Advantages and Disadvantages of Low VOC Vegetable Based Metalworking Fluids

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Outline

- Metalworking Types
- Potential Areas for Use
- Advantages and Disadvantages
- Summary

Metalworking Fluids – Rule 1144

Are:

- Metal Removal Fluids — Coolants, cutting oils
- Metal Protecting Fluids — Rust inhibitors
- Metal Forming Fluids — Stamping, drawing, forging
- Metal Treating Fluids — Quench oils

Are Not

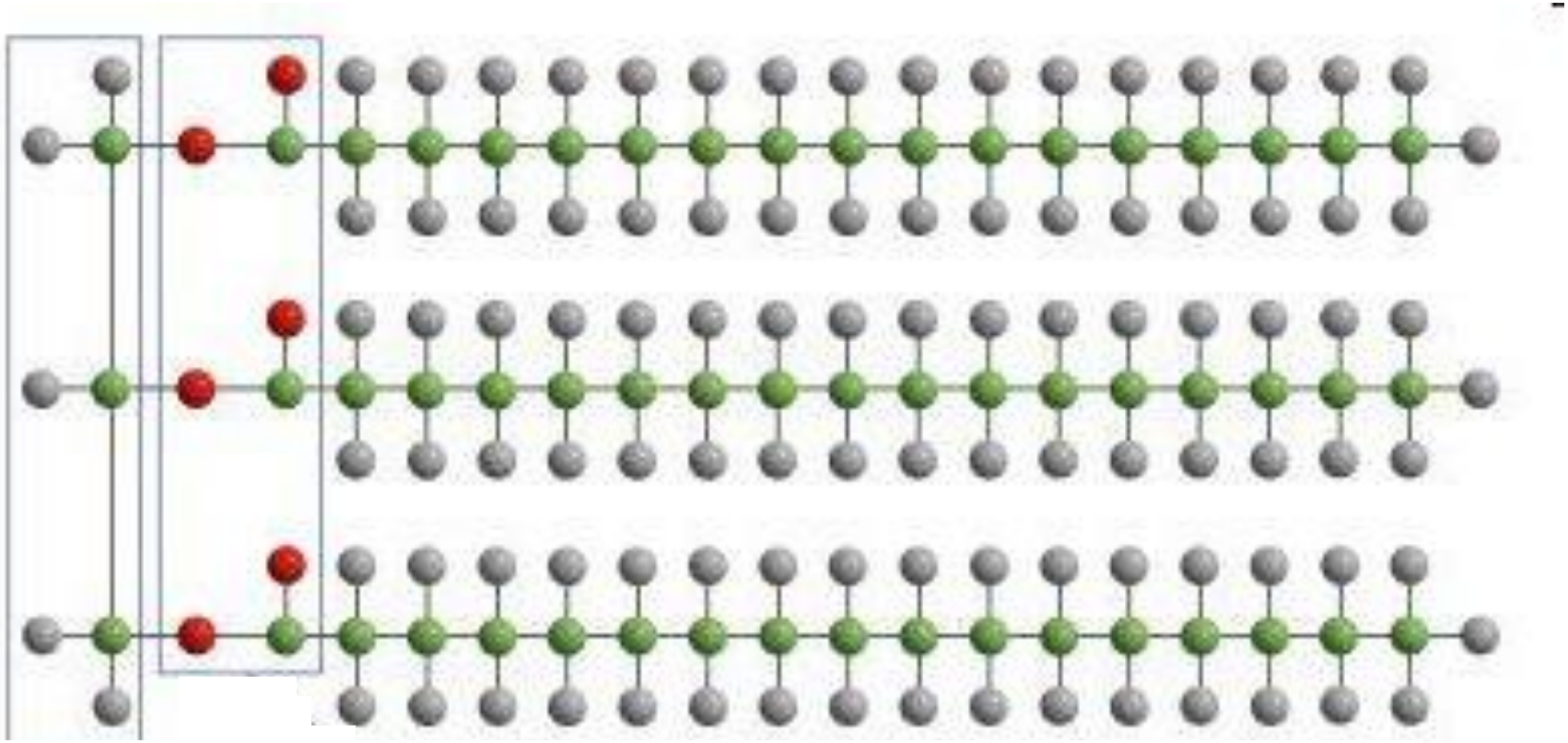
- Metal Cleaning Fluids — Parts washing soaps, detergents

Natural Vegetable Oils - Manufacturing

- Canola , Rapeseed
- Soybean
- Sunflower

- Mostly triglycerides

Triglycerides



Glycerol

Three Fatty Acids

Mineral Oil / Petroleum Oil

- No fatty acids
- No glycerol
- Alkanes, cycloalkanes, and various aromatic hydrocarbons
- Contain nitrogen, oxygen, and sulfur, and trace amounts of metals such as iron, nickel, copper and vanadium

- Lubricating oil = 16 carbon atoms
- Paraffin wax = 25 carbon atoms
- Asphalt = 35++ carbon atoms

Structures are Different

- Vegetable
- Mineral

Therefore performance should be different

- AND IT IS – Each has advantages and disadvantages over each other

Vegetable oil applications

Metalworking

- Metal removal fluids – emulsions, straight oils
- Metal protecting - Low VOC Rust Protectors
- Metal forming – wire drawing, stamping

Other

- Conventional and Fire resistant hydraulic oils
- Gear oils
- Way oils
- Spindle oils

Volatile Organic Compounds

VOC expressed as grams / liter
Per ASTM E1868-10

Viscosity Grade cSt @ 40 Degrees C	**Paraffinic Oil**	**Naphthenic Oil**	**Vegetable Oil - Canola**
4.4	400	718	NA
9.6	50	130	NA
20.5	10	64	NA
39.0	< 1*	5*	< 1**

* Blended, two base stocks
** Food grade

Lubricity

- Determined by many standard lubricity tests

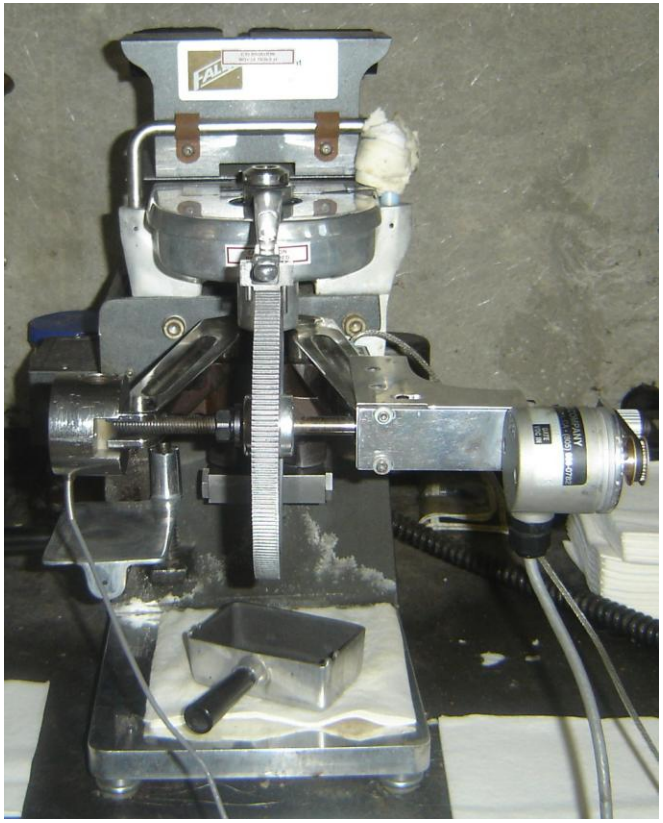
- Mineral oil = good
- Vegetable oils = better

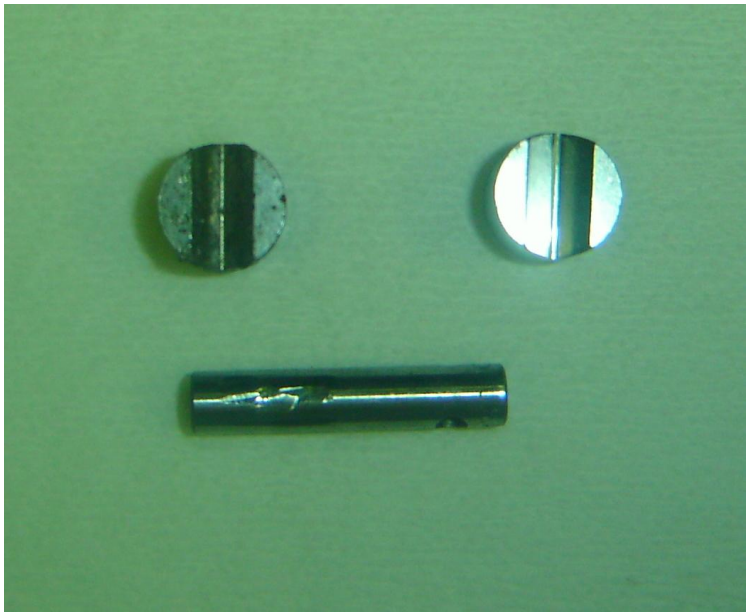
- **Note: Without additive vegetable oils will generally outperform mineral oil in standard lubricity tests**

- Reference
  - Pin and V block
  - 4 ball
  - Tap torque
  - hydraulic pump/wear tests, such as ASTM D2882 and ASTM D2271

Pin and V Block

- V blocks are clamped around the spinning pin and pressure is increased until failure.



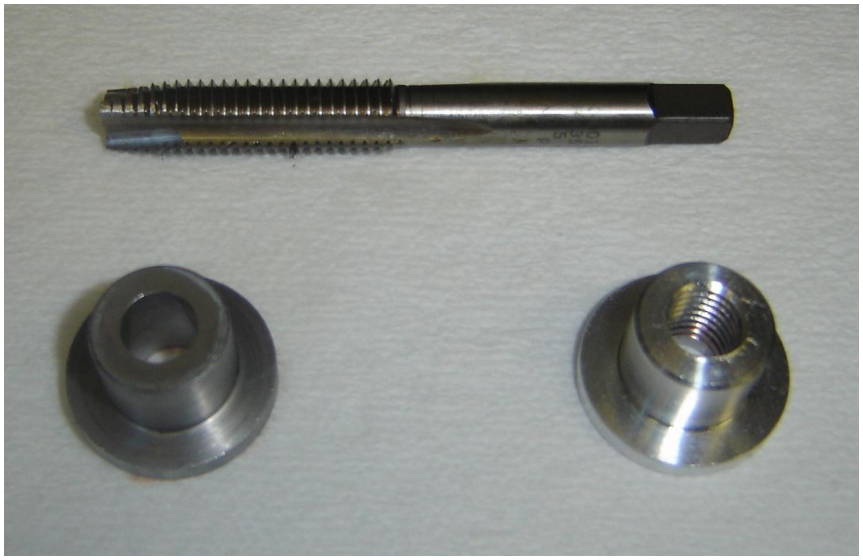


Four Ball

- One ball spins on top of three under pressure to scar the surface of the three.

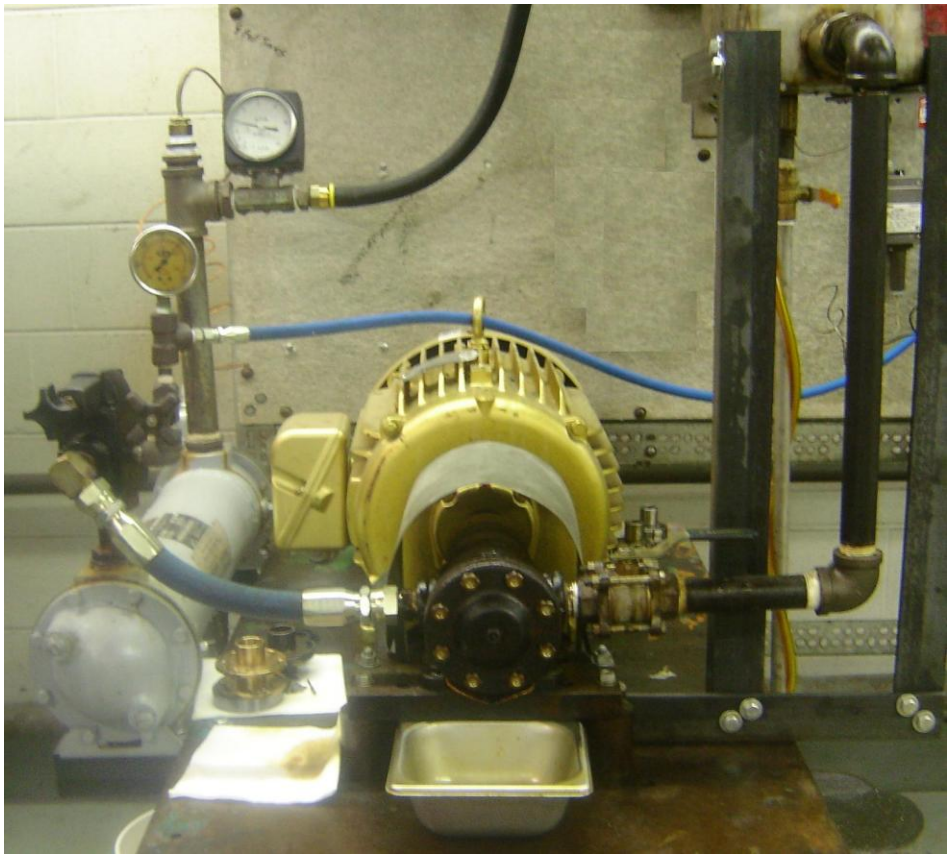
Tapping Torque

- Measures the amount of torque required to thread a standardized part.



Hydraulic Pump/Wear Tests

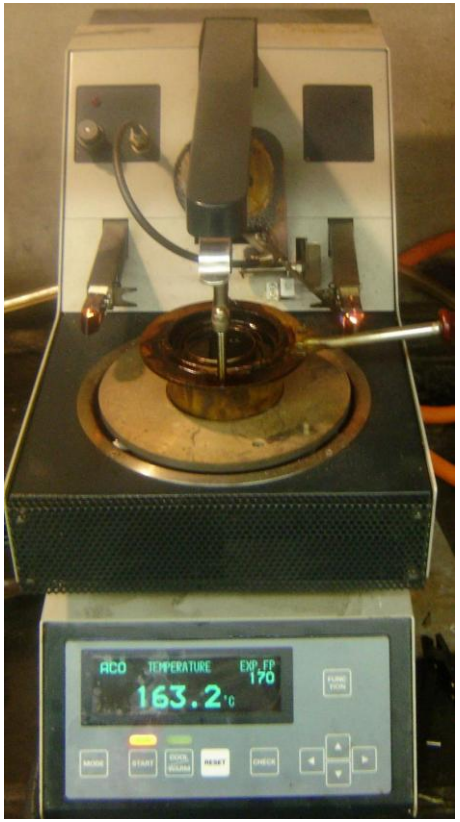
- ASTM D-2882 – V104C pump test



Flash Point

- Mineral Oil = 300°F – 400° F (typical 390°F)
- Canola Oil = 620°F - 625°F
- Soybean = 605°F - 615°F

- Method ASTM D92



Biodegradability

Biodegradation is a process of chemical breakdown or transformation of a substance caused by micro-organisms (bacteria, fungi) or their enzymes.

- Mineral Oil = Considered to be slow to biodegrade
- Canola, Soy = Considered readily biodegradable

- Reference: OECD 301 B (Organization for Economic Cooperation and Development)
  ASTM D-5864
  CEC EC-L-33-A-94 (Coordinating European Council)

Biodegradable – both good and bad

- Triglyceride – Breaks down into free fatty acids
- Fatty acids + Calcium + oil + alkali = grease
  - Especially problematic in wastewater treatment using Acid Alum treatment
- Can be so thick that it can be unpumpable
- Grease has no reclaimable potential!

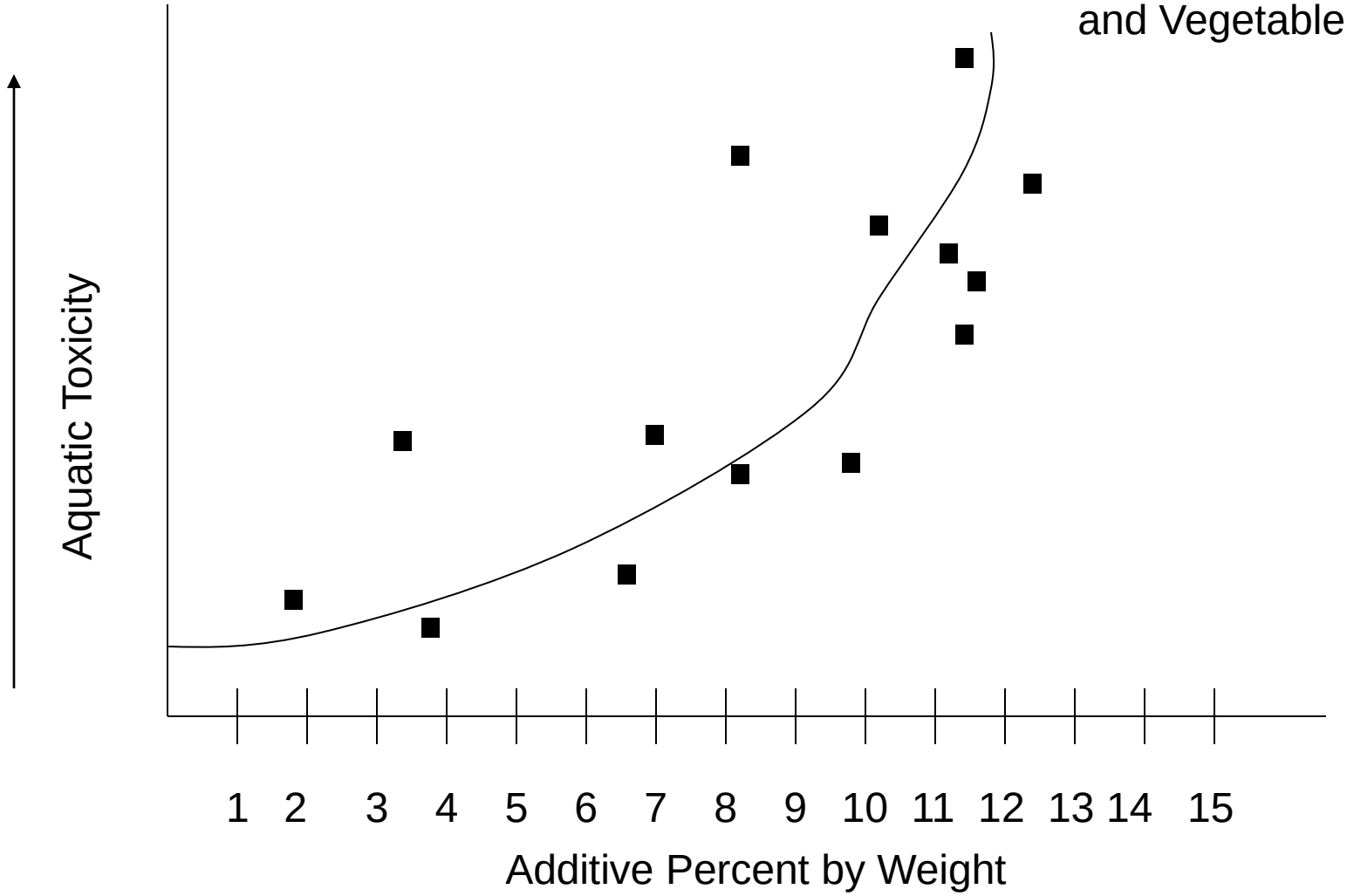
Aquatic Toxicity

- Daphnia
- Fat head minnow
  - LC50 > 100 mg/L – “Practically Non-toxic”
  - LC50 > 1,000 mg/L – “Relatively Harmless”

- **Note: Additive make or break toxic properties of fluids**

Comment on Additives

Same for Mineral and Vegetable Oils



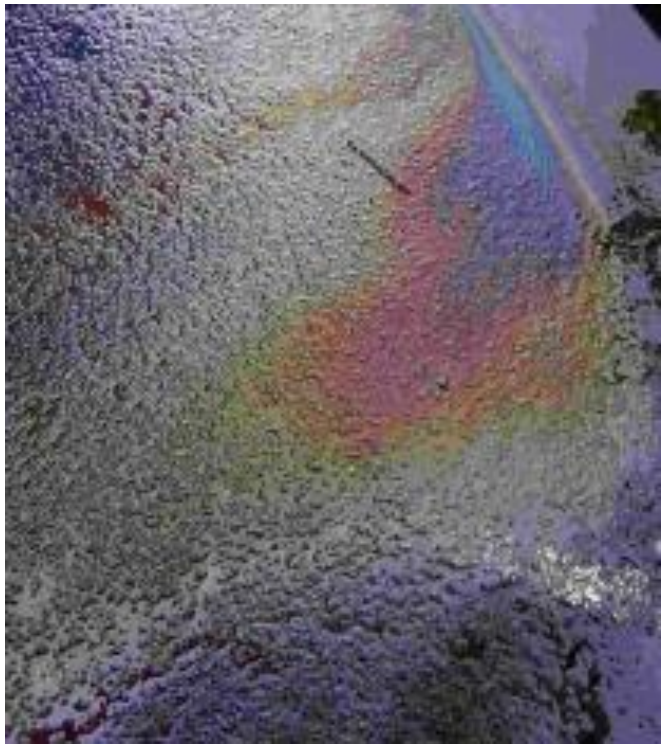
Oil and Grease Measurement

- EPA method 1664 and Standard Methods 5520B,F are used to determine oil and grease and hydrocarbons in wastewater – (hexane extraction, silica gel)

Product Type	Dose mg/L	Response 5520B mg/L	Recovery %	Hydrocarbon 5520F mg/L
Mineral Oil 20.5 cSt Naphthenic	**109**	**95**	**87.2**	**79**
Canola Oil 39 cSt Food Grade	**105**	**100**	**95.8**	**6**

Visible Sheen

- Mineral oil = Yes
- Vegetable oil = Yes



Renewable Resource

- Mineral Oil = no
- All vegetable oils = yes

Competes with existing food crops

- Mineral oil = no
- Vegetable oils = yes

Oxidative Stability

- Low oxidative stability: oil will oxidize rather during use, becoming thick and polymerizing to a plastic-like or tar-like consistency

- Mineral Oil = Good
- Vegetable oil = Poor

Residue on Machines

- No standard tests
- Mineral oil = low residue, cleanable
- Vegetable oils = poor oxidative stability – may form very sticky residues and be very hard to clean
- Some vegetable oils are more stable than others
  - As measured by iodine value
  - Monounsaturated based oils are better (75% or higher)

Hydrolytic Stability

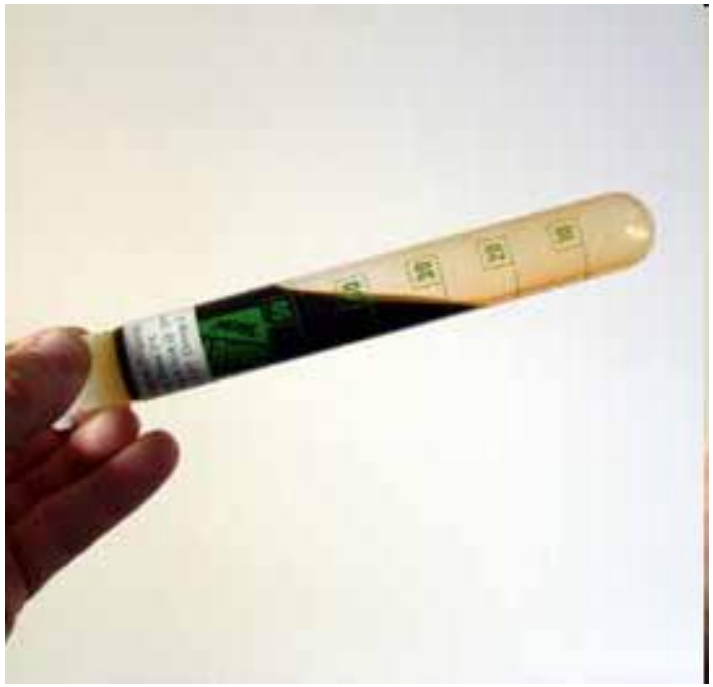
- Stability when exposed to water

- Mineral = Good – may for invert emulsions
- Vegetable oil = poor, breaks down to release acids

Pour Point

- Cold weather stability
  - Not really applicable to metalworking fluids

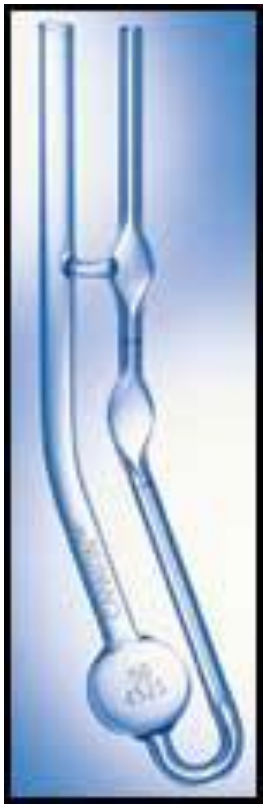
- Mineral Oil = minus 30 F
- Vegetable oils = +5 - +25F



Viscosity Index

- Maintains Viscosity at high temperature
- Viscosity Index (VI); for example, 223 for soybean oil vs. 90 to 100 for mineral oil
  - Higher number is better

- Mineral oil = fair
- Vegetable oil = very good



Misting from Machining Operations

- Mineral Oil = Medium
- Vegetable oil = low

Dermal Sensitivity

- Likelihood to cause Dermatitis

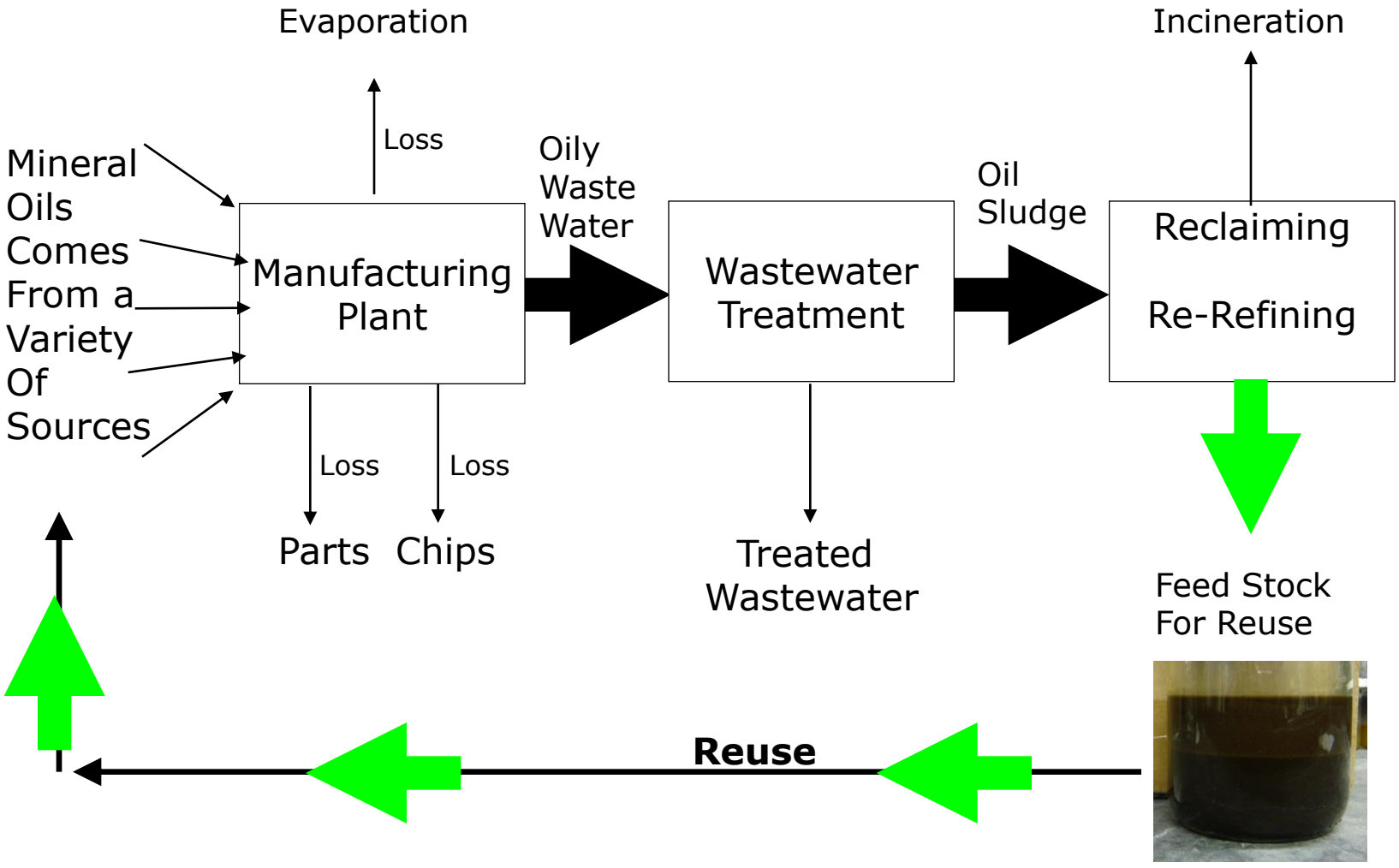
- Mineral oil = known to cause dermatitis
- Vegetable oil = minimal dermal issues
- Again – Additives can be irritants

Carcinogenicity Potential

- Likelihood to cause cancer
- Mineral Oil = low if solvent refined and severely hydro treated
- Vegetable oil = naturally low

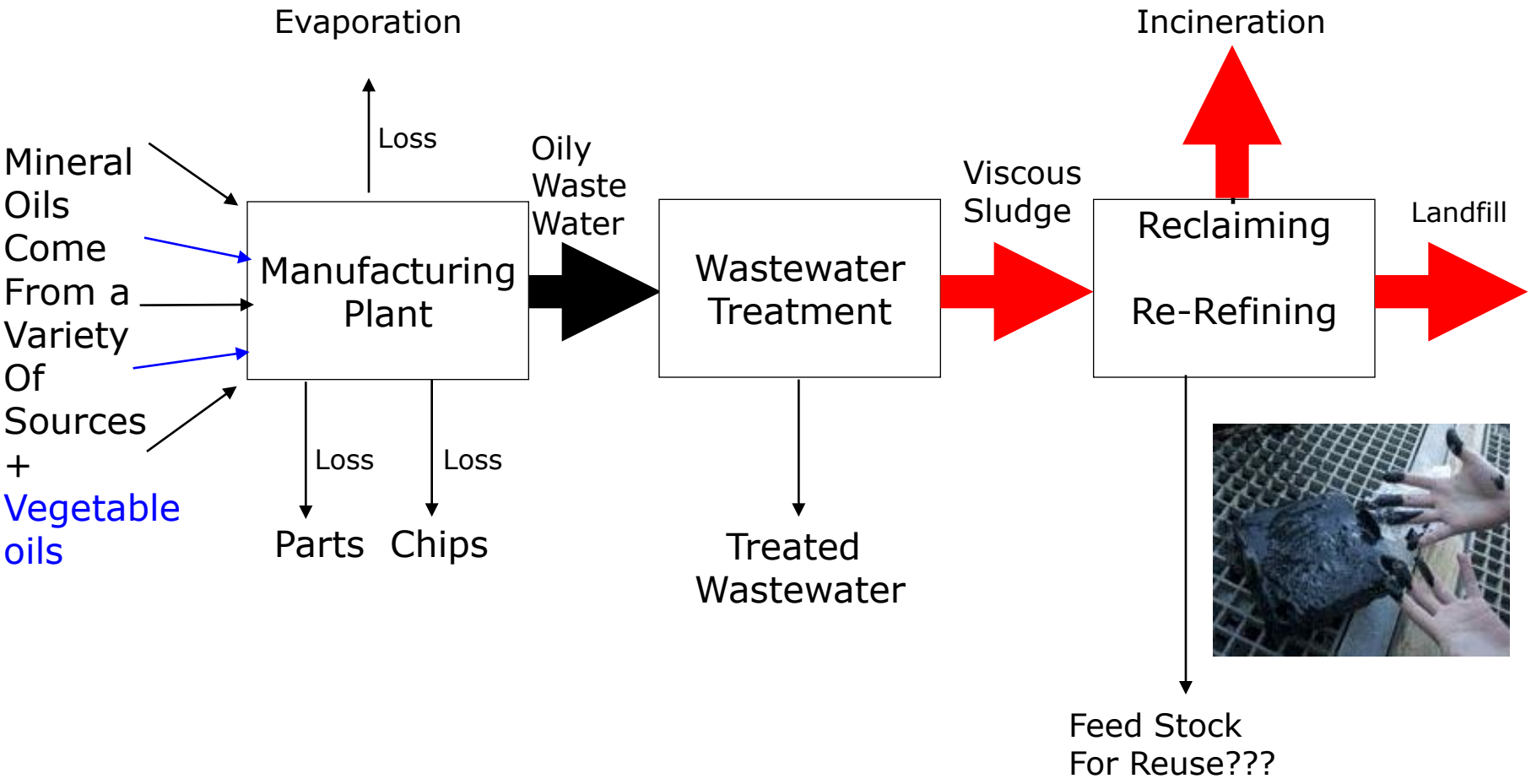
Can be recycled

Waste Infrastructure – Mineral Oil



Can be recycled – Maybe not

Waste Infrastructure – Mineral Oil + vegetable oil



What about cost

- Base stock cost for vegetable oils generally track crude oil pricing
- Vegetable oils are generally more expensive
  - Mineral oil require multiple refining steps
  - Naphthenic oils are in limited supply, thus more costly
- Always exceptions to the rule
- Depending on the application and additive level, finished good price will vary

Summary – Vegetable Oils

- Vegetable Oils compete favorably with mineral oil
  - VOC, Lubricity, Dermal Sensitivity
- Additives needed to correct for
  - Pour point, oxidative stability, hydrolytic stability
  - Additives increase toxicity
  - Additive can increase dermal sensitivity
- May not be readily recycled

Comparison Chart

Attributes	Vegetable	Mineral
VOC		
Lubricity		
Flash Point		
Biodegradable		
Aquatic Toxicity		
Oil and Grease		
Petroleum Hydrocarbons		
Visible Sheen		
Renewable Resource		
Food Crop - Compete		
Oxidative Stability		
Machine / Part Residue		
Hydrolytic Stability		
Pour Point		
Viscosity Index		
Misting		
Dermal Sensitivity		
Carcinogenic Potential		
Can Be Recycled		

Good
Fair
Poor

SCORE

	Vegetable	Mineral
Good	10	6
Fair	4	7
Poor	5	5

Summary

- Vegetable oils are in use right now
- Can meet manufacturing demands
- Disposal of residuals needs research
- Costs are generally higher for vegetable oils than mineral oils

Thank You

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