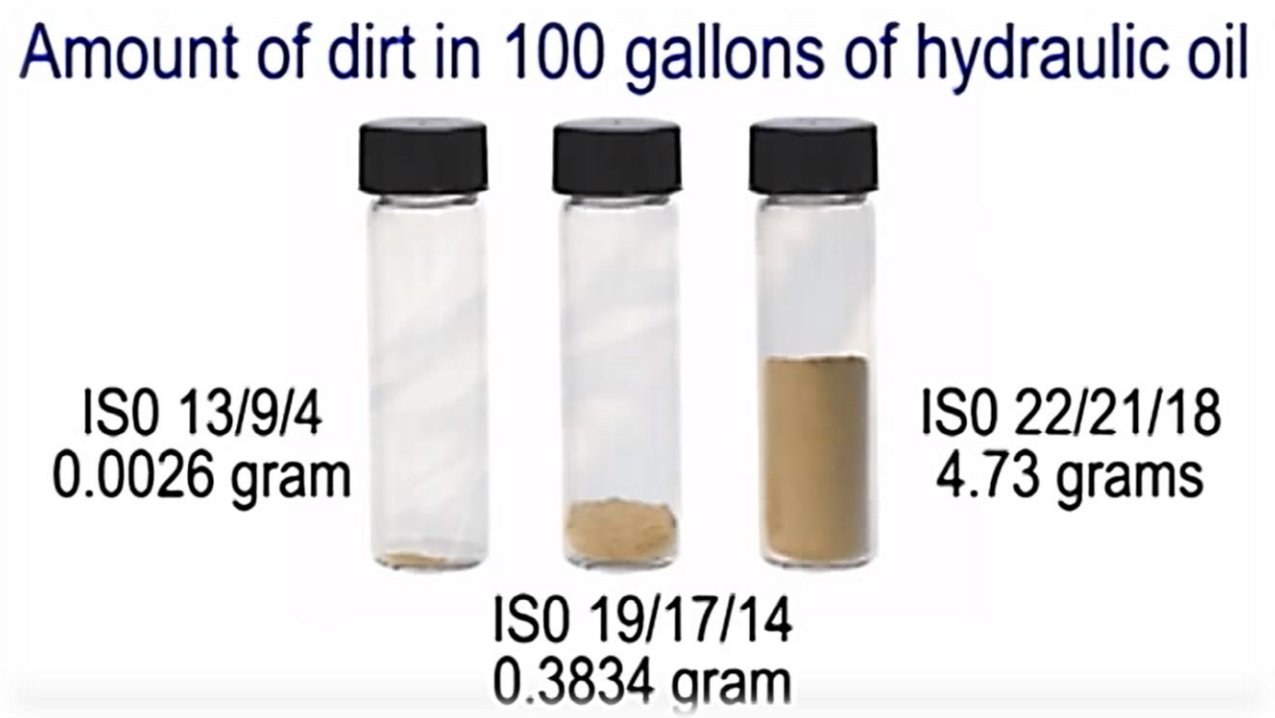
Number of Particles Per Milliliter

ISO 4406 Range Number	Greater Than	Less Than
24	80,000	160,000
23	40,000	80,000
22	20,000	40,000
21	10,000	20,000
20	5,000	10,000
19	2,500	5,000
18	1,300	2,500
17	640	1,300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	0.64	1.3
6	0.32	0.64
5	0.16	0.32
4	0.08	0.16
3	0.04	0.08
2	0.02	0.04
1	0.01	0.02

Q: What is a common oil filter micron size?

A: 10 micron

Particle Size Matters



A cleanliness code for new oil can be 21/19/16

ISO 4406 Range Number	Greater Than	Less Than
24	80,000	160,000
23	40,000	80,000
22	20,000	40,000
21	10,000	20,000
20	5,000	10,000
19	2,500	5,000
18	1,300	2,500
17	640	1,300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	0.64	1.3
6	0.32	0.64
5	0.16	0.32
4	0.08	0.16
3	0.04	0.08
2	0.02	0.04
1	0.01	0.02

https://www.youtube.com/watch?v=DouGwx_ia3o

Clean Oil Extends Equipment Life

LET – Cleanliness Level
ISO Codes, Complete

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

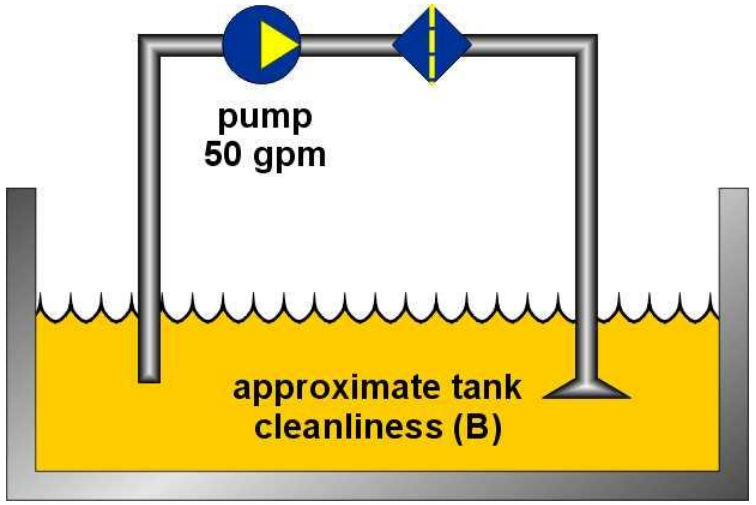
Oil Pump or Dirt Pump?

Filter (A)	ISO Code (B)	Dirt (lbs.) (C)	50 lb Bags	Relative Pump life
25 micron nominal	21/18/13	6789	136	1
10 micron nominal	19/16/13	1809	36	1.9
10 micron absolute	16/13/11	211	4.2	4.4
6 micron absolute	14/11/9	53	1	8.8
3 micron absolute	12/9/7	14	0.28	15

All figures are approximations.

At ISO 21/18/13, this hydraulic system passes **136 – 50lb bags of dirt** through the pump in one year.

At ISO 14/11/9, (128 x cleaner) only one 50-lb. bag of dirt passes through the pump



167.03 Ref: JCF, BHRA

Understanding an Oil Analysis Report

Castrol

Interpretation of Sample Results

Castrol LABCHECK NEXTGENERATION

1 **Bureau Veritas - Oil Analysis**
12715 Royal Drive, Stafford, TX, 77477
800 - 248 - 7778

2 **Sample Analysis Report**
Status: D Reason: Coolant Leak

ISO 17025 Accredited

3 **Account Information**

Customer ID #:	Customer PK
Company Name:	ACME Industries, Inc.
Company Worksite:	Demo Site #12
Company Address:	12345 Main Street Houston, TX 77086

4 **Sample Information**

Lab No:	201705260886
Sample Tracking #:	S22434208234
Sample Date:	5/16/2017
Received Date:	5/23/2017
Completed Date:	5/24/2017

5 **Other Sample Information**

PO No:	1298798712
Work Order No:	WK-23124

Unit Information

Unit ID:	81629
Unit Mfg:	International, 2007
Unit Model:	IH7400 TAN RL
Unit Serial No:	1HTWGAZT87J445473
Unit Worksite:	Demo Site #12

Component Information

Component Description:	Diesel Engine
Component Mfg:	International
Component Model:	DT570
Component Serial #:	2134108
Completed Type:	Engine

6 **Fluid Information**

Fluid Manufacturer:	Castrol
Fluid Brand / Product:	Vecton
Fluid Grade:	15W40

7 **SAMPLE ANALYSIS & RECOMMENDATIONS** - Evaluated by Charles Gay

ANALYSIS INDICATES CRITICAL CONDITIONS! COOLANT additives are present. GLYCOL test POSITIVE. Silicon present may be wholly or partially coolant additives. CHECK for recent coolant loss or unusual required additions. PERFORM a coolant pressure test. If leak-down is confirmed, INSPECT for the source of coolant intrusion. Data provided indicates oil and filter were changed at sampling. RESAMPLE at 1/2 normal interval.

8 **SPECTROCHEMICAL ANALYSIS (D5185) IN PART PER MILLION**

10

LAB NO.	SAMPLE DRAWN	WEAR METALS										CONTAMINANTS			ADDITIVES							
		Iron	Chromium	Nickel	Aluminium	Lead	Copper	Tin	Silver	Titanium	Vanadium	Silicon	Sodium	Potassium	Phosphorus	9 Zinc	Calcium	Magnesium	Barium	Boron	Molybdenum	Antimony
Reference Sample		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1300	1200	1800	425	<1	<1	80	<1
0886	15-May-17	49	2	<1	5	25	29	<1	<0.1	<1	<1	122	3829	3965	1412	1006	1523	485	<1	102	110	<1
0916	20-Feb-17	40	3	<1	3	2	3	<1	<0.1	<1	<1	22	443	1379	1521	1254	1853	417	<1	43	78	<1
0606	22-Dec-16	17	<1	1	<1	<1	1	1	<0.1	<1	<1	3	24	55	1157	1339	1962	416	<1	95	70	1
0716	18-Oct-16	47	1	<1	<1	<1	2	<1	<0.1	<1	<1	7	33	75	1165	1331	1973	447	<1	98	75	<1
0832	8-Aug-16	31	1	<1	<1	<1	2	<1	<0.1	<1	<1	6	26	55	947	1159	1645	353	<1	31	53	<1

SAMPLE INFORMATION

Lab No.	Sample Drawn	Unit Time	11 Fluid Time	UoM	Filter Change	Oil Change
Reference Sample		-	-	-	-	-
0886	15-May-17	-	-	HRS	Y	Y
0916	20-Feb-17	-	2253	MI	Y	Y
0606	22-Dec-16	-	475	HRS	Y	Y
0716	18-Oct-16	-	476	HRS	Y	Y
0832	8-Aug-16	-	-	HRS	Y	Y

FLUID PROPERTIES / CONTAMINANTS

	Ds279 VIS 100C (cSt)	Visc Grade 13	E2412 Soot (abs)	E2412 Glycol (abs)	Water %	Fuel %
Reference Sample	12.5	40	<0.1	NEG	<0.1	0
0886	12.5	40	0.1	POS	<0.1	<1.0
0916	12.9	40	0.2	NEG	<0.1	<1.0
0606	13.2	40	0.1	NEG	<0.1	<1.0
0716	12.7	40	0.2	NEG	<0.1	<1.0
0832	12.7	40	0.3	NEG	<0.1	<1.0

12 14 15

KEY: UoM - UNIT OF MEASURE Y - YES N - NO > - GREATER THAN < - LESS THAN N/R - NOT REPORTED

Sample Data

Sample	Status	Date Sampled	Date Received	Date Reviewed	Fluid Time	Unit Time	Product Sampled
406591	Caution	06/18/2008	06/23/2008	06/27/2008	72	72	Castrol Anvol SWX 46
407527	Caution	07/04/2008	07/10/2008	07/15/2008	477	0	Castrol Anvol SWX 46
414346	Caution	11/07/2008	11/13/2008	12/09/2008	3,272	3,284	Castrol Anvol SWX 46
419521	Caution	02/13/2009	02/18/2009	02/20/2009	1,000	0	Castrol Anvol SWX 46

Spectrograp

Iron wear

Sample	Fe	Cr	Ni	Al	Pb	Cu	Sn	Si	Na	B	Mo	P	Zn	Ca	Mg	Ba	Li	Ti
406591	43	<1	<1	4	1	2	12	<1	4	1	<1	443	16	2	<1	3	<1	<1
407527	59	<1	<1	4	<1	1	8	1	4	<1	<1	440	22	2	<1	5	<1	<1
414346	74	<1	<1	4	3	5	8	<1	5	1	<1	476	45	<1	<1	10	<1	<1
419521	97	<1	<1	6	1	5	6	2	8	1	<1	423	23	<1	<1	1	<1	<1

Contaminants present

Physical Properties

Sample	VIS 40°C	VIS 100°C	VI	Water, %	SOLIDS	TAN
406591	48.9	9.5	182	<.05	0.1	1.30
407527	49.2	9.5	181	<.05	0.1	1.42
414346	51.0	9.5	173	<.05	0.1	1.55
419521	47.5	9.0	174	<.05	0.1	1.64

Particle Count - ISO 4406 - Per 1mL

Particle counts high

Sample	4-6µ	6-14µ	14-21µ	21-38µ	38-70µ	>70µ	ISO	NAS
406591	12184	8433	248	22	0	1	22/20/15	12
407527	9172	2354	109	9	1	0	21/18/14	10
414346	29384	2934	23	4	0	0	22/19/12	11

COMMENTS/RECOMMENDATIONS FOR SAMPLE 419521

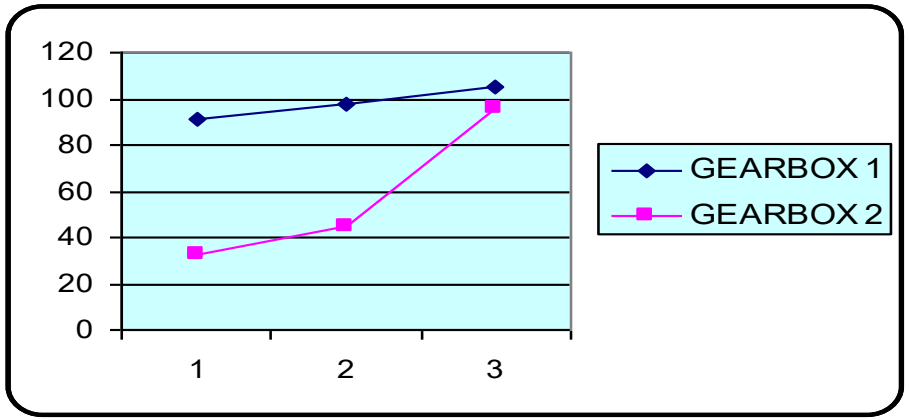
ANALYSIS INDICATES ABNORMAL RESULTS AND/OR CONDITIONS! Elevated levels of wear materials(Fe) present in this sample. Unable to perform the Particle Count test as requested due to insufficient sample volume. All else appears to be acceptable. Resample at next scheduled interval.

Interpretation of Sample Results

Set Limits vs Trend Analysis

Trending is important in oil analysis

- A single data set provides limited knowledge
- Changing behavior over time is most telling
- To help accomplish this, take a baseline sample soon after a change-out.
- Then sample consistently over time



GEARBOX No. 1					GEARBOX No. 2			
Sample	Iron, ppm	Set Limit	Trend		Sample	Iron, ppm	Set Limit	Trend
1	91	Normal	Normal		1	33	Normal	Normal
2	98	Normal	Normal		2	45	Normal	Normal
3	105	Abnormal	Normal		3	96	Normal	Abnormal

Non-Routine Tests

- DR Ferrography
  - Provides levels of iron particles within large and small size ranges
  - Helps to clarify if increased wear is small or larger failure wear
- Analytical Ferrography
  - Chemist reviews and photographs iron particles under microscope
  - Used for detailed investigation of wear problems.
- Millipore Filtration
  - All fines are filtered, weighed, and examined
  - Used for detailed analysis of contamination materials
- Used Grease Testing
- Filter Content Analysis
- Sludge / Deposit Analysis
- Foam Test

ANALYTICAL FERROGRAPHIC ANALYSIS

PARTICLE TYPE	POPULATION	MICRONS	COMMENTS / OBSERVATIONS
Normal Rubbing Wear (Fe)	10	Sub - 15	Typical wear particles. See photo 1.
Severe Wear (Fe)	3	15 - 200	Check for visible metals.
Dark Metallo-Oxides (Fe)	0		
Red Oxides (Rust)	0		
Spheres	0		
Nonferrous Wear	10	Sub - 300	Copper / Bronze particles. See photo 2.
Inorganic Materials	10	15 - 150	Airborne dust particles. See photo 3.
Organic (Carbonaceous)	3	Sub - 280	Some agglomerated formations.
Fibers	0		

Population Key:	None = 0	Trace = 1	Few = 3	Moderate = 5	Elevated = 7	Heavy = 9

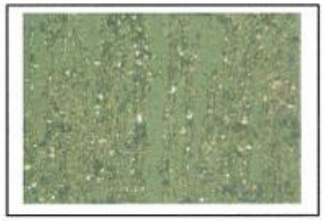


PHOTO 1. Magnification: 100x

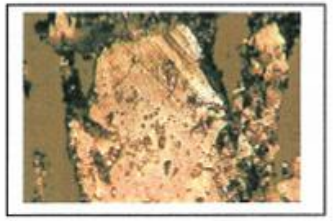


PHOTO 2. Magnification: 400x

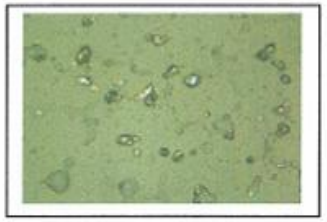


PHOTO 3. Magnification: 100x

Oil Recommendation Scenarios

Castrol

Scenario 1

Hacksaw's Hydraulic Inc. has a new hydraulic unit that will run outside on their facility. The OEM manual recommends multiple hydraulic oils from various companies. Hyspin AWS 32, Hyspin AWH-M 32, and Tribol HM 943/32 are all mentioned. Which would be the most appropriate product to recommend?

Hyspin AWS 32

- Meets DIN 51502 classification HLP
- Meets ISO 6743/4 classification HM
- Part of our "standard" hydraulic line
- ISO 32
- VI of 118
- FZG of 12
- Highest selling hydraulic line

Hyspin AWH-M 32

- Meets DIN 51502 classification HVLP
- Meets ISO 6743/4 classification HV
- Comes in 'Superclean' version
- ISO 32
- VI > 150
- FZG of 11
- More expensive than AWS 32

Tribol HM 943/32

- Meets DIN 51502 classification HLP
- Meets ISO 6743/4 classification HM
- Part of our high-performance lubricant (HPL) line
- ISO 32
- VI > 100
- FZG of 12
- Most expensive option of the 3

Scenario 2

Spacely Sprockets has machines with gearboxes using a standard ISO 320 mineral oil gear oil. One gearbox is located in a hot part of the process where it is constantly experiencing higher than average operating temperatures. The life of the gear oil is unusually short with the customer frequently changing the oil based on used oil analysis. Which of the following products would be a good replacement given the operating conditions? Why did you consider the product that you did?

Alpha SP 320

- Meets DIN classification CLP
- Group II Oil
- ISO 320
- Flash point (open cup) 440 °F
- VI of > 95
- FZG of >12

Alpha SP 680

- Meets DIN classification CLP
- Group II Oil
- ISO 680
- Flash point (open cup) 445 °F
- VI of > 95
- FZG of >12

Alphasyn EP 320

- Meets DIN classification CLP
- Group IV Oil
- ISO 320
- Flash point (open cup) 446 °F
- VI of 140
- FZG of >14

Castrol

Scenario 3

Barry's Bearing Co is going through too much grease. They often need to regrease bearing in a wet part of their process which costs them time & money. The resulting ingress of water is causing their bearing to fail frequently. Which grease replacement would be best suited to solve the problem and why? What factors did you consider in your choice?

Mollub-Alloy 6040/460-1.5

- Calcium-complex sulfonated thickener
- Mineral base oil
- NLGI grade 1.5,
- ISO 460
- Water washout ASTM D 1264 1.7%
- "multi-purpose grease that exhibits excellent adhesive and cohesive characteristics"

Tribol GR 100-2PD

- Lithium thickener
- Mineral base oil
- NLGI grade 2,
- ISO 100
- Copper corrosion rating of 1b
- "enhanced with the MicroFlux Trans (MFT) additive system...[which] achieves a non-sacrificial micro-smoothing of the friction surfaces"

Tribol GR 1000 HT

- Organic sodium thickener
- PAO-Ester base oil
- NLGI grade 1,
- 540 cSt @ 40C
- Dropping point >500 °F
- "extreme temperature grease utilizes synthetic base oils in conjunction with a blend of lubricating solids selected for high temperature service"

Scenario 4

Peter Piper's Precision Parts Inc. is experiencing stick-slip and chatter on their CNC machine slideways, leading to poor surface finish and inconsistent part dimensions. They currently use a generic ISO 68 hydraulic oil as way lubricant.

Tribol CM ATO 100

- AW and Molybdenum additives
- Mineral base oil
- Emulsifies with water
- ISO 22

- "oil that emulsifies water to prevent rust/sticking"

Magna SW D 68

- AW and Friction Modifiers
- Mineral base oil
- Demulsifies with water
- ISO 68

- "Good demulsibility, wash resistance & wear protection. "

Hyspin HVI 46

- AW and VI Improver additives
- Mineral Oil
- Wide Temperature Capability
- ISO 46

- "Systems requiring high viscosity index fluids. Cold and/or wide temperature systems."