stle
Annual Meeting & Exhibition
A Virtual Event | May 17 - 20, 2021

Sustainable Base Oils for High-Performance EAL & MWF formulations

BIOSYNTHETIC®
TECHNOLOGIES

Biosynthetic Technology

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TABLE OF CONTENTS

ABOUT BIOSYNTHETIC TECHNOLOGIES

Biosynthetic® Technologies manufactures a revolutionary new class of biobased synthetic compounds called **Estolides** that are made from organic fatty acids found in various bio-derived oils. These highly functional biosynthetic oils have numerous uses in lubricant, automotive, marine, and personal care applications and can be used as the primary base oil of a lubricant formulation, a component of a base oil co-blend, or even as an additive. In addition to their high-performance properties, these oils are:

Biodegradable,
Sustainable,
Renewable,
Non-bioaccumulative, and
Non-toxic.

In addition, because Biosynthetic Base Oils are compatible with common lubricant base oils and additives, they serve as an easy drop-in for most existing formulations available in the market.

Biosynthetic® Technologies strives to make their mark on the world by delivering innovations for a sustainable future.

BIOSYNTHETIC®
TECHNOLOGIES

Our Vision

To deliver Innovative Solutions for a Sustainable Future.

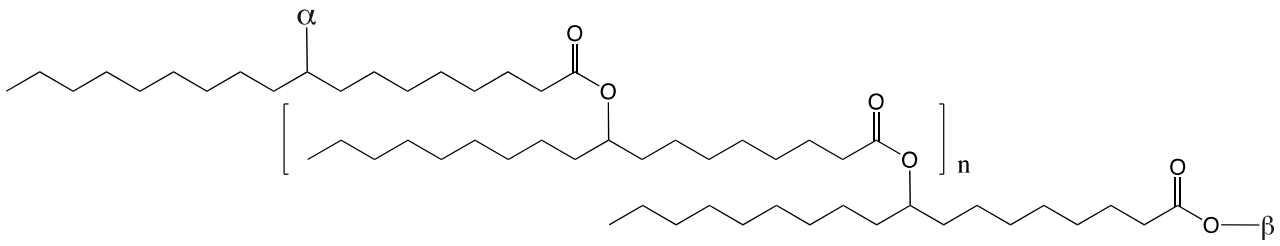
Our Mission

To be the Premier Synthetic Base Fluid Supplier Across a Variety of Specialty Markets.

ESTOLIDE TECHNOLOGY

Biosynthetic® Technologies manufactures a revolutionary new class of biobased synthetic compounds called Estolides. These are naturally derived oils that improve the quality of formulated products and are biodegradable.

Estolides are a class of unique bio-based oils with a variety of uses. Their oligomeric structure contains fatty acid repeat units, with secondary ester linkages on the alkyl backbone. The general structure is shown below:



Functional groups denoted as α and β, oligomer length n, and the fatty acid feedstock can all be manipulated in order to achieve desirable performance properties. Relevant technical performance properties include increasing or decreasing viscosity and polarity, as well as improving cold temperature properties and oxidative stability.

The base oils offered by Biosynthetic Technologies exhibit excellent lubricity and load carrying characteristics, strong oxidative stability, and good demulsibility. In addition, they show high flash point, with closed-cup values ranging from 200°C to 245 °C (ASTM D93) and open-cup values ranging from 240°C to >260 °C (ASTM D92). Biosynthetic Technologies base oils display good cold temperature performance as well, with pour points ranging from -18 °C to -21 °C (ASTM D97).

On top of their impressive technical performance, Estolides offer excellent environmental performance. These oils contain high bio-content, are biodegradable and nontoxic, and do not bioaccumulate.

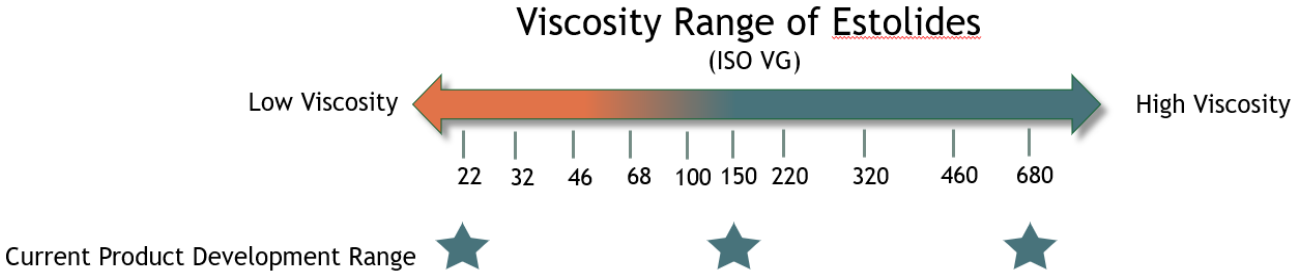
At Biosynthetic Technologies, our base oil products are 70-90% biodegradable (OECD 301) with 65-95% bio-content (ASTM D6866). Additionally, they displayed no bioaccumulation (OECD 107) and were non-toxic at 1000 mg/mL (OECD 201, OECD 202, OECD 203, OECD 209).

With a highly customizable structure, Estolides' physical properties can be manipulated for specific applications. In addition, their environmental compatibility allows them to be used in widespread industries ranging from lubricants to personal care. Overall, Estolides serve as naturally derived oils that improve the quality of formulated products.

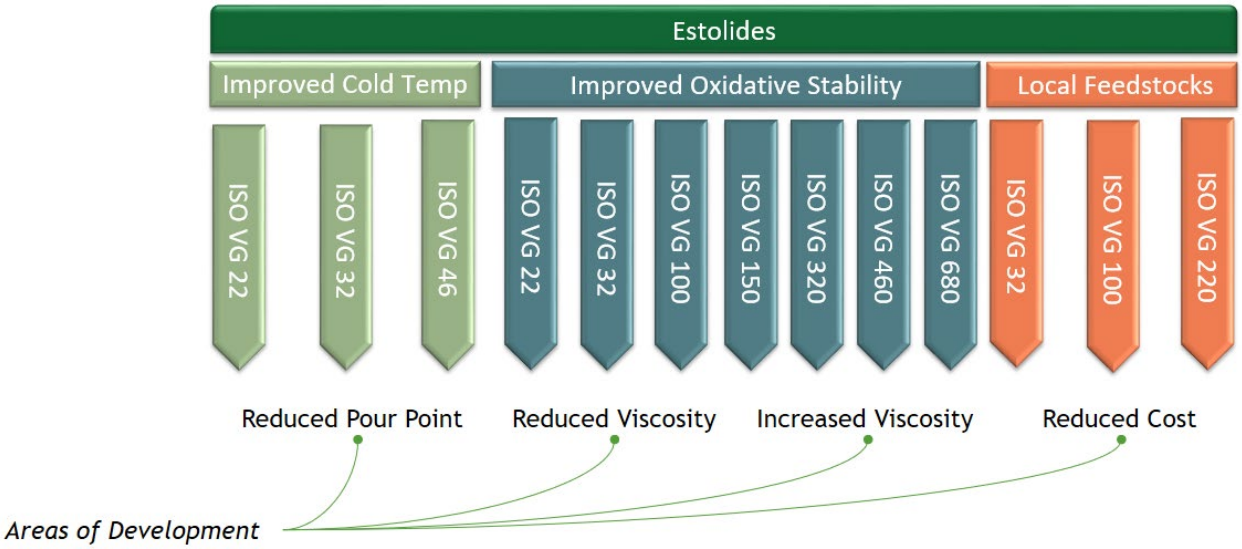
Estolides:

- Are made from natural fatty acids found in various bio-derived oils.
- Are highly functional “biosynthetic” oils. Have numerous uses in the lubricant, personal care, automotive, marine and industrial industries.
- Approved for used in H1 Lubricants, VGP & Marine Lubricants, Environmentally Acceptable Lubricants and Engine Oils.
- Outperform their petroleum counterparts in similar applications.
- Can be used as the primary base oil of a lubricant formulation, a component of a base oil co-blend, or even as an additive.
- Have high-performance properties. Are renewable, biodegradable, nonbioaccumulative and nontoxic.

Estolides are currently being developed in a range of viscosities. This effort is expanding the reach of estolides to incorporate both lower and higher viscosities than what has been historically available.



Estolides are a chemical platform and can be designed to support a wide range of industries or applications. These Estolides are high customizable to meet any customer or market need. Should you have specific opportunities please reach out to Mike Woodfall and discuss your options.



SUSTAINABLE BASE OILS

To help meet the demands of today's industrial lubricant applications, Biosynthetic Technologies' has manufactured a high performance sustainable base oil. Our sustainable base oils are available in in a dynamic range of viscosities. In addition, they are compatible with common industrial lubricant base oils and additives and serve as an easy drop in replacement for most existing formulations available in the market today. Biosynthetic Technologies is proud to offer the most advanced, sustainable base oils available for developing high performance industrial lubricants.

Base oils are used to make various lubricants and greases across all industries. Base oils can represent from between 70% and 99% of a finished lubricant. These might be industrial lubricants, grease or metal processing fluids. BT base oils are medium viscosity oils used by manufacturers to produce a wide variety of specialist products including industrial and marine lubricants. Other industries use them in a broad range of industrial and automotive applications including:

- Hydraulic Oils
- Heavy Duty Lubricants
- Process oils
- Greases

In addition to the specialty oils highlighted above, Biosynthetic Technologies can customize high-quality specialty hydrocarbon products to meet your specific requirements across a wide range of applications including. Biosynthetic Technologies' sustainable base oil are available in several ISO grade viscosities:

- BT4 - ISO 22
- BT22 - ISO 150
- BT75 - ISO 680

Physical Properties	Method	Unit	BT4	BT22	BT75
Kinematic Viscosity @ 100°C cST	D445	cSt	4.5-5	21-23	66-80
Kinematic Viscosity @ 40°C cST	D445	cSt	21-24	140-160	620-740
Viscosity Index	D2270	-	150 min	170 min	190 min
Pour Point °C	D97	°C	-21	-21	-18
Flash Point °C	D92	°C	250 min	260 min	260 min
NOACK	D5800		8.3	3.4	-
Total Acid Number	D664	mg KOH/g	0.1 max	0.2 max	0.2 max
Color	D1500	-	1	2	2
Water	D1533	wt%	0.1 max	0.1 max	0.1 max
Specific Gravity	D4052	-	0.90 - 0.92	0.91 - 0.93	0.91 - 0.93
KRL Shear	CEC L-45-99		-2.07	0.30%	0.98%
Aniline Point	ASTM 611	°C	2.7	0.7	31.8
Environmental Properties	**Method**	**Unit**	**BT4**	**BT22**	**BT75**
Biodegradability	OECD 301B	-	88%	79%	76%
Bio Content	ASTM D6866	-	68%	86%	94%
Toxicity	-	-			
Alga Toxicity EC50	OECD 201	-	>1000 mg/L	>1000 mg/L	>1000 mg/L
Daphnia Toxicity EC50	OECD 202	-	>1000 mg/L	>1000 mg/L	>1000 mg/L
Fish Toxicity EC50	OECD 203	-	>1000 mg/L	>1000 mg/L	>1000 mg/L
Bacteria Toxicity EC50	OECD 209	-	>1000 mg/L	>1000 mg/L	>1000 mg/L
Performance Testing	**Method**	**Unit**	**BT4**	**BT22**	**BT75**
4-Ball Wear	D4172	mm	0.59	0.58	0.35
4-Ball Weld	D2783				
Weld Load		kg.	126	160	160
Load-Wear Index		kg.	14.77	27.11	39.86
Oxidative Stability	D2272	mins	50	96	81
with Anti-Oxidant		mins	1215	949	1181
Hydrolytic Stability	D2619	-	-	-	-
Total Acidity Water Layer - 144 hours		mg KOH/g	TBD	0.07	TBD

SUSTAINABLE BASE OIL PRESENTATIONS

Biosynthetic Technologies hosted 5 different sessions at the STLE Annual Meeting. Below please find a short description of each session followed by the PowerPoint presentation.

New Hydrolytic Stability Testing on Biobased Lubricants and Base Fluids

Dr. M. Lutz, R&D, Biosynthetic Technologies, Indianapolis, Indiana

Esters are a class of compounds that have performance characteristics and use as a petroleum replacement in lubricant formulations. However, in aquatic applications esters have the tendency to thermally hydrolyze in the presence of water leading to organic acids which catalyzes the subsequent hydrolysis of unreacted esters leading to high total acid number resulting in corrosion of metal working equipment. Estolides are a distinct class of esters that has demonstrated exceptional hydrolytic stability compared to traditional esters. A modified hydrolytic stability test was developed by Biosynthetic Technologies to monitor the extensive stability of estolides versus traditional lubricant esters over a long duration of time under real world applications.

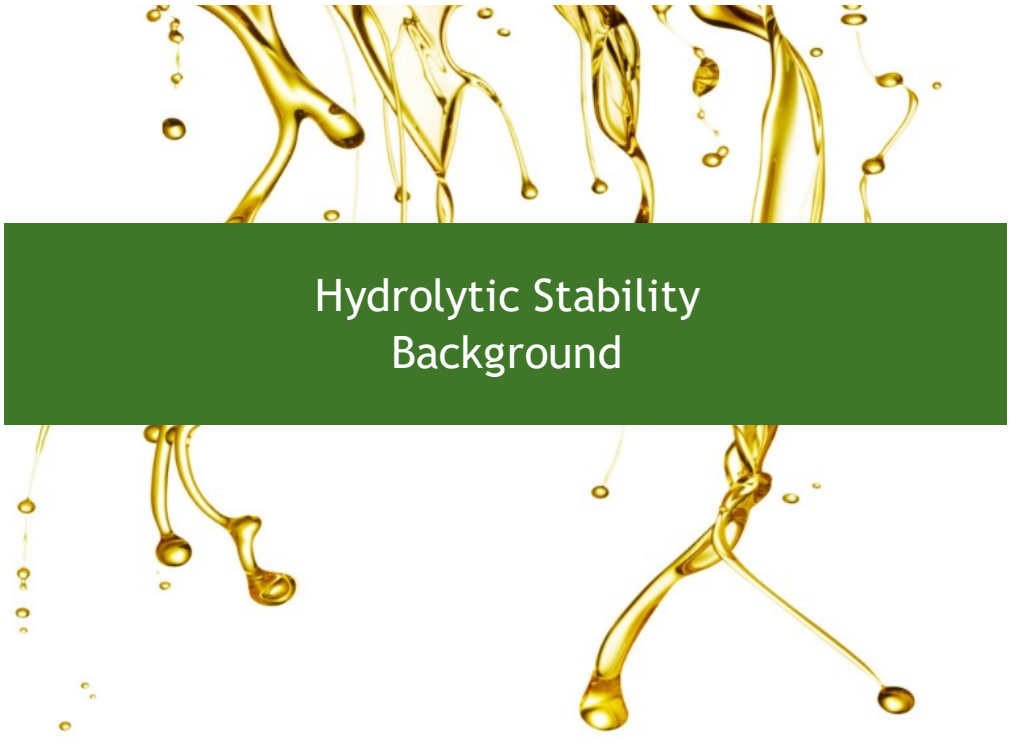
SESSION DAY & DATE: Monday, May 17, 2021

Agenda

Agenda

- Introduction
- Hydrolytic Stability Background
- Importance of Hydrolytic Stability
- Long Term Hydrolytic Stability Assessment of Commercial Base Oils
- Cause, Mechanism, Prevention of Hydrolysis
- What is an Estolide?
- Estolides as a special and superior class of esters
- Conclusion

2



Hydrolytic Stability Background

What is Hydrolytic Stability?

- For most lubricants and oils in general, water is a very destructive element
- Oils are generally hygroscopic, meaning that they will naturally absorb moisture from the air
- Hydrolytic stability is the ability of an oil to resist hydrolysis while in the presence of water
- Hydrolysis reactions occur and form acid components
- In order to determine how susceptible oils are to water, tests can be run to determine when and how much hydrolysis will occur
- Additives can either hurt or help hydrolytic stability
  - Additives with high TAN can cause more rapid hydrolysis, leading to a faster breakdown
  - Additives such as epoxides and carbodiimides can act as "acid catchers" but it is important to consider their impact on other properties, such as oxidation and ecotoxicity.

4

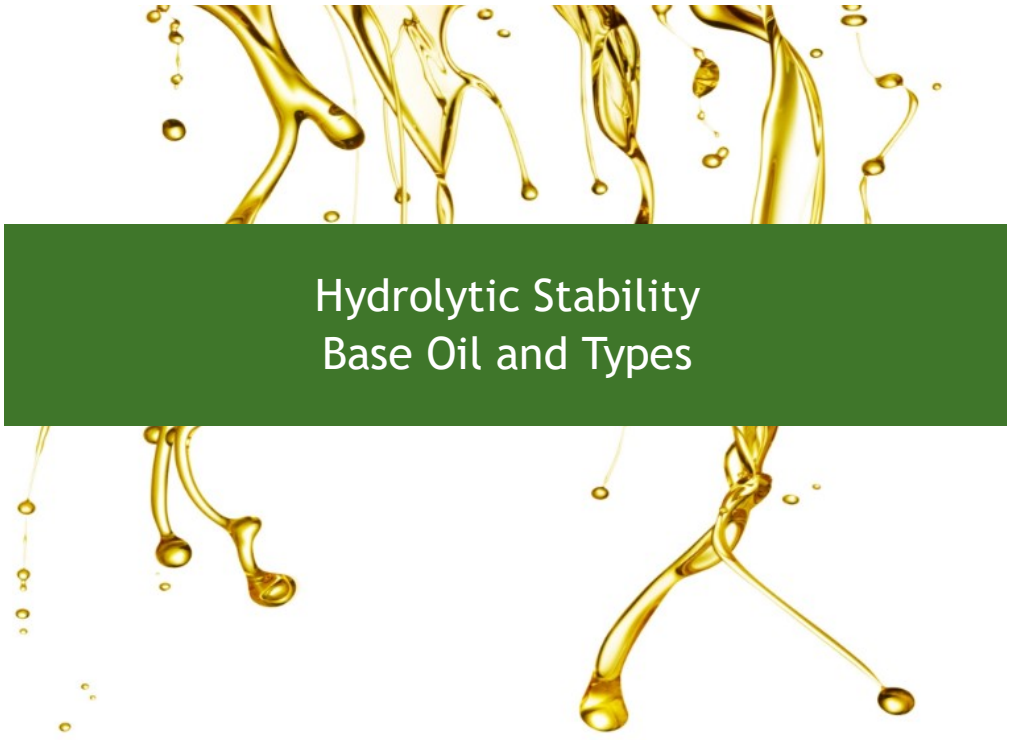
Why is hydrolytic stability important?

- 80 to 90% of hydraulic failures are due to air and water contamination.
- Moisture enters through air or the location of the machinery (e.g. aquatic environments).
- Metals are susceptible to degradation (corrosion) when they are used over time or come in contact with other elements.
- Corrosion is a chemical reaction between an acid and a metal.
- The ability of a lubricant to resist hydrolysis will greatly affect machinery lifespan and performance.

5

What are the effects of hydrolysis on oils

- Formations of acids and solids
- Rust
- Corrosion
- Degradation of the oil
  - Viscometric changes (impacting VI, equipment performance)
  - Increased seal swelling (leaks, spills, poor machine performance)
- Decreased load-carrying capacity of oil
- Part replacements
- Monetary losses dealing with spills, part replacements, labor, loss in productivity, etc.



Hydrolytic Stability
Base Oil and Types

Base Oils

Base Oil Classification	Description
Group I	Conventional, solvent, refined
Group II	Hydro-treated
Group III	Rigorously hydro-treated or isomerized wax
Group IV	Polyalphaolefins (synthetic)
Group V	Synthetics not in Group I – IV Esters, PIOs, PAGS, Estolides

8

Synthetic Esters and Applications

Esters Classes

- Esters used in lubricant formulations are categorized into two categories
  - Naturally produced triglycerides from plant or animal sources
  - Synthetic esters derived from carboxylic acid and alcohol in a manufacturing process

Triglyceride esters

- Have found use in hydraulic oils and as a base in greases
- Downsides
  - Exhibit poor lubricant performance when water and operational temperatures exist
  - Poor temperature stability
  -
  - Exhibit poor cold temperature properties
  - Poor hydrolytic stability performance leading to formation of acidic species causing damage to machinery and seals

Synthetic Esters

- Traditional monoesters
- Dibasic esters
- Complex esters
- Polyol esters
- Aromatic
- Estolides

Applications of Synthetic Esters

- Used in wide range of applications
- Enhanced polarity and solvency properties
- Their properties can be tailored for specific performance conditions
- Ability to be employed in wide range of temperatures
- Exhibit high viscosities, lubricity, corrosion protection, and oxidative stability
- Performance area of high criticism: hydrolytic stability.

9

Hydrolytic Stability of Esters

When it relates to hydrolytic stability, most Group V esters typically perform very poorly on this test.

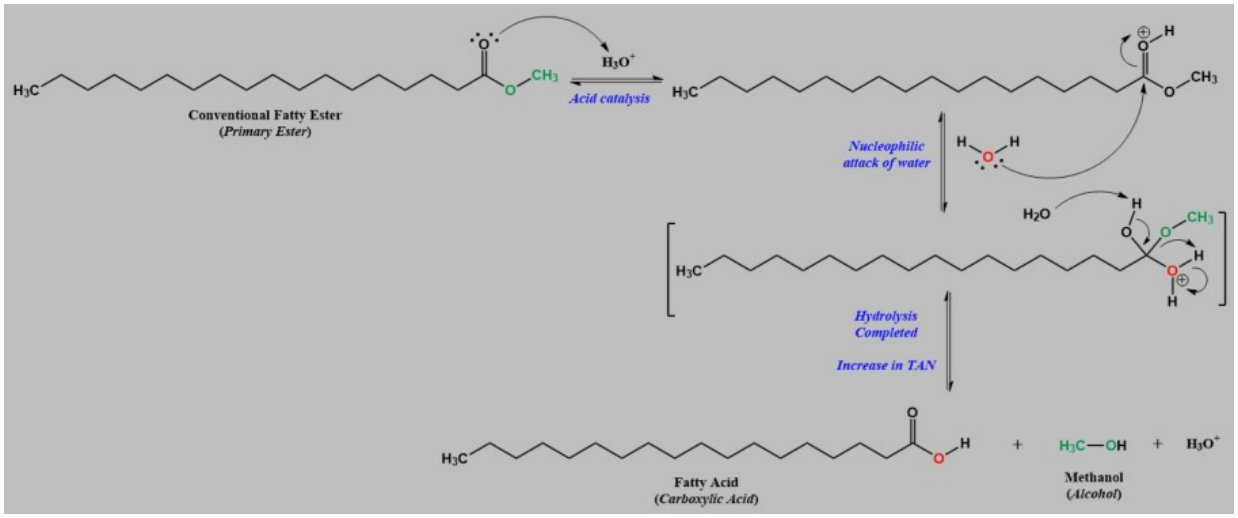
This is in large part because the esters are susceptible to nucleophilic additions at the carbonyl position.

When the water reacts with the carbonyl, the molecule splits into two parts:
1) a carboxylic acid and an alcohol.
2) Additional carboxylic acid generated only further accelerate hydrolysis

The rate of which hydrolysis occurs is temperature dependent meaning that hydrolysis at higher temperatures leads to hig
hydrolyzed byproducts, and *vice versa*.

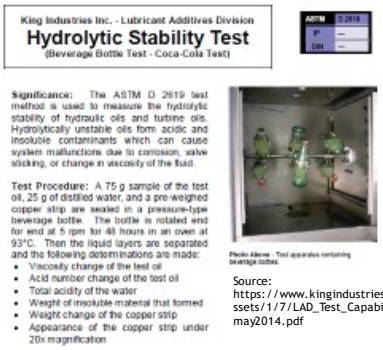
During the hydrolysis reaction, one must remember that:
the hydrolysis reaction exists as an equilibrium meaning that the hydrolysis has the potential of forward and reverse reacti

Mechanistic Hydrolytic Cleavage of Esters



Hydrolytic Stability Testing

How do we measure hydrolytic stability?


King Industries Inc. - Lubricant Additives Division

Hydrolytic Stability Test

(Beverage Bottle Test - Coca-Cola Test)

Significance: The ASTM D 2619 test method is used to measure the hydrolytic stability of hydraulic oils and turbine oils. Hydrolytically unstable oils form acidic and insoluble contaminants which can cause system malfunctions due to corrosion, valve sticking, or change in viscosity of the fluid.

Test Procedure: A 75 g sample of the test oil, 25 g of distilled water, and a pre-weighed copper strip are sealed in a pressure-type beverage bottle. The bottle is rotated end for end at 5 rpm for 48 hours in an oven at 93°C. Then the liquid layers are separated and the following determinations are made:

- Viscosity change of the test oil
- Acid number change of the test oil
- Total acidity of the water
- Weight of insoluble material that formed
- Weight change of the copper strip
- Appearance of the copper strip under 20x magnification

Photo Above - Test apparatus containing beverage bottles

Source: https://www.kingindustries.com/assets/1/7/LAD_Test_Capabilities_may2014.pdf

- ASTM D2619 is the method that assesses the hydrolytic stability of oils
  - Hydrolytic Stability of Hydraulic Fluids (Beverage Bottle Method)
- ASTM D2619 evaluates:
  - Weight change of copper
  - Appearance of copper (ASTM D130)
  - Change in TAN of oil layer
  - Change in TAN of water layer
- ASTM D2619 consists:
  - Method requires 25 wt% DI water, 75wt% oil, copper strip, and a Coke Bottle.
  - Objective is to ensure that base oil is always exposed to full moisture saturation
  - Temperature: 93 °C,
  - The bottles are sealed and rotated at 5 rpm for 48 hours, then the layers are separated.

ASTM D2619 (48 hr test)
Comparisons of Commercialized Base Oils

	LV Estolide	MV Estolide	HV Estolide	PAG Low Vis	PAG High Vis	Group III Low Vis	PAO Low Vis	PAO High Vis	C18 Penta	Complex Ester
Weight Change of Copper Panel (mg/cm2)	-0.042	-0.117	-0.033	-0.117	0.008	-0.008	0.017	-0.058	-1.250	-0.192
Appearance of Copper Panel	1b	1b	1b	1b	2c	1b	dull, dark brown	1b	dull, dark brown	1b
Change in Acid Number - D974 (mg KOH/g)	0.070	0.000	-0.050	0.010	0.000	0.010	0.000	0.010	9.000	Sample formed a stable emulsion
Total Acidity of Water Layer (mg KOH)	2.2	1.6	5.9	3.4	0.11	0.8	0.48	2.8	6.1	

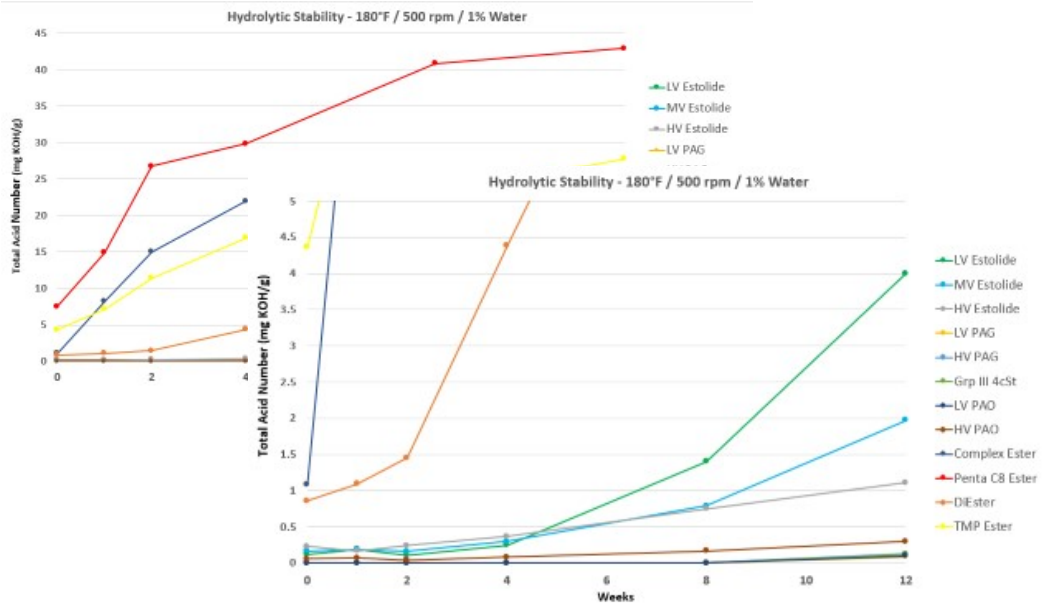
Hydrolytically Stable at Three Times Test Time

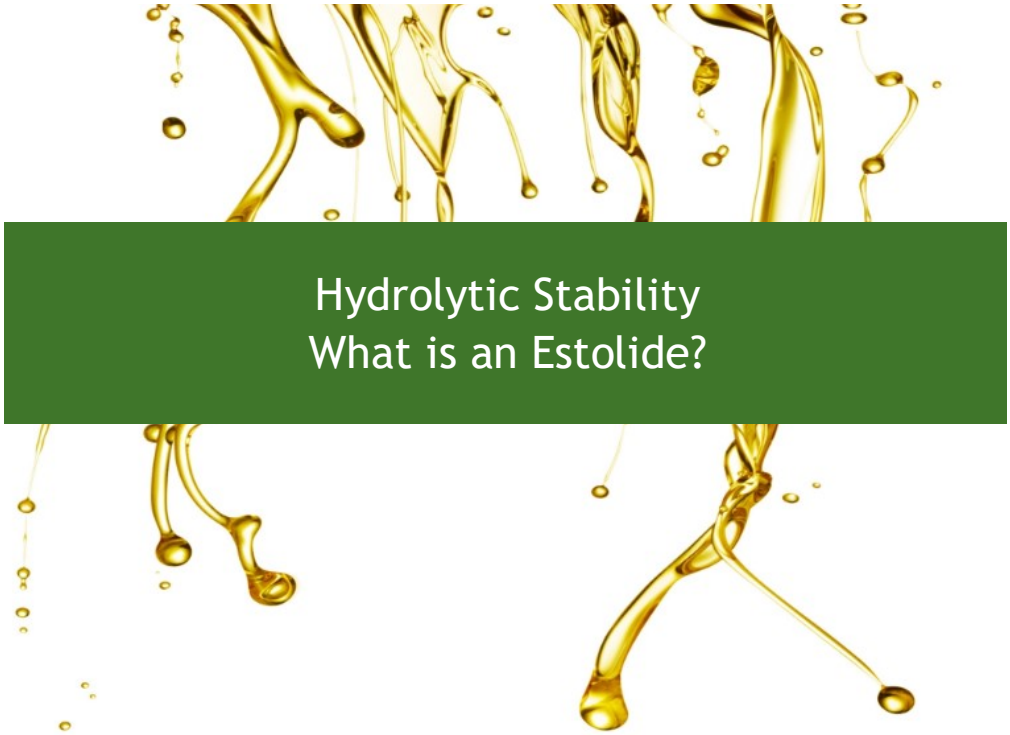
Test Method: ASTM D2619 Conditions: 93℃, 144 hours (modified from 48 hours)	Estolide ISO VG 680	PAO ISO VG 460	PAO ISO VG 1000	Bright Stock Paraffinic	Bright Stock Naphthenic
Weight Change of Copper Panel, (mg/cm2)	-0.033	-0.092	-0.033	0.00	-0.033
Appearance of Copper	Shiny, 2c	Shiny, 2c	Shiny, 1b2c	Shiny, 1b2c	Shiny, 1b
% Change in Viscosity	-0.67	-0.41	-0.64	+0.04	+11.3
Change in Acid Number, mg KOH/g	+0.17	+0.05	+0.06	+0.01	+0.17
Total Acidity of Water Layer, mg KOH/g	0.17	3.11	0.89	0.11	0.06

BT Hydrolytic Torture Test

- **BT's Hydrolytic Stability Test**
  - Variety of commercial base fluids evaluated with 1% deionized water
  - Amount of water used in experiment
    - Based on worst case scenarios of lubricant contamination
  - Temperature: 180 °F
  - Duration: 3 months (12 weeks)
  - Stir rate: 500 rpm, stirring continuously
  - Sealed container
  - Only the TAN of oil layer was evaluated for simplicity.
- **Purpose of Testing:**
  - Understand the long -term hydrolytic stability of commercial base oils
    - When exposed to water and heat
    - How does TAN change over time?
    - Differentiate estolides from conventional esters
    - Understand how estolide compare to known hydrolytically stable base oils

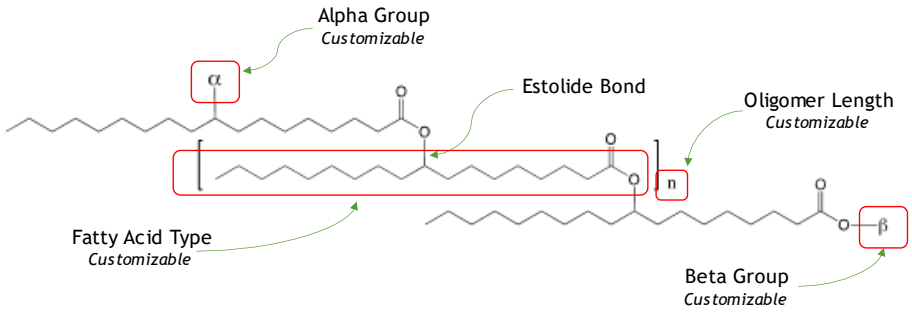
BT Hydrolytic Torture Test





Hydrolytic Stability
What is an Estolide?

Estolides are Highly Customizable

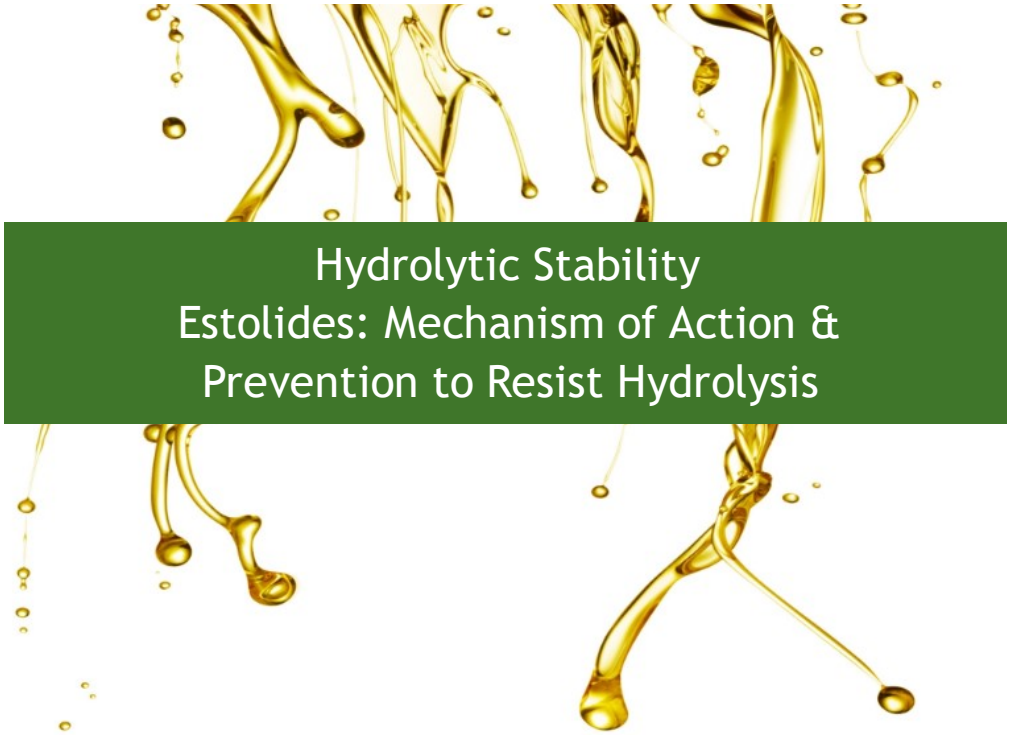


Synthetic Variations

- Use of different fatty acid feedstocks
- Oligomerization (n)
- Unique functional groups (α□β)

Performance Focus

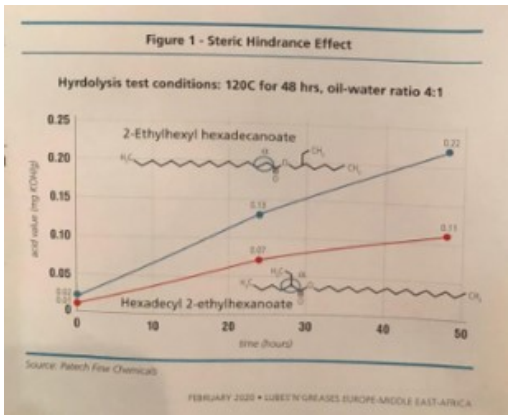
- Increased or reduced viscosity
- Improved cold temperature properties
- Increased or decreased polarity
- Improved oxidative stability

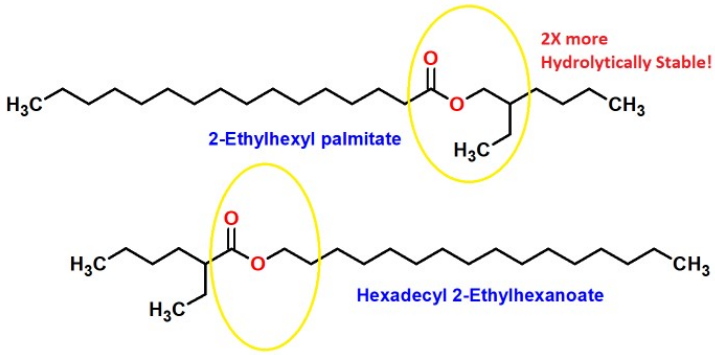


Hydrolytic Stability
Estolides: Mechanism of Action & Prevention to Resist Hydrolysis

Primary Ester - Proof of Concept for Hydrolytic Stability

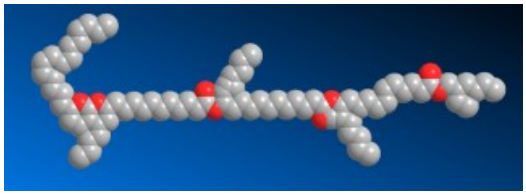
- Trevor Gauntlett – Enhancing Esters article (Lubes'N'Greases, Feb 2020)
  - Steric Hindrance Effect
  - Model studies showed significant effect on HS
    - Evaluated ester functionality comparing 2-EH vs. C16 group
    - Results confirmed that the 2-EH group provided 2X higher HS
    - 2-EH is bulkier and provides better protection of carbonyl reaction center





Estolides – Mechanism of Action for Resisting Hydrolytic Cleavage

- Estolides provide exceptional protection against hydrolysis
- Why are estolides more resistance to hydrolysis?
  - Secondary esters are more stable than primary esters
  - Steric Hindrance, molecular complexity
    - As the bulkiness of the substituent increases, the steric effect also increases.
    - Steric effects always decreases the hydrolysis rate constant.
    - Steric effects include both
      - steric obstruction of reaction site accessibility
      - strain in achieving the transition state.
  - Molecular rotational movement about the ^{3}sparbon atoms allows
    - Further protection of carbonyl moiety
    - Enhanced blocking of the carbonyl site
  - Estolide is a secondary ester
    - Estolides offer
      - Increased branching
      - Increase molecular complexity
  - Accessibility of water attacking carbonyl site
    - Very limited based on the molecular structure of estolides
    - Many molecular conformations when estolides are heated



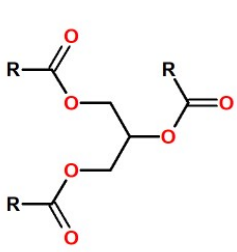
22

Sterics, Ester stability, Spatial Influences

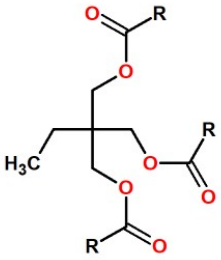
Secondary ester stability

Spatial Influences (degree of separation of reaction center).

Polar group clusters and influence of water at reaction sites



Triglyceride



TMP Ester

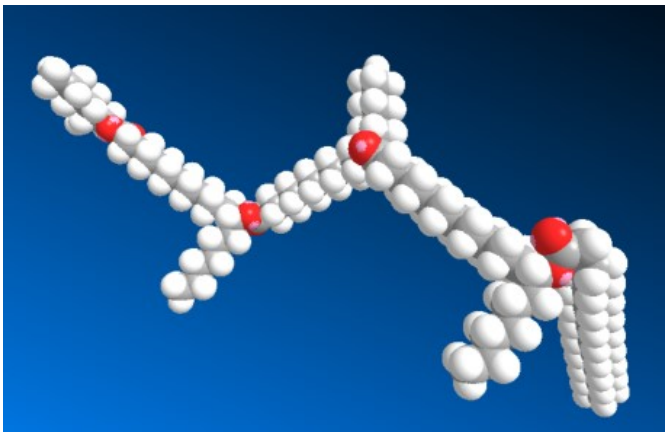
(c) *Steric Hindrance.*—It is necessary now to give attention to the circumstance that the whole of the space in the neighbourhood of a reacting centre is not *free* space in the sense envisaged by the kinetic theory, on which Boltzmann's theorem depends; in short, the effect of steric hindrance must be considered.

Journal of the Chemical Society, pg 1375, 1930

23

Estolides – Mechanism of Action Resisting Hydrolytic Cleavage

- Static 3D Image of an Estolide



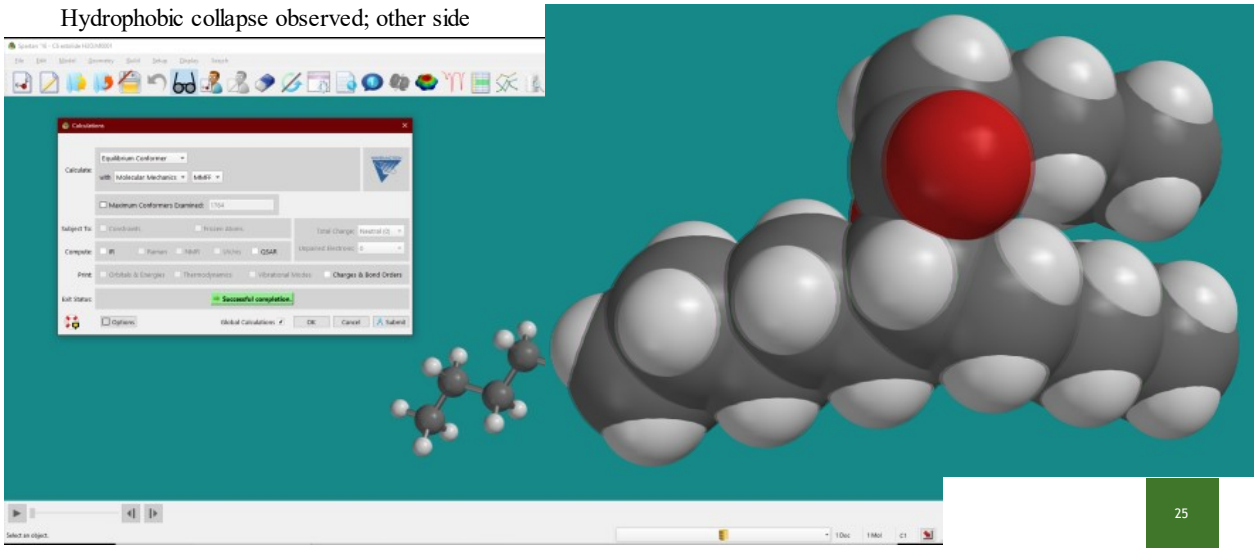
24

3D Modeling of Estolide

Minimum energy conformer

Molecular mechanics (MMFF) equilibrium conformer (of 1764 unique conformers).

Hydrophobic collapse observed; other side



25

Items to Heavily Consider to Prevent Hydrolytic Cleavage

- To prevent or substantially slow hydrolysis of a base oil, employ “bio -based” base oils that have all the following:
  - Starting Total Acid Number must be low
  - High degree of molecular complexity
  - Provides exceptional steric hindrance benefits
  - Oxidatively stable
  - Great demulsibility characteristics

26

Conclusions and Next Steps

- Esters are a class of compounds that have performance characteristics and use as a petroleum replacement in lubricant formulations.
- However, in aquatic applications esters have the tendency to thermally hydrolyze in the presence of water leading to organic acids which catalyzes the subsequent hydrolysis of unreacted esters leading to high total acid number resulting in corrosion of metal working equipment.
- Estolides are a distinct class of esters that has demonstrated exceptional hydrolytic stability compared to traditional esters.
- A modified hydrolytic stability test was developed by Biosynthetic Technologies to monitor the extensive stability of estolides versus traditional lubricant esters over a long duration of time.
- Estolides provide exceptional bio -based solutions for formulators who desire high performance and yet exceptional hydrolytic stability that still competes with PAOs, PAGs, and Grp III oils.
- Next steps is to evaluate the same hydrolytic study while in the presence of specific metals/metal alloys that require lubricants for operation.

27

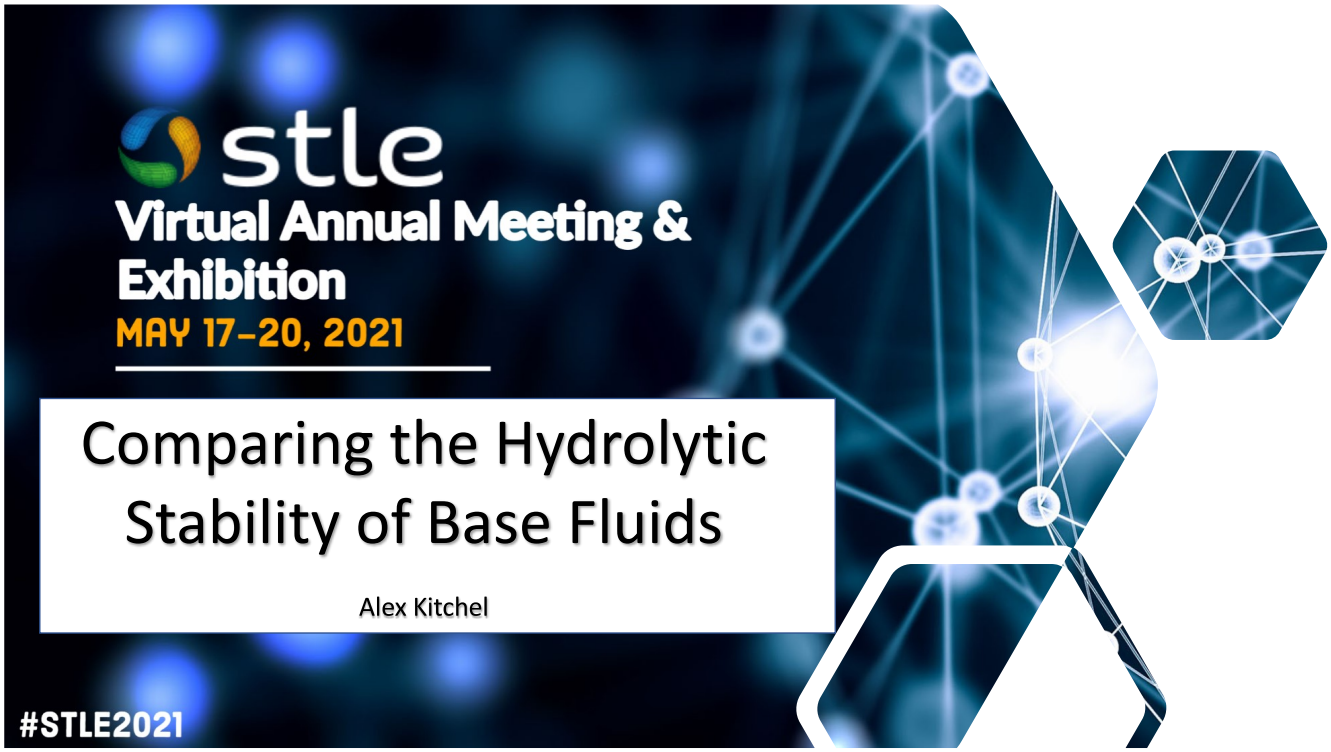
Questions and Thank You!
mlutz@biosynthetic.com

New Hydrolytic Stability Testing on Biobased Lubricants and Base Fluids

Mr. Alex Kitchel, Biosynthetic Technologies, Indianapolis, Indiana

There is more and more interest in biobased and biodegradable lubricants in and around the marine environment. The hydrolytic instability of vegetable and ester base oils is well known. Conventional hydrolytic tests do not demonstrate "real world" performance adequately. A new test has been developed that closely simulates the hydrolytic performance of lubricants and base oils in the presence of water and heat. This paper will describe test methodology and demonstrate the results of various biobased lubricants and base oils. The result of the testing is reviewed and supported with the original test data, and compared to standard industry hydrolytic tests.

SESSION DAY & DATE: Monday, May 17, 2021



Topics & Agenda

- Environmentally Friendly Fluids (EFF) Background & Terminology
- Environmentally Friendly Fluids Requirements & EALS
- What is Hydrolytic Stability?
- Hydrolytic Stability Testing and Results
- Why is Hydrolytic Stability important for EFFs?

Introduction

- Historically, and is as it is well-known and documented, petro-derived products are not sustainable product and they are NOT eco-friendly.
- These products contaminate the environment and can cause severe environmental harm, especially in the form of oil spills.
- Thus, a new era arrived (and is still arriving) where leading scientists, formulators, governments, and environmentalists searching for eco-friendly products.
- Conclusively, these new eco-friendly products are now known as EALs.
- While EALs reduce environmental impacts, many come with performance disadvantages compared to there petro-derived counterparts.
- One such disadvantage is hydrolytic stability.

Why should we use EALs?

What do these terms mean?

- Renewable – a product that is made from plants or other regenerating material or a product that can be restored to its original state
- Recyclable – can be restored to its original state
- Biobased – made from renewable sources, generally plant-based
- Biodegradable – able to be decomposed by bacteria or other living organisms; fluids that meet the standards for biodegradability; can be from any source
- Non-toxic – not toxic to wildlife
- Bioaccumulative – the contaminant concentrations inside wildlife when consumed

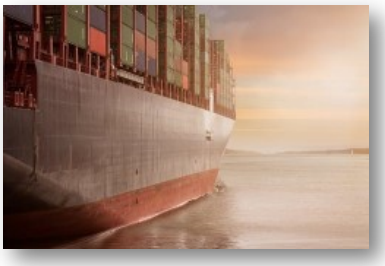
EALs – Environmentally Accepted Lubricants

U.S. EPA Vessel General Permit Definition: *"A lubricant that is:*

1. *Biodegradable*
2. *Exhibits low toxicity to aquatic organisms*
3. *Has a low potential for bioaccumulation" **

Applicable to all vessels constructed on or after December 19, 2013:

- Must use an environmentally acceptable lubricant in all oil-to-sea interfaces.



Government Regulations - EALs

Governments are looking for ways to regulate the use of lubricants that could potentially harm the environment

- Hydraulic Environmental Triglycerides (**HETG**)
- Hydraulic Environmental Polyalkylene Glycols (**HEPG**)
- Hydraulic Environmental Synthetic Esters (**HEES**)
- Hydraulic Environmental PAO (polyalphaolefins) and related products (**HEPR**)
- **Undefined**
  - Estolides (Biosynthetic), EcoHydrocarbons (Renewable Hydrocarbons)

Conventional Vegetable Fluids (HETG)

- Excellent Frictional Characteristics and Viscosity Index.
- Oxidative Stability Weakness:
  - Under high temperature application more susceptible to oxidation.
  - Typically shorter drain intervals recommended.
- Hydrolytic Stability Weakness:
  - More prone to hydrolysis in the presence of water (typically > 1%).
- Compatible with most seals and metals until hydrolyzed.

Polyalkylene Glycol Synthetic (HEPG)

- Fire Resistant.
- Good hydrolytic stability.
- Not Compatible with Conventional Seals or Filters.
- Not Compatible with Petroleum, Vegetable, Esters.
- Absorbs Water (creates rust and acid).

Synthetic Esters (HEES)

- Oxidative Stability:
  - Under high temperature application more susceptible to oxidation.
  - Typically shorter drain intervals recommended.
- Hydrolytic Stability Weakness:
  - More prone to hydrolysis in the presence of water (typically > 1%).
- Compatible with most seals and metals when new.
- More expensive than vegetable oil-based products

PAO and related Products (HEPR)

- Excellent Frictional and Anti-wear Performance.
- Similar durability to mineral and synthetic oils.
- Good Hydrolytic Stability.
- Long Fluid Life.
- Separates From Water.
- Good Seal Compatibility.
- Broad Temperature Range.

Hydraulic Fluid EAL Comparison

	HETG	HEPG	HEES	HEPR	Mineral Oil
Hydrolytic Stability	Poor	Excellent	Poor	Good	Excellent

Typical Base Oil Hydrolytic Stability Comparisons

- Group II, Group III, Renewable Hydrocarbons, PAOs, and PAGs are typically excellent when it comes to hydrolytic stability
- Meanwhile, Esters perform very poorly
  - The exception are Estolides, which tend to perform very well.

What is Hydrolytic Stability?

- For most lubricants and oils in general, water is a very destructive.
- Hydrolytic stability is how stable the fluid is in the presence of water.
  - It is also the ability of a fluid to resist hydrolysis.
- Oils are inherently hygroscopic, meaning that they will naturally absorb moisture from the air.
- In order to determine how susceptible oils are to water, tests can be run to determine when and how much hydrolysis will occur.
- Additives can either hurt or help hydrolytic stability
  - Additives with high TAN can cause more rapid hydrolysis, leading to a faster breakdown.
  - Additives such as epoxides andcarbodi-imides can act as “acid catchers” but it is important to consider their impact on other properties, such as oxidation and anti-wear.

What are the effects of hydrolysis on oils?

- Formations of acids (usually carboxylic)
- Rust
- Corrosion
- Valve Sticking
- Degradation of the oil
  - Viscometric changes (impacting VI, equipment performance)
  - Increased seal swelling (leaks, spills, poor machine performance)
- Decreased load-carrying capacity of oil

How do we measure hydrolytic stability?

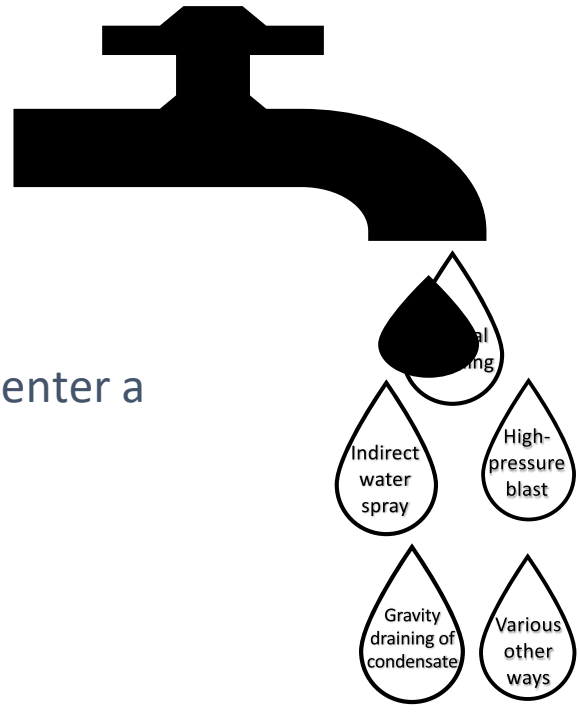
ASTM D2619 is the current method that assesses the hydrolytic stability of oils.

ASTM D2619 evaluates:

- Weight change of copper
- Appearance of copper (ASTM D130)
- Change in TAN of oil layer
- Change in TAN of water layer
- Also may report change in viscosity

ASTM INTERNATIONAL

How does water enter a system?



ASTM D2619 Method – How Does It Work?

The common test method to check hydrolytic stability is known as ASTM D2619 – Hydrolytic Stability of Hydraulic Fluids (Beverage Bottle Method).

This test, which is run at 93 °C, takes 75 g of fluid, 25 g of distilled water, a copper strip and seals them into a Coke Bottle. The bottles are sealed and then are rotated at 5 rpm for 48 hours . Afterwards, the layers are then separated, and full analysis is performed.

Photo from King Industries

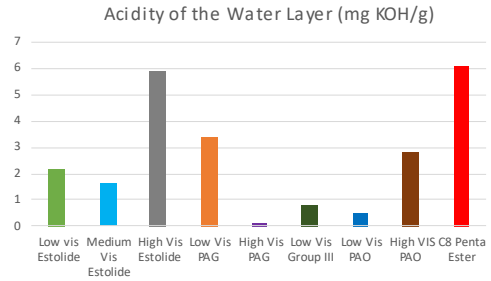
Example of Hydrolytic Stability Results

Test Method: ASTM D2619 Conditions: 93°C, 144 hours (modified from 48 hours)	Estolide ISO VG 680	PAO ISO VG 460	PAO ISO VG 1000	Bright Stock Paraffinic	Bright Stock Naphthenic
Weight Change of Copper Panel, (mg/cm2)	-0.033	-0.092	-0.033	0.00	-0.033
Appearance of Copper	Shiny, 2c	Shiny, 2c	Shiny, 1b-2c	Shiny, 1b-2c	Shiny, 1b
% Change in Viscosity	-0.67	-0.41	-0.64	+0.04	+11.3
Change in Acid Number, mg KOH/g	+0.17	+0.05	+0.06	+0.01	+0.17
Total Acidity of Water Layer, mg KOH/g	0.17	3.11	0.89	0.11	0.06

Property	Unit	Parker Denison Limit	Medium Vis Estolide + Comm Adpack	Commercial EAL HF 32	Commercial EAL HF 46
Copper Weight Loss	mg/cm2	0.2 max	0	0	0
Copper Appearances	rating	-	1b	2a	2c
TAN Increase in oil layer	mg KOH/g	-	0.02	0.04	0.34
TAN Increase in water layer	mg KOH/g	4.0 max	0.5	-	1.39

Base Oil Comparison –ASTM D2619

	Low Vis Estolide	Medium Vis Estolide	High Vis Estolide	Low Vis PAG	High Vis PAG	Low Vis Group III	Low Vis PAO	High Vis PAO	C8 Pentaerythritol ester	Complex Ester
Weight Change of Copper Panel (mg/cm2)	-0.042	-0.117	-0.033	-0.117	0.008	-0.008	0.017	-0.058	-1.250	-0.192
Appearance of Copper Panel	1b	1b	1b	1b	2c	1b	dull, dark brown	1b	dull, dark brown	1b
Change in Acid Number - D974 (mg KOH/g)	0.070	0.000	-0.050	0.010	0.000	0.010	0.000	0.010	9.000	Sample formed a stable emulsion
Total Acidity of Water Layer (mg KOH/g)	2.2	1.6	5.9	3.4	0.11	0.8	0.48	2.8	6.1	



Hydrolytic Stability Torture Test

Hydrolytic Stability Test

- Variety of commercial base fluids evaluated with 1% deionized water
- Based on worst case scenarios of lubricant contamination
- Temperature: 180°F
- Duration: 3 months (12 weeks)
- Stir rate: 500 rpm, stirring continuously
- Sealed container
- Only the TAN of oil layer was evaluated for simplicity.

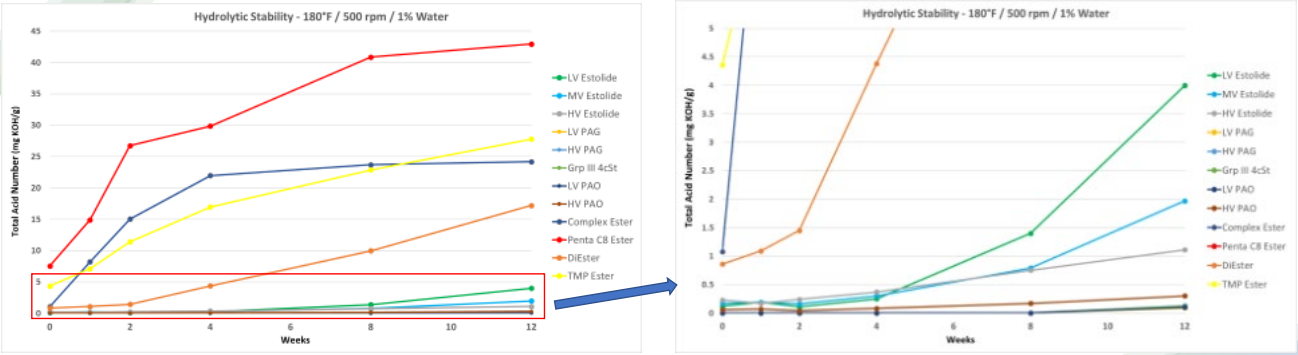
Purpose of Testing:

- Understand the long-term hydrolytic stability of commercial base oils
  - When exposed to water and heat
  - How does TAN change over time?
  - Compare several different types of base oils

Hydrolytic Stability Torture Test Results

Hydrolytic Stability								
Sample	Viscosity		TAN (mg KOH/g)					
	KV40 (cSt)	KV100 (cSt)	0	1	2	4	8	12
LV Estolide	23.1	4.9	0.12	0.19	0.11	0.25	1.4	4
MV Estolide	148.1	22.1	0.17	0.19	0.16	0.3	0.79	1.97
HV Estolide	668.4	75.9	0.23	0.17	0.24	0.37	0.75	1.11
LV PAG	16.6	3.75	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.09
HV PAG	658	72	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.13
Grp III 4cSt	20.7	4.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.12
LV PAO	17.29	3.95	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.1
HV PAO	415.1	48.8	0.06	0.07	0.04	0.08	0.17	0.3
Complex Ester	446	54.1	1.08	8.23	15.03	21.98	23.7	24.18
Penta C8 Ester	25.3	5.2	7.55	14.91	26.75	29.87	40.87	42.95
DiEster	11.8	3.2	0.86	1.09	1.45	4.38	9.97	17.21
TMP Ester	47.1	9.4	4.36	7.13	11.42	16.95	22.88	27.77

Graphs of the Hydrolytic Stability Torture Test



Preventing Hydrolytic Breakdown

- To prevent or substantially slow hydrolysis, employ “bi-based” base oils that have all the following:
  - Starting Total Acid Number must be low
  - High degree of molecular complexity
  - Provides exceptional steric hindrance benefits
  - Oxidatively stable
  - Great demulsibilitycharacteristic (ASTM D1401)

Importance of Good Hydrolytic Stability

- Less molecular breakdown of the lubricant, ensuring longer performance
- Can particularly help in areas where there is a high chance of water contamination, including marine applications, other outdoor environments, hydraulic systems, etc.
- Strongly helps to avoid rust and corrosion issues, helping to limit damage to systems, system malfunctions, etc.

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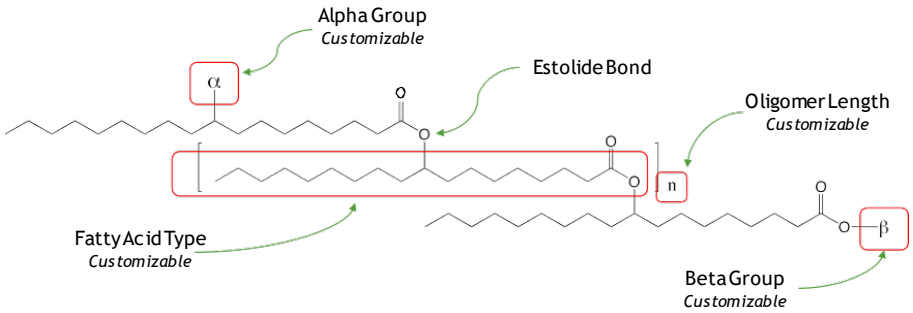
Latest in Biosynthetic Base Oils – Evaluating Estolide Performance Characteristics in Expanding Viscosity Ranges

Dr. Matthew Kriech, R&D, Biosynthetic Technologies, Indianapolis, Indiana

Estolides are an environmentally acceptable base oil that is referred to as a “biosynthetic”. They are known for their performance characteristics and use as a petroleum replacement in lubricant formulations. The number of estolide products being offered to the market is growing as new viscosities are being offered. We look at how these products compare to each other and to other commercial base oils in the industry. Estolides are very versatile and can be used in several industries and products within the marine, automotive, and industrial markets. Findings from example formulations will show performance benefits of these estolides.

SESSION DAY & DATE: Monday, May 17, 2021

Estolides are Highly Customizable



Synthetic Variations

- Use of different fatty acid feedstocks
- Oligomerization (n)
- Unique functional groups (α, β)

Performance Focus

- Increased or reduced viscosity
- Improved cold temperature properties
- Increased or decreased polarity
- Improved oxidative stability

2

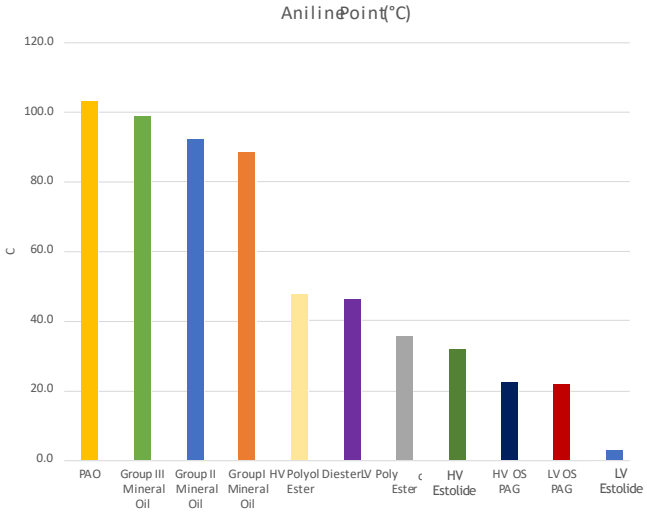
Estolide Physical Properties

	Estolide LV	Estolide HV
Kinematic Viscosity @ 100°C cST	4.7	78.8
Kinematic Viscosity @ 40°C cST	20.7	695.6
Viscosity Index	152	197
Pour Point °C	-21	-18
Flash Point °C	242	288
Total Acid Number mg KOH/g	0.1	0.3
Color D1500	1	2
Water ppm	500 max	500 max
Specific Gravity	0.90 - 0.92	0.91 - 0.93
Noack	8.3	1.5
KRL Shear Stability, 20 hours % loss	-2.07%	0.98%

3

Base Oil Performance

Solvency - Aniline Point – ASTM D611



Base Oil	KV 100°C (cSt)	KV 40°C (cSt)	Aniline Point (°C)
Group I Mineral Oil	6.3	50	88.1
Group II Mineral Oil	6.6	44.0	92.0
Group III Mineral Oil	6.5	37.0	98.4
PAO	7.0	38.0	102.7
LV OS PAG	6.5	28.0	21.8
HV OS PAG	12.0	150.0	22.4
Diester	5.5	28.0	46.0
LV Polyol Ester	8.8	53.0	35.4
HV Polyol Ester	17.5	178.0	47.1
Estolide LV	4.5	22.0	2.7
Estolide HV	75.0	680.0	31.8

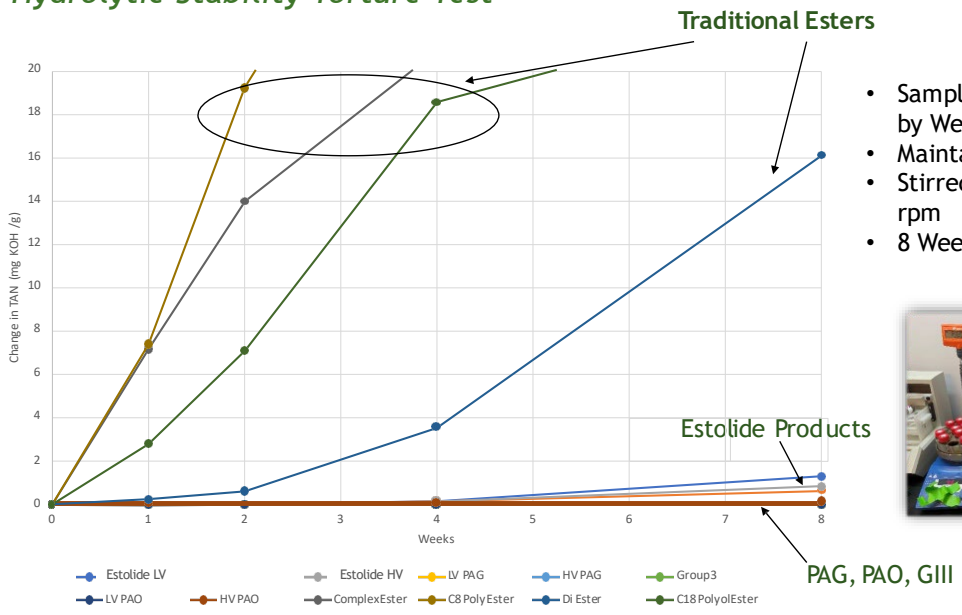
Hydrolytic Stability – ASTM D2619

Even at 3 times the recommended test duration the Estolide base oil shows excellent hydrolytic stability

Test Method: ASTM D2619 Conditions: 93°C, 144 hours (modified from 48 hours)	Estolide ISO VG 680	PAO ISO VG 460	PAO ISO VG 1000	Bright Stock Paraffinic	Bright Stock Naphthenic
Weight Change of Copper Panel, (mg/cm2)	-0.033	-0.092	-0.033	0.00	-0.033
Appearance of Copper	Shiny, 2c	Shiny, 2c	Shiny, 1b-2c	Shiny, 1b-2c	Shiny, 1b
% Change in Viscosity	-0.67	-0.41	-0.64	+0.04	+11.3
Change in Acid Number, mg KOH/g	+0.17	+0.05	+0.06	+0.01	+0.17
Total Acidity of Water Layer, mg KOH/g	0.17	3.11	0.89	0.11	0.06

6

Hydrolytic Stability Torture Test



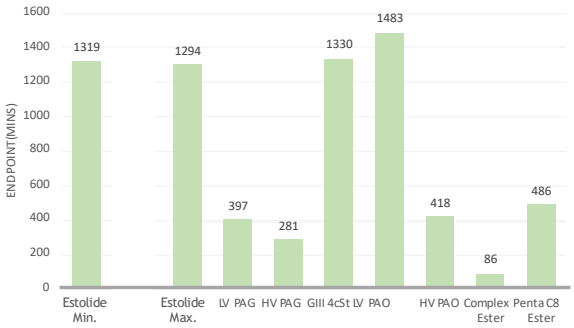
- Sample Mixed with 1% Water by Weight
- Maintained @ 180°F
- Stirred Continuously at 500 rpm
- 8 Week Study

7

Oxidative Stability Study – ASTM D2272

- All base oils treated with 0.5% Phenolic and 0.5% Aminic Anti-Oxidant

Oxidative Stability Update (mins) ASTM D2272			
Sample	KV40 cSt	KV100 cSt	End Point
Estolide LV	4.9	23.1	1319
Estolide HV	75.9	668.4	1294
LV PAG	3.75	16.6	397
HV PAG	72	658	281
GIII 4cSt	4.5	20.7	1330
LV PAO	3.95	17.29	1483
HV PAO	48.8	415.1	418
Complex Ester	54.1	446	86
Penta C8 Ester	5.2	25.3	486
DiEster	3.2	11.8	TBD
TMP Ester	9.4	47.1	TBD

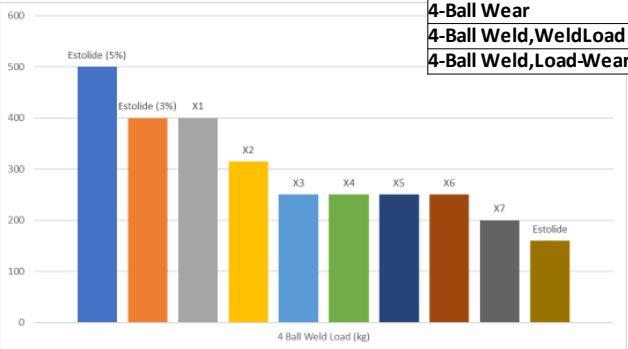


8

Gear Oil ISO680 - Estolide (Ecolbael)

Formulation	
Component	Gear Oil
Estolide	95%
Additive	5%

Performance Data	Method	Unit	ISO 680 Gear Oil
Viscosity KV 100°C	ASTM D445	cSt	**77.1**
Viscosity KV 40°C	ASTM D445	cSt	**682.5**
Viscosity Index	ASTM D2270	-	**195**
Pour Point	ASTM D97	C	**-21**
Gardner Color	ASTM D1544	-	**5.5**
Water Content	ASTM D6304	wt%	**< 0.01**
4-Ball Wear	ASTM D4172	mm	**0.31**
4-Ball Weld, Weld Load	ASTM D2783	kgf	**500**
4-Ball Weld, Load-Wear Index	ASTM D2783	kgf	**42.06**



Gear Oil ISO220 - Estolide (Ecolabel)

Formulations	
Component	Gear Oil
Estolide	97.1%
Additive Package	2.9%

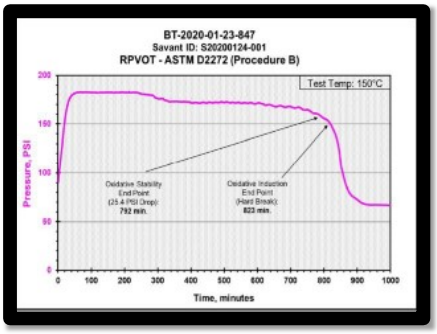
Results	
Test	Gear Oil
Pour Point (°C)	-21
KV40 (cSt)	226.58
KV100 (cSt)	30.659
VI	178
Specific Gravity (60 °F)	0.9189
Flash Point (°C) ASTM D92 - Flash Point, Cleveland Open Cup	272
Four Ball Wear (Average Wear Scar) ASTM D4172 - Four Ball Wear	0.321
Four Ball Weld ASTM D2783 - Four Ball Extreme Pressure - Above 400 kg	Last Non-Seizure Load = 126 kg, Weld Point = 315 kg Load Wear Index = 59.09
Rust Testing, B Salt Water ASTM D665 - Rust Preventing Characteristics - 4 Hours	Pass

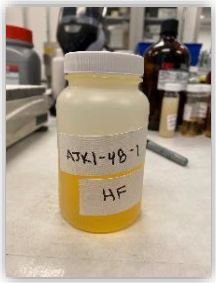
Gear Oil ISO220 - Estolide (Ecolabel)

Test Method	Property	DIN51517-3	China GB 5903 CKC	Estolide Gear Oil	Commercial A	Commercial B
ASTM D2270	KV40 (cSt)	In Grade	In Grade	221.6	216.5	223.4
	KV100 (cSt)	N/A	Report	30.3	26.9	26
	VI	≤ 90	≤ 90	178	159	148
ASTM D974	TAN (mg KOH/g)	Report	N/A	0.68	1.57	0.62
ASTM D4052	Density @ 15C (kg/m3)	Report	N/A	918.1	920.1	936.8
ASTM D5950	Pour Point (C)	≤ -9	≤ -9	-21	-42	-30
ASTM D92	Flash Point (C)	≥ 200	≥ 200	260	246	300
DIN 51777-2	Water Content (%)	≤ 0.1	Trace	0.01	nd	nd
ASTM D130	Copper Corrosion	1 max	1 max	1B	1B	1A
ASTM D665A	Rust Performance	Pass	N/A	Pass	**Fail**	Pass
ASTM D1401	Demulsibility (min)	≤ (30)	N/A	42-38-00 (15)	41-36-03 (15)	**43-33-04 (60)**
Flender Foam	Volume Increase (%)	≤ 15	N/A	8	**16**	4
ISO 12152	Total Air after 5 (%)	≤ 10	N/A	5	9	3
Oxidative Stability	KV100 Change (%)	≤ 6	≤ 6	1.49	1.67	1.97
ASTM D2893	Precip # Change, mL	≤ 0.1	≤ 0.1	0	0	0

Hydraulic Formulation ISO46 – Estolide & PAO BLEND

Formulation	
Component	Hydraulic
Estolide	68.43%
PAO	30.75%
Additive	0.82%





Test	Hydraulic
Pour Point (°C)	-32
KV40 (cSt)	44.41
KV100 (cSt)	8.813
VI	182.9
Specific Gravity (60 °F)	0.8763
Flash Point (°C) ASTM D92 - Flash Point, Cleveland Open Cup	174
Oxidative Stability (RPVOT) ASTM D2272- Rotating Pressure Vessel Oxidation Test (RPVOT) Method B - End of Test/Hard Break	Oxidative Stabilty End Point= 792 minutes, Oxidative Induction En Point= 823 minutes
Hydrolytic Stability ASTM D2619- Hydrolytic Stability of Hydraulic Fluids	Weight change of copper panel (mg/cm²) = 0.00, Appearance of copper panel = 1B Change in Acid Number = 0.060 mg KOH/g Total acidity of the water layer (mg KOH) = 0.010

Hydraulic Formulation ISO46 – Estolide & Group III BLEND

Formulation	
Component	Hydraulic
Estolide	39.7%
Group III	59.3%
Additive	0.87%

Environmental Performance		
Biodegradability	OECD 301B	75%
Ecotoxicity		
Pseudokirchneriella subcapitata	OECD 201, 100 ppm for 72 hrs	Not acutely toxic
Daphnia magna	OECD 202, 100 ppm for 48 hrs	Not acutely toxic
Pimephales promelas	OECD 203, 100 ppm for 96 hrs	Not acutely toxic

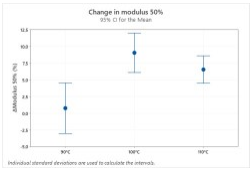
Performance Data	Method	Unit	ISO 46 Hydraulic
Viscosity KV 100°C	ASTM D445	cSt	**8.43**
Viscosity KV 40°C	ASTM D445	cSt	**46.0**
Viscosity Index	ASTM D2270	-	**162**
Pour Point	ASTM D97	C	**-26**
Flash Point (COC)	ASTM D92	C	**224**
Total Acid Number	ASTM D664	mg KOH/g	**0.39**
Color	ASTM D1500	-	**<1**
Gardner Color	ASTM D1544	-	**5.5**
Water Content	ASTM D6304	wt%	**< 0.01**
Rust Testing, A Fresh Water	ASTM D665	-	**Pass**
Rust Testing, B Salt Water	ASTM D665	-	**Pass**
Copper Corrosion	ASTM D130	Rating	**1a**
Demulsibility	ASTM D1401	-	**40, 40,0 (15) - Pass**
Foam	ASTM D892	-	**0/0,0/0,0/0**
4-Ball Wear	ASTM D4172	mm	**0.413**
4-Ball Weld, Weld Load	ASTM D2783	kgf	**160**
4-Ball Weld, Last Non-Seizure Load	ASTM D2783	kgf	**100**
4-Ball Weld, Load-Wear Index	ASTM D2783	kgf	**39.96**
Hydrolytic Stability			
TAN Increase in oil layer	ASTM D2619	mg KOH/g	**0.24**
TAN Increase in water layer	ASTM D2619	mg KOH/g	**0.63**
Oxidative Stability, RPVOT	ASTM D2272	min	**584**

Hydraulic Formulation ISO 68 – Estolide & Group III BLEND

Formulation	
Component	Hydraulic
Estolide	58.5%
GIII 4	40.2%
Additive	1.3%

Environmental Performance		
Biodegradability	OECD 301B	77%
Ecotoxicity		
Pseudokirchneriella subcapitata	OECD 201, 100 ppm for 72 hrs	Not acutely toxic
Daphnia magna	OECD 202, 100 ppm for 48 hrs	Not acutely toxic
Pimephales promelas	OECD 203, 100 ppm for 96 hrs	Not acutely toxic

Performance Data	Method	Unit	ISO 68 Hydraulic
Viscosity KV 100°C	ASTM D445	cSt	**11.1**
Viscosity KV 40°C	ASTM D445	cSt	**65.8**
Viscosity Index	ASTM D2270	-	**163**
Pour Point	ASTM D97	C	**-26**
Gardner Color	ASTM D1544	-	**4.2**
Water Content	ASTM D6304	wt%	**< 0.01**
Rust Testing, A Fresh Water	ASTM D665	-	**Pass**
Rust Testing, B Salt Water	ASTM D665	-	**Pass**
Demulsibility	ASTM D1401	-	**40, 40,0 (5) - Pass**
Foam	ASTM D892	-	**0/0,10/0,0/0**
Copper Corrosion	ASTM D130	Rating	**1a**
Oxidative Stability, RPVOT	ASTM D2272	min	**1112**
4-Ball Wear	ASTM D4172	mm	**0.52**
4-Ball Weld, Weld Load	ASTM D2783	kgf	**160**
4-Ball Weld, Last Non-Seizure Load	ASTM D2783	kgf	**80**
4-Ball Weld, Load-Wear Index	ASTM D2783	kgf	**32.84**



AEGIR Marine

Approved

16

Hydraulic Fluid Formulation – Estolide & HOSO Blend

ISO 46 HOSO Hydraulic Formulation	
Component	%
LV Estolide	35
HV Estolide	30.5
High Oleic Soy Oil	30
Additive	4.5
Total	100

ISO 46 Estolide Hydraulic Formulation	
Component	%
LV Estolide	55
HV Estolide	35.5
Oleic Estolide	5
LZ 4370G Additive	4.5
Total	100

ISO 68 HOSO Hydraulic Formulation	
Component	%
LV Estolide	15.5
HV Estolide	50
High Oleic Soy Oil	30
Additive	4.5
Total	100

ISO 68 Estolide Hydraulic Formulation	
Component	%
LV Estolide	30.5
HV Estolide	60
Oleic Estolide	5
Additive	4.5
Total	100

Project Sponsored by the United Soybean Board Grant USB#2140-362-0705

17

Hydraulic Fluid Formulation – Estolide & HOSO Blend

Environmental Performance		Results	Target
Biodegradability	OECD 301B	TBD	> 60%
Ecotoxicity			
Pseudokirchneriella subcapitata	OECD 201 100 ppm for 72 hrs	Not acutely toxic	Not acutely toxic
Daphnia magna	OECD 202 100 ppm for 48 hrs	Not acutely toxic	Not acutely toxic
Pimephales promelas	OECD 203 100 ppm for 96 hrs	Not acutely toxic	Not acutely toxic

- Results are pending from the Environmental Lab
- Calculated Biodegradability is expected to be greater than 75%
- Review of additive technology suggest the material will have no toxicity concerns

Project Sponsored by the United Soybean Board Grant USB#2140-362-0705

Hydraulic Fluid Formulation – Estolide & HOSO Blend

Properties	Test Method	Parameters	ISO 46 HOSO	ISO 68 HOSO	ISO 46 Estolide	ISO 68 Estolide
Viscosity - KV 40°C	**ASTM D445**	**cSt**	48.6	70.02	46.2	73.9
Viscosity - KV 100°C	**ASTM D445**	**cSt**	9.25	12.24	8.51	12.25
Viscosity Index	**ASTM D2270**	**-**	176	174	163	164
Specific Gravity	**ASTM D4052**		0.9134	0.9153	0.9103	0.9123
Gardner Color	**ASTM D1544**	**-**	3.2	3.7	3.3	3.9
Pour Point	**ASTM D97**	**°C**	-19	-21	-22	-22
Flash Point (COC)	**ASTM D92**	**°C**	212	210	210	210
Total Acid Number	**ASTM D664**	**mg KOH/g**	0.79	0.83	0.78	0.86
Water Content	**ASTM D6304**	**wt%**	0.02	<0.02	0.02	0.02
Rust Testing, A - Fresh Water (24h)	**ASTM D665**	**-**	PASS	PASS	PASS	PASS
Rust Testing, B - Salt Water (24h)	**ASTM D665**	**-**	PASS	FAIL	PASS	PASS
Copper Corrosion	**ASTM D130**	**Rating**	1A	1A	1A	1A

Project Sponsored by the United Soybean Board Grant USB#2140-362-0705

Hydraulic Fluid Formulation – Estolide & HOSO Blend

Properties	Test Method	Parameters	ISO 46 HOSO	ISO 68 HOSO	ISO 46 Estolide	ISO 68 Estolide
Demulsibility	ASTM D1401	-	40/40/0 (10)	40/40/0 (15)	40/40/0 (10)	40/40/0 (15)
Foam	ASTM D892	-	450/90, 75/0, 50/0	45/0, 135/0, 100/0	30/0, 80/0, 30/0	390/100, 110/0, 30/0
4-Ball Weld, Weld Load	ASTM D2783	kgf	200	200	200	200
4-Ball Weld, Last Non-Seizure Load	ASTM D2783	kgf	100	100	100	80
4-Ball Weld, Load Wear Index	ASTM D2783	kgf	40.59	40.61	40.71	33.38
Oxidative Stability, RPVOT	ASTM D2272	min	223	220	723	762
Hydrolytic Stability, Change in Acid Number	ASTM D2619	mg KOH/g	.46	.47	.29	.22
Hydrolytic Stability, Copper Apperance	ASTM D2619	-	1b	1b	1b	1b

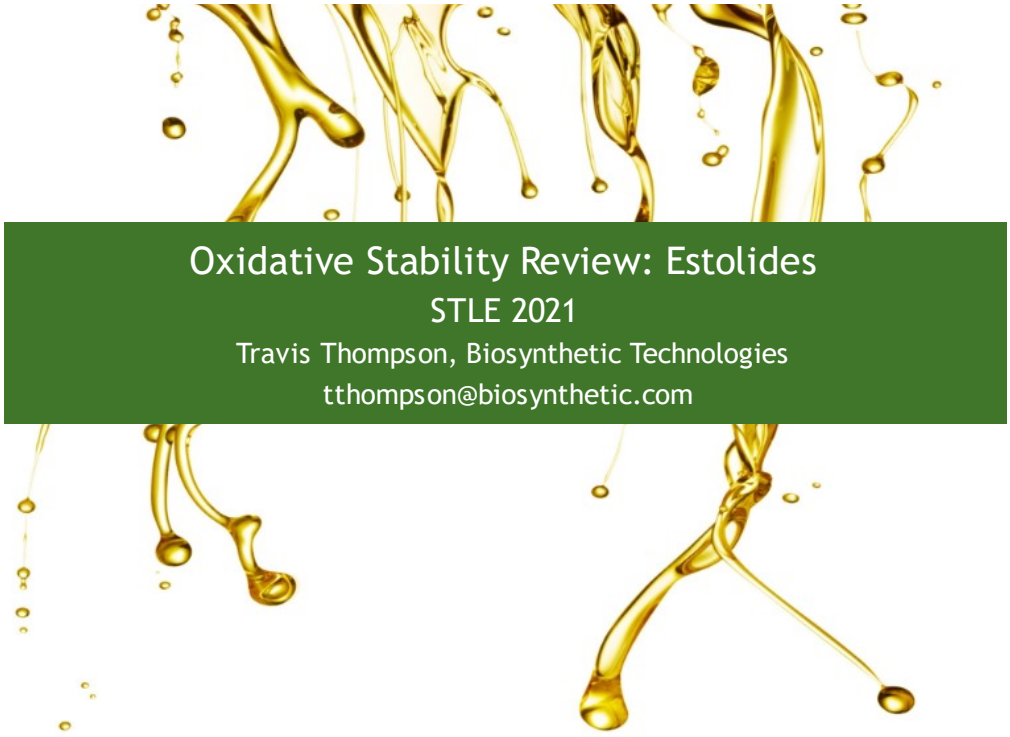
Project Sponsored by the United Soybean Board Grant USB#2140-362-0705

Oxidative Stability of Estolides

Mr. T. Thompson, R&D, Biosynthetic Technologies, Indianapolis, Indiana

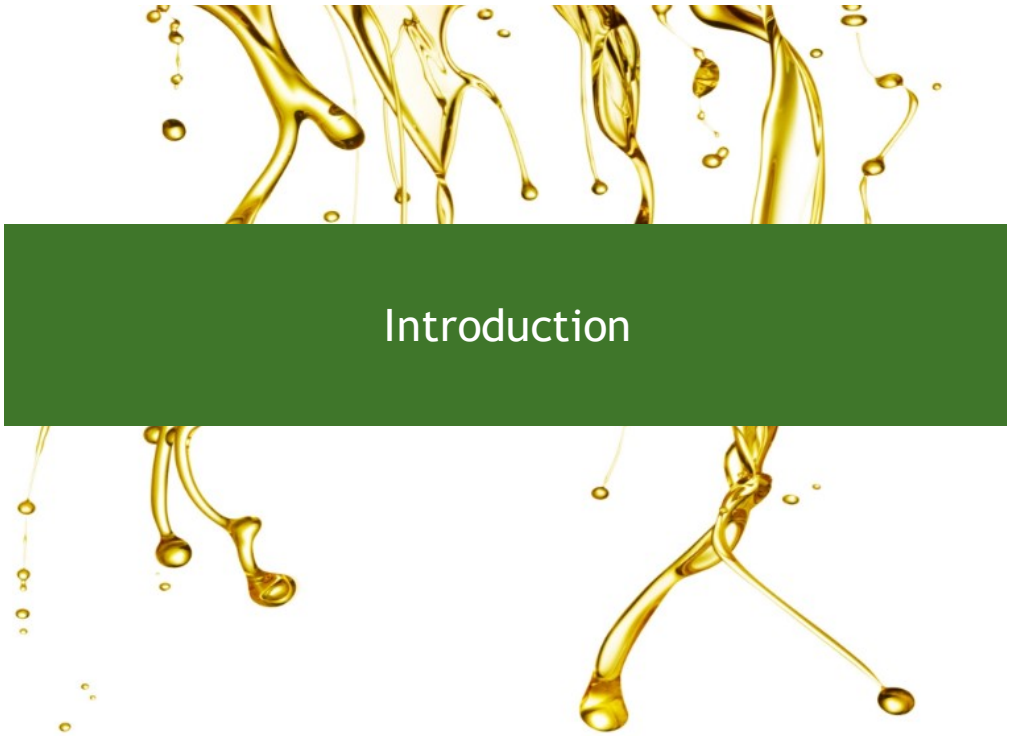
A set of base oil samples, including estolides, esters, PAGs, PAOs, and mineral oils were tested for their resistance to oxidation, according to the industry standard RPVOT test (ASTM D2272). The raw data from these experiments suggest that the RPVOT method underestimates the oxidative stability of estolides and esters relative to the other base oils tested. Different oxidative stability methods were also explored and a comparative analysis was performed.

SESSION DAY & DATE: Tuesday, May 18, 2021



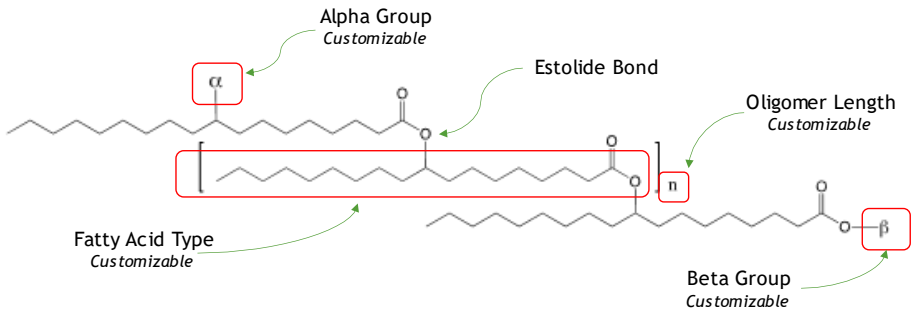
Overview

- Introduction to Estolides
- Review of Oxidation Mechanisms and Antioxidants
- Antioxidant Optimization Studies for Estolides
- Base Oil Oxidative Stability Comparison
- Method Review: RPVOT vs. RSSOT
- Formulation Advantages of Estolides



Estolides

- Estolides are a class of synthetic base oils with several performance advantages over traditional products
- These products have high oxidative stability, hydrolytic stability, and favorable environmental characteristics
- Estolide products can be custom-tailored to meet the needs of nearly any application - properties such as pour point, viscosity, polarity, and others can be optimized



5

Oxidation Mechanism

- **Initiation:** RH → R•
- **Propagation:** R• + O_2 → ROO•
  ROO• + RH → ROOH + R•
- **Branching:** ROOH → RO• + •OH
  RO• + RH → ROH + R•
  •OH + RH → H_2O + R•
- **Termination:** R• + R•
  R• + ROO•
  ROO• + ROO•
  RO• + R•

(needs high temp, light/catalyst)

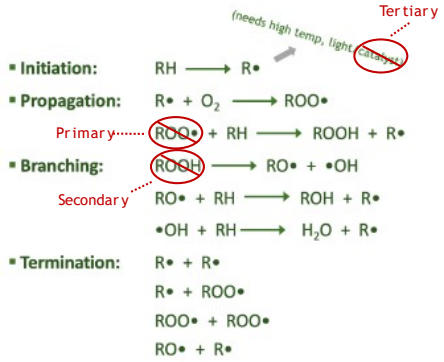
- Initiation requires high temperature and light or other catalyst source
- Free radicals (R•) are highly reactive species - once formed, a cascade of secondary reactions follow, until the radicals are terminated
- Termination products can cause increases in fluid viscosity, formation of sludge, increased acidity, and accelerate further oxidation
- If the process is interrupted prior to termination, these negative effects can be avoided
- Additives that interrupt this cascade of chemical reactions, or prevent it from occurring in the first place, are called antioxidants

6

Types of Antioxidants

- Primary
  - Function as peroxide radical scavengers (**capture -ROO•**)
  - Includes aromatic amines (e.g. alkylated diphenylamines) and hindered phenols (e.g. BHT)
- Secondary
  - Function by decomposing hydroperoxides (**capture -ROOH**)
  - Includes phosphites , sulfites, thiocarbamates, metal dithiocarbamates , ZDDP
- Tertiary
  - Function by inhibiting formation of **catalyst species** (typically oxidized metal or metal surfaces)
  - Usually added as metal deactivators
  - Includes aromatic triazoles (TTA), substituted thiadiazoles and azoles

Antioxidants:
Modes of Oxidation Interruption

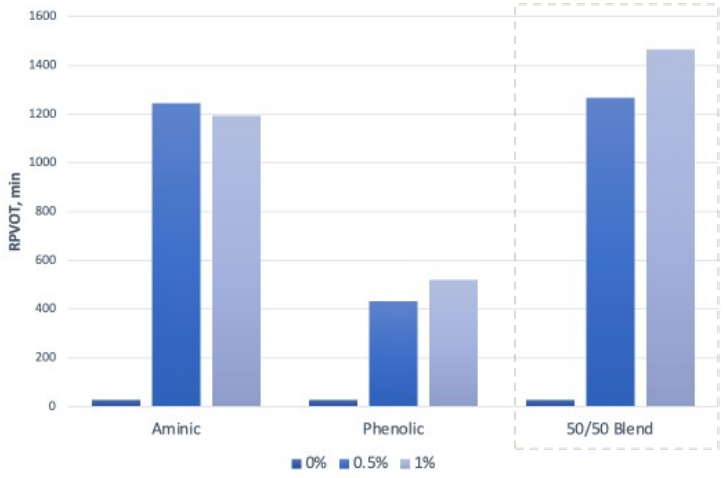


Antioxidant Selection

- For the purposes of this initial evaluation, only primary antioxidants were screened, with a focus on aminic and phenolic chemistries
- Aminic additives are typically recommended for higher temperatures (>120C), and phenolic for lower temperatures (<120C)
- Typical treat rates are anywhere from 0.1 % 2.0%, depending on the base oil, the additive, and the application
- Aminic/phenolic chemistries are known to yield synergistic AO effects, so a combination of these additives was also tested

Antioxidant Optimizations

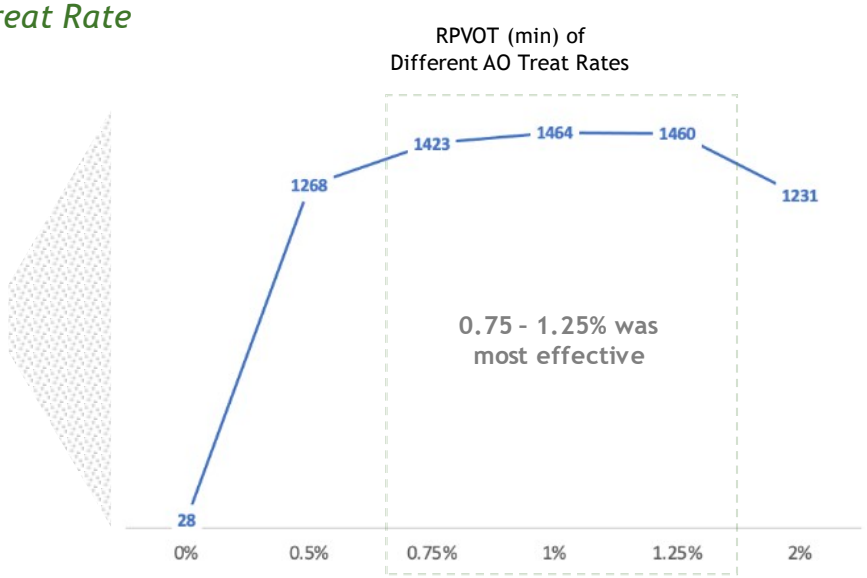
Antioxidant Screening



- RPVOT screening of different AO additives on a low viscosity estolide
- Additives tested
  - *Aminic (nonylated diphenylamine)*
  - *Phenolic (2-6-tert-butylphenol)*
  - *50/50 blend of aminic/phenolic chemistries*
- Additives tested at 0.5% and 1%
- 50/50 blend was most effective

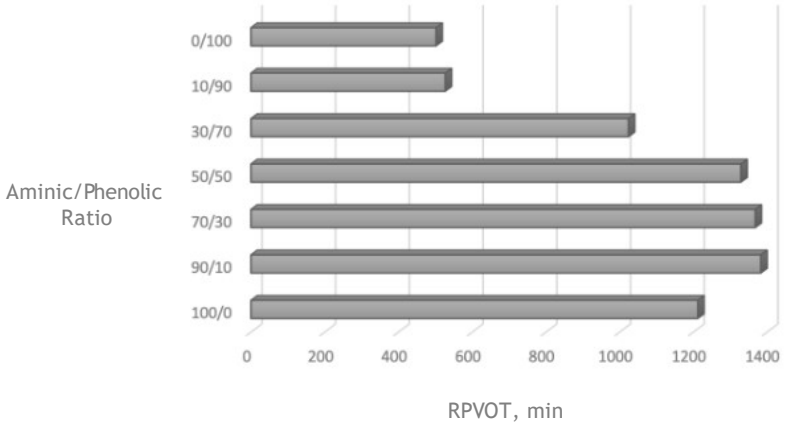
AO Optimization, Treat Rate

- Using the 50/50 aminic/phenolic blend, RPVOT was measured at different treat rates in the low viscosity estolide
- Range tested was 0%- 2%
- Effectiveness began to taper at 2%



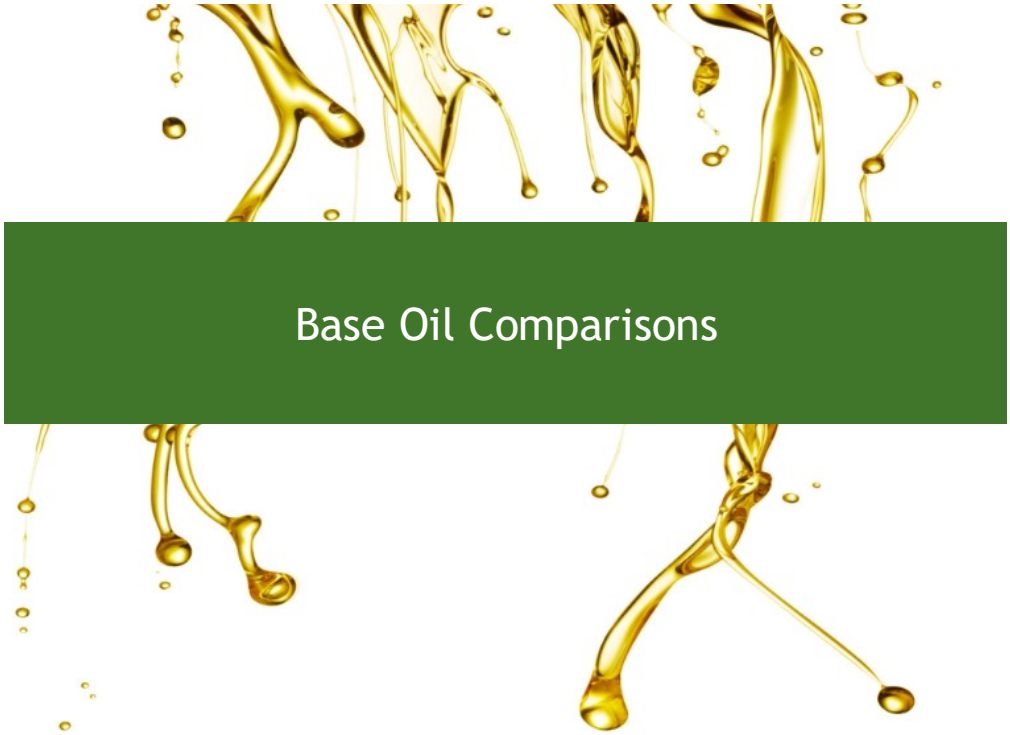
11

AO Optimization, Aminic Phenolic/Ratio



- **Various ratios of the aminic/phenolic chemistries were used at 1% net treat on the low viscosity estolide, and tested on RPVOT**
- **The most effective ratio tested was 90/10 aminic/phenolic**
- **Conclusions:**
  - Primary useful AO additive chemistry is aminic
  - Small amounts of phenolic chemistry may be added for a net synergistic effect on AO behavior

12

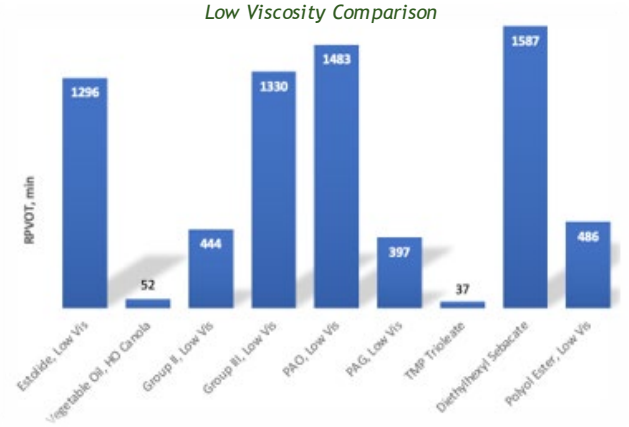


Base Oil Comparisons

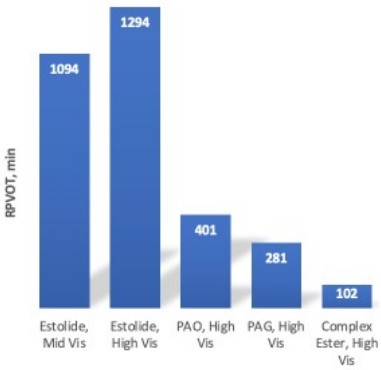
Product Comparison

- 1% of the 50/50 aminic/phenolic AO blend was added to a variety of low vis base oils (below), and run on RPVOT
- Estolide product was comparable to other high quality base stocks, including Group III, PAO, and diethylhexyl sebacate

Low Viscosity Comparison



High Viscosity Comparison



- 1% of the 50/50 aminic/phenolic AO blend was added to a variety of high vis base oils (above), and run on RPVOT
- Estolide products were superior to the other base oils evaluated, including PAO, PAG, and a complex ester

Method Comparisons: RPVOT and RSSOT

Oxidation Tests: RPVOT & RSSOT

- RPVOT (Rotating Pressure Vessel Oxidation Test) is the most common test method used to characterize relative oxidation times of lubricants
- BT has access to another instrument in the lab, which can run RSSOT (Rapid Small Scale Oxidation Test)
- To determine if there was a correlation between the methods, methods were run on various base oil types and the data was analyzed

RPVOT Analyzer

RSSOT Analyzer

RPVOT & RSSOT Comparison

Less sample required (RSSOT) →

Shorter test durations (RSSOT) →

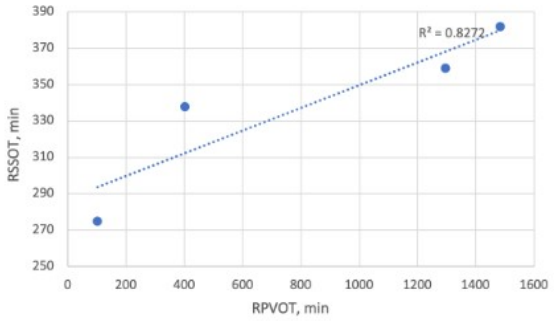
	RPVOT	RSSOT
Equipment	RPVOT Test Apparatus	Anton Parr Rapidoxy 100
Method	D2272	D7545
Volume	50 mL	5 mL
Temperature	150C	140C
Pressure O2	90 psi	102 psi (700 kPa)
End of Test	25.4 psi drop (-28%)	10 psi drop (-10%)
Time	As long as 2000 min	As long as 500 min

17

RPVOT & RSSOT Correlation

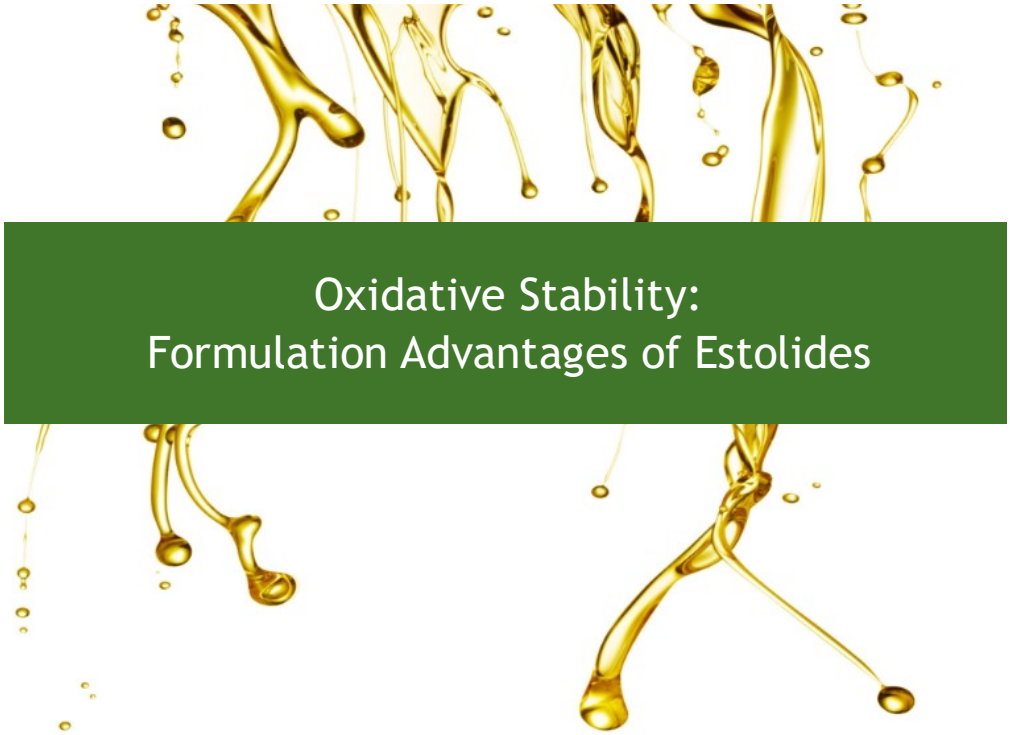
	RPVOT ASTM D2272 minutes	RSSOT ASTM D7545 minutes
Estolide, Low Vis	1296	359
PAO, Low Vis	1483	382
PAO, High Vis	401	338
Complex Ester, High Vis	102	275

- Four (4) samples were run on both RPVOT and RSSOT
- Each sample had the same AO blend added - a 1% treat, half aminic and half phenolic



- Data was positively correlated, with an R2 value of 0.8272
- Initial data indicates RSSOT may be a good alternative to RPVOT, but more testing is needed

18



Oxidative Stability: Formulation Advantages of Estolides

Oxidation Benefits of Estolide Formulations

- **Three ISO 68 formulations were blended - each contained the same additive type and concentration**
- **Only the base oil types were modified**
  - Form. 1: complex ester with PAO6
  - Form. 2: high vis estolide with PAO6
  - Form. 3: mid-vis estolide with PAO6
- **Oxidative stability gains of 25-35%!**

	Formulation 1 (Complex Ester)	Formulation 2 (Estolide)	Formulation 3 (Estolide)
Estolide, Mid Vis	-	-	51%
Estolide, High Vis	-	25%	-
High Vis Complex Ester	25%	-	-
PAO 6	74%	74%	48%
EcoLabel HF Ad Pack	1%	1%	1%
RPVOT	**980 min**	**1214 min**	**1328 min**

Closing Comments

Conclusions and Future Studies

- Aminic and phenolic AO chemistries are effective with estolides, and a combination of the two yields a synergistic effect
- Optimal treat rates of the 50/50 aminic/phenolic blend is 0.75% - 1.25%
- Optimal ratio of aminic/phenolic is 90/10, though ratio can be adjusted to as low as 50/50 without much of an effect (<5%, possibly within error of the RPVOT test)
- Low viscosity estolides have oxidative stability on par with top base oil performers, including Group III, PAO, and saturated synthetic esters
- High/mid viscosity estolides have oxidative stability superior to other synthetics, including PAO and PAG
- RSSOT (ASTM D7545) results showed a correlation to RPVOT (ASTM D2272), but more data is needed to understand the strength of this trend
- Exchanging complex esters with estolides in an ISO VG 68 formulation yielded oxidative stability gains of 25-35%
- Future work: (1) Evaluate secondary and tertiary antioxidants, and (2) further testing to evaluate robustness of RPVOT/RSSOT correlation

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FOR A SUSTAINABLE
FUTURE

info@biosynthetic.com

BT4 Biosynthetic® Base Oil

Delivering innovations for a sustainable future.

BIOSYNTHETIC® TECHNOLOGIES

BT4 is a low viscosity, lubricant base oil designed specifically to help customers in the lubrication industries meet their production quality standards. This high quality renewable base oil offers exceptional technical performance and environmental benefits.

TECHNICAL PERFORMANCE

- High Oxidative Stability
- Low Volatility
- High Viscosity Index
- Hydrolytic Stability
- Natural Detergency
- Longer Lasting
- Increased Safety
- Fewer Additives Needed
- Increased Stability
- Less Maintenance

ENVIRONMENTAL BENEFITS

- High Biodegradability
- Low Bioaccumulation
- Low Toxicity
- High Bio-Content
- Rapid Breakdown
- Low Environmental Risk
- Reduced Risk to Wildlife
- Renewable Carbon Based

LOW VISCOSITY	BIODEGRADABLE	BIO-BASED
22	88 %	68 %
ISO VG	(OECD 301B)	(ASTM D6866)

APPLICATIONS

Metalworking | Motor Oil | Hydraulic Fluid | Compressor Oil

SEE REVERSE FOR PRODUCT SPECIFICATIONS

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www.linkedin.com/company/biosynthetic-technologies
REV 1.2 - 1/2020

BT4 Product Specifications

BIOSYNTHETIC® TECHNOLOGIES

PHYSICAL PROPERTIES

Property	Unit	Method	Typical Result*
Viscometrics			
Kinematic Viscosity at 100°C	cSt	D445	4.7
Kinematic Viscosity at 40°C	cSt	D445	20.7
Viscosity Index	–	D2270	152
Cold Temperature			
Pour Point	°C	D97	-21
Volatility			
Flash Point	°C	D92	242
Noack	wt%	ASTM D5800	8.3
Titrations			
Total Acid Number	mg KOH/g	D664	0.1
Others			
Color	–	D1500	1
Water	wt%	D1533	0.1 max
Specific Gravity (15°C)	–	D4052	0.90-0.92
KRL Sheer Stability, 20 hours	% loss	CEC L-45-99	-2.07%

*Typical results are provided. To the best of our knowledge, the information is accurate, but given without guarantee. All results are for an unadditized base oil.

LuSC-List

ENVIRONMENTAL PROPERTIES

Biodegradability	OECD 301B	88%
Renewable Carbon Content	ASTM D6866	68%
EcoToxicity	OECD 201	>1000 mg/L
	OECD 202	>1000 mg/L
	OECD 203	>1000 mg/L

PERFORMANCE TESTING

4-Ball Wear	ASTM D4172	0.59 mm
4-Ball Weld	ASTM D2783	
Weld Load		126 kgf
Load-Wear Index		14.77 kgf
Oxidative Stability	ASTM D2272	50 min
with Anti-Oxidant		1215 min
Hydrolytic Stability	ASTM D2619	
Total Acidity Water Layer		2.2 mg KOH/g

Typical properties depicted on this document are average values only and do not constitute a specification. Minor variations that do not affect product performance are to be expected during normal manufacture, and at different blending locations. Product formulations are subject to change without notification.

BT22 Biosynthetic® Base Oil

Delivering innovations for a sustainable future.

BIOSYNTHETIC® TECHNOLOGIES

BT22 is a low viscosity, lubricant base oil designed specifically to help customers in the lubrication industries meet their production quality standards. This high quality renewable base oil offers exceptional technical performance and environmental benefits.

TECHNICAL PERFORMANCE

- High Oxidative Stability
- Low Volatility
- High Viscosity Index
- Hydrolytic Stability
- Natural Detergency
- Longer Lasting
- Increased Safety
- Fewer Additives Needed
- Increased Stability
- Less Maintenance

ENVIRONMENTAL BENEFITS

- High Biodegradability
- Low Bioaccumulation
- Low Toxicity
- High Bio-Content
- Rapid Breakdown
- Low Environmental Risk
- Reduced Risk to Wildlife
- Renewable Carbon Based

LOW VISCOSITY	BIODEGRADABLE	BIO-BASED
150	79 %	86 %
ISO VG	(OECD 301B)	(ASTM D6866)

APPLICATIONS

Metalworking | Motor Oil | Hydraulic Fluid | Compressor Oil

SEE REVERSE FOR PRODUCT SPECIFICATIONS

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www.linkedin.com/company/biosynthetic-technologies
REV 1.2 - 1/2020

BT22 Product Specifications

BIOSYNTHETIC® TECHNOLOGIES

PHYSICAL PROPERTIES

Property	Unit	Method	Typical Result*
Viscometrics			
Kinematic Viscosity at 100°C	cSt	D445	22.4
Kinematic Viscosity at 40°C	cSt	D445	157.5
Viscosity Index	–	D2270	170
Cold Temperature			
Pour Point	°C	D97	-21
Volatility			
Flash Point	°C	D92	268
Noack	wt%	ASTM D5800	3.4
Titrations			
Total Acid Number	mg KOH/g	D664	0.2
Others			
Color	–	D1500	1
Water	wt%	D1533	0.1 max
Specific Gravity (15°C)	–	D4052	0.90-0.92
KRL Sheer Stability, 20 hours	% loss	CEC L-45-99	0.30%

*Typical results are provided. To the best of our knowledge, the information is accurate, but given without guarantee. All results are for an unadditized base oil.

LuSC-List

ENVIRONMENTAL PROPERTIES

Biodegradability	OECD 301B	79%
Renewable Carbon Content	ASTM D6866	86%
EcoToxicity	OECD 201	>1000 mg/L
	OECD 202	>1000 mg/L
	OECD 203	>1000 mg/L

PERFORMANCE TESTING

4-Ball Wear	ASTM D4172	0.584 mm
4-Ball Weld	ASTM D2783	
Weld Load		160 kgf
Load-Wear Index		27.11 kgf
Oxidative Stability	ASTM D2272	96 min
with Anti-Oxidant		949 min
Hydrolytic Stability	ASTM D2619	
Total Acidity Water Layer		1.6 mg KOH/g

Typical properties depicted on this document are average values only and do not constitute a specification. Minor variations that do not affect product performance are to be expected during normal manufacture, and at different blending locations. Product formulations are subject to change without notification.

BT75 Biosynthetic® Base Oil

Delivering innovations for a sustainable future.

BIOSYNTHETIC® TECHNOLOGIES

BT75 is a low viscosity, lubricant base oil designed specifically to help customers in the lubrication industries meet their production quality standards. This high quality renewable base oil offers exceptional technical performance and environmental benefits.

TECHNICAL PERFORMANCE

- High Oxidative Stability
- Low Volatility
- High Viscosity Index
- Hydrolytic Stability
- Natural Detergency
- Longer Lasting
- Increased Safety
- Fewer Additives Needed
- Increased Stability
- Less Maintenance

ENVIRONMENTAL BENEFITS

- High Biodegradability
- Low Bioaccumulation
- Low Toxicity
- High Bio-Content
- Rapid Breakdown
- Low Environmental Risk
- Reduced Risk to Wildlife
- Renewable Carbon Based

LOW VISCOSITY	BIODEGRADABLE	BIO-BASED
680	76 %	94 %
ISO VG	(OECD 301B)	(ASTM D6866)

APPLICATIONS

Gear Oil | Bearing | Chain Oil | Grease

SEE REVERSE FOR PRODUCT SPECIFICATIONS

For more info contact us at **info@biosynthetic.com** or visit our website: **www.biosynthetic.com**
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www.linkedin.com/company/biosynthetic-technologies
REV 1.2 - 1/2020

BT75 Product Specifications

BIOSYNTHETIC® TECHNOLOGIES

PHYSICAL PROPERTIES

Property	Unit	Method	Typical Result*
Viscometrics			
Kinematic Viscosity at 100°C	cSt	D445	75.9
Kinematic Viscosity at 40°C	cSt	D445	668.4
Viscosity Index	–	D2270	195
Cold Temperature			
Pour Point	°C	D97	-18
Volatility			
Flash Point	°C	D92	260
NOACK	wt%	D5800	1.5
Titrations			
Total Acid Number	mg KOH/g	D664	0.3
Others			
Color	–	D1500	2
Water	wt%	D1533	0.1 max
Specific Gravity (15°C)	–	D4052	0.90-0.93
KRL Sheer Stability, 20 hours	% loss	CEC L-45-99	0.98%

*Typical results are provided. To the best of our knowledge, the information is accurate, but given without guarantee. All results are for an unadditized base oil.

LuSC-List

ENVIRONMENTAL PROPERTIES

Biodegradability	OECD 301B	76%
Renewable Carbon Content	ASTM D6866	94%
EcoToxicity	OECD 201	>1000 mg/L
	OECD 202	>1000 mg/L
	OECD 203	>1000 mg/L

PERFORMANCE TESTING

4-Ball Wear	ASTM D4172	0.31 mm
4-Ball Weld	ASTM D2783	
Weld Load		160 kgf
Load-Wear Index		42.06 kgf
Oxidative Stability	ASTM D2272	81 min
with Anti-Oxidant		1181 min
Hydrolytic Stability	ASTM D2619	
Total Acidity Water Layer		5.9 mg KOH/g

Typical properties depicted on this document are average values only and do not constitute a specification. Minor variations that do not affect product performance are to be expected during normal manufacture, and at different blending locations. Product formulations are subject to change without notification.

SUSTAINABLE MWF ADDITIVES

Biosynthetic® Technology has developed a revolutionary new class of high-performance bio-based additives for metalworking fluids, called **Biocea™**. These novel sustainable additives use the patented estolide technology and are biobased, biodegradable, non-bioaccumulative, and non-toxic. Biocea additives deliver superior lubricity, film strength, biostability, hydrolytic stability, oxidation stability, and increased polarity on both ferrous and non-ferrous alloys. They are derived from natural oils and improve the overall quality of formulated metalworking fluid. Biocea additives can result in increased productivity, reduced waste and down time, and lower cost in your overall manufacturing operation.

SUSTAINABLE MWF ADDITIVES PRESENATION

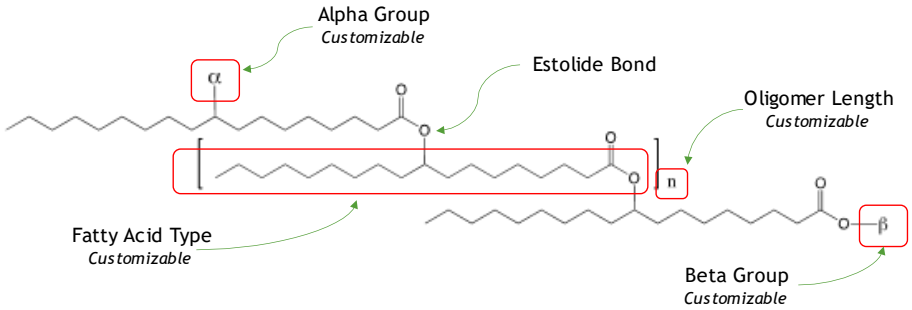
The Future of Metalworking Fluid: It's Biobased!

Mr. J. Mackey, Biosynthetic Technologies, Indianapolis, Indiana

The environmental and safety aspects of metalworking fluids are becoming increasingly more important. Forced by new regulations lubricants manufacturers worldwide are replacing the mineral base oils in metalworking fluids by natural sourced derivatives. As several additives have been eliminated from use in MWFs, including nitrites and short-chain chlorinated paraffins, there is a growing pressure to further eliminate additives that may be harmful to the worker or the environment. In this session, we will cover the new requirements for performance and reduced environmental and human exposure that lead to the development of bio-based metalworking fluids. In addition, this session will cover how government regulation of MWFs (particularly their additives) is almost certain to tighten, creating a conundrum for formulators who need to produce fluids that perform well for extended periods and also protect the machinery, workpiece, environment and most of all the workers.

SESSION DAY & DATE: Tuesday, May 18, 2021

Estolides are Highly Customizable

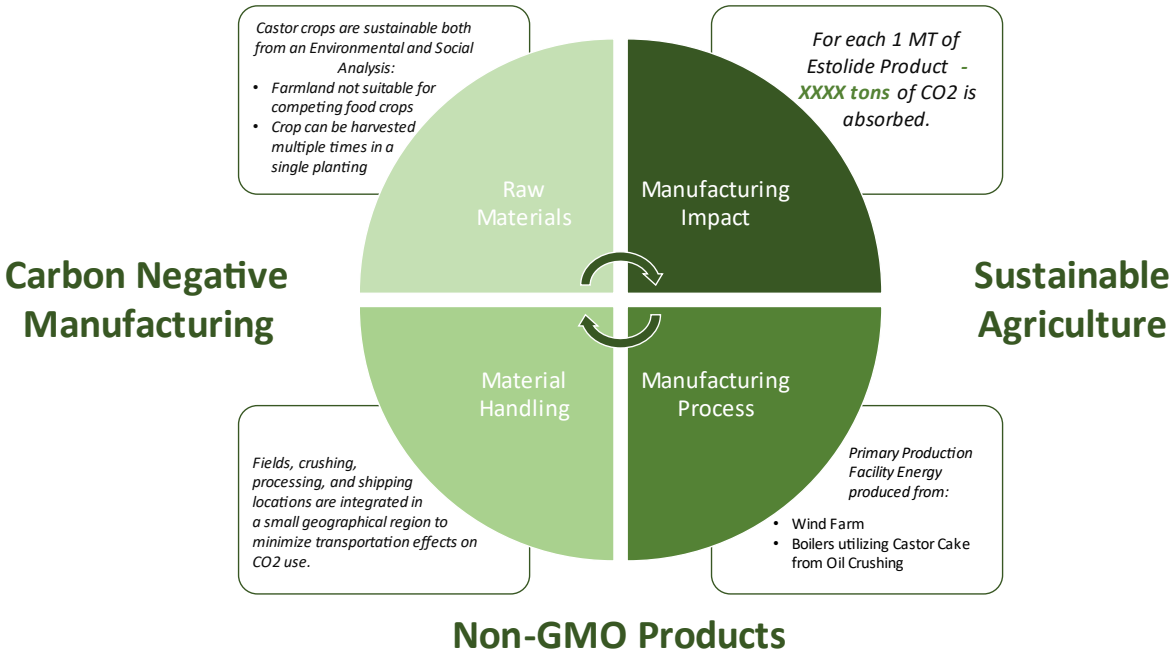


Synthetic Variations

- Use of different fatty acid feedstocks
- Oligomerization (n)
- Unique functional groups (α□β)

Performance Focus

- Increased or reduced molecular weight
- Improved cold temperature properties
- Increased or decreased polarity
- Improved oxidative stability



Carbon Negative Manufacturing

Sustainable Agriculture

Non-GMO Products

Estolide Physical Properties (range)

	Estolide LMW	Estolide HMW
Kinematic Viscosity @ 100°C cST	4.7	78.8
Kinematic Viscosity @ 40°C cST	20.7	695.6
Viscosity Index	152	197
Molecular Weight	Approx. 500	Approx. 2500
Flash Point °C	242	288
Total Acid Number mg KOH/g	0.1	0.3
Color D1500	1	2
Water ppm	500 max	500 max
Specific Gravity	0.90 - 0.92	0.91 - 0.93
Noack	8.3	1.5
KRL Shear Stability, 20 hours % loss	-2.07%	0.98%

4

Biodegradation Classifications/Definitions

1. ***Readily*** Biodegradable Products Break Down
   - > 60% in 28 Days and within 10 days **(10 day window)**

2. ***Ultimately*** Biodegradable
   - > 60% in 28 days **(no window)**

3. ***Inherently*** Biodegradable Products Break Down
   - > 20% & < 60% in 28 days

4. ***Non-biodegradable*** Products Break Down
   - < 20 % in 28 Days

5

The Gold Standard for Environmental Performance

	Estolide LMW	Estolide HMW	Benchmark
Biodegradability OECD 301	88%	76%	60%
Bio Content ASTM D6866	68%	94%	25%
Bioaccumulation OECD107	Low Potential	Low Potential	Low Potential
Toxicity			
OECD 201 Alga Toxicity EC 50 mg/L	1000 (not acutely Toxic)	1000 (not acutely Toxic)	100
OECD 202 Daphnia Toxicity EC 50 mg/L	1000 (not Acutely Toxic)	1000 (not acutely Toxic)	100
OECD 203 Fish Toxicity EC 50 mg/L	1000 (not acutely toxic)	1000 (not acutely Toxic)	100
OECD 209 Bacteria Toxicity EC 50 mg/L	1000 (not acutely toxic)	1000 (not acutely Toxic)	

Estolide Certifications

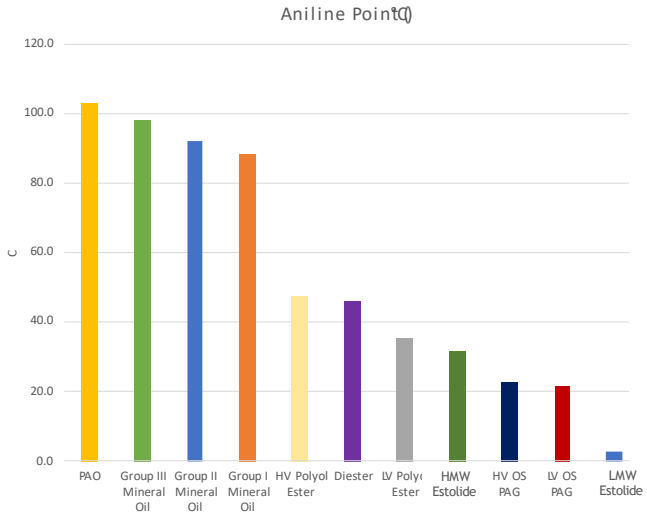
Product	US	Canada	Europe, REACH	Environmental Claims		Food Contact	
	Approval	Approval	Approval	Eco Label LuSC List	BioPreferred	HX-1 InS	HX-1 NSF
Estolide	✓	✓	✓	✓	68% - 94% Biocontent	✓	✓

No Dermal Irritation

- Estolide additives generally show **no signs** of Dermal irritation or allergic sensitization
- Estolides additives can be evaluated through computational toxicological chemical modeling to ascertain its skin sensitization potential known as the CADRE Method.
- The CADRE Method safely determines the risk of skin sensitization concerns without requiring any animal testing.
- This method has been proven effective and is now accepted by various government agencies as part of product registration.

Estolide Performance

Solvency - Aniline Point – ASTM D611



Traditional Lubricants	KV 100°C (cSt)	KV 40°C (cSt)	Aniline Point (°C)
Group I Mineral Oil	6.3	50	88.1
Group II Mineral Oil	6.6	44.0	92.0
Group III Mineral Oil	6.5	37.0	98.4
PAO	7.0	38.0	102.7
LV OS PAG	6.5	28.0	21.8
HV OS PAG	12.0	150.0	22.4
Diester	5.5	28.0	46.0
LV Polyol Ester	8.8	53.0	35.4
HV Polyol Ester	17.5	178.0	47.1
Estolide LMW	**4.5**	**22.0**	**2.7**
Estolide HMW	**75.0**	**680.0**	**31.8**

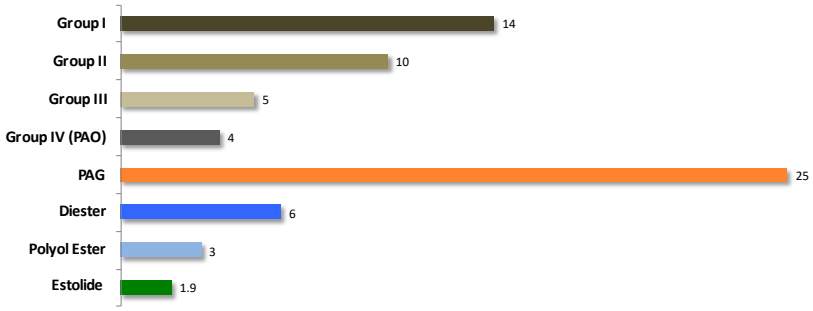
10

Help with Poor Solubility

11

Estolide Technology Can Offer Excellent Volatility – Evaporative Loss

NOACK of Unadditized Common Low Viscosity Base Oils and Esters
ASTM D5800 (wt%)



12

Hydrolytic Stability

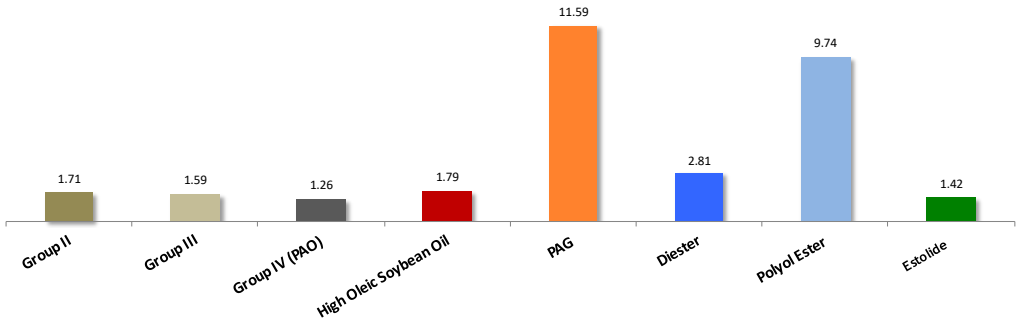
Even at 3 times the recommended test duration the Estolides shows excellent hydrolytic stability

Test Method: ASTM D2619 Conditions: 93°C, 144 hours (modified from 48 hours)	Estolide HMW	PAO ISO VG 460	PAO ISO VG 1000	Bright Stock Paraffinic	Bright Stock Naphthenic
Weight Change of Copper Panel, (mg/cm2)	-0.033	-0.092	-0.033	0.00	-0.033
Appearance of Copper	Shiny, 2c	Shiny, 2c	Shiny, 1b2c	Shiny, 1b2c	Shiny, 1b
% Change in Viscosity	-0.67	-0.41	-0.64	+0.04	+11.3
Change in Acid Number, mg KOH/g	+0.17	+0.05	+0.06	+0.01	+0.17
Total Acidity of Water Layer, mg KOH/g	0.17	3.11	0.89	0.11	0.06

13

Estolides Can Provide Top-tier Hydrolytic Stability

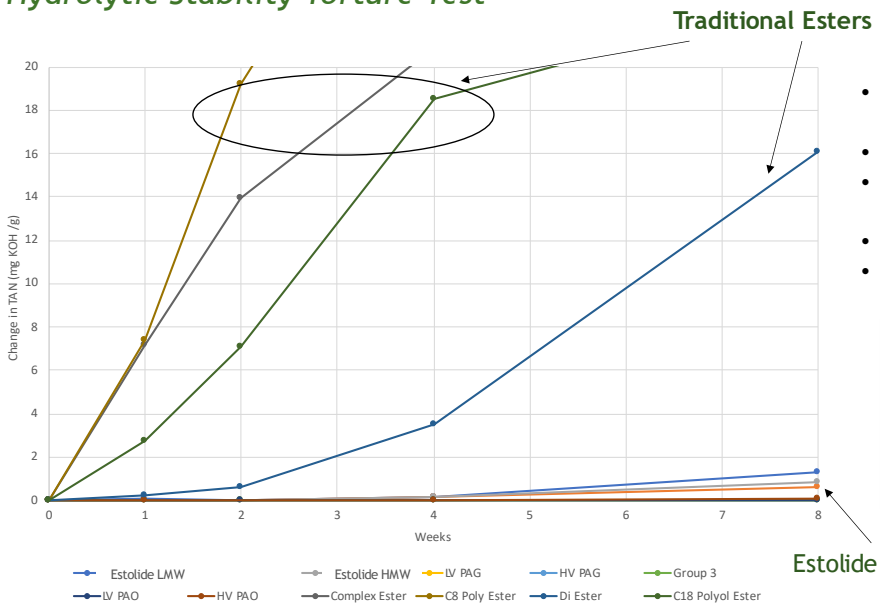
Common Similar Viscosity Unadditized Base Oils (6 to 8 cSt)
Modified ASTM D2619, Water Acidity Increase at 144 Hours (mg KOH/g)



Notes:
(1) Base oil samples are unadditized.

14

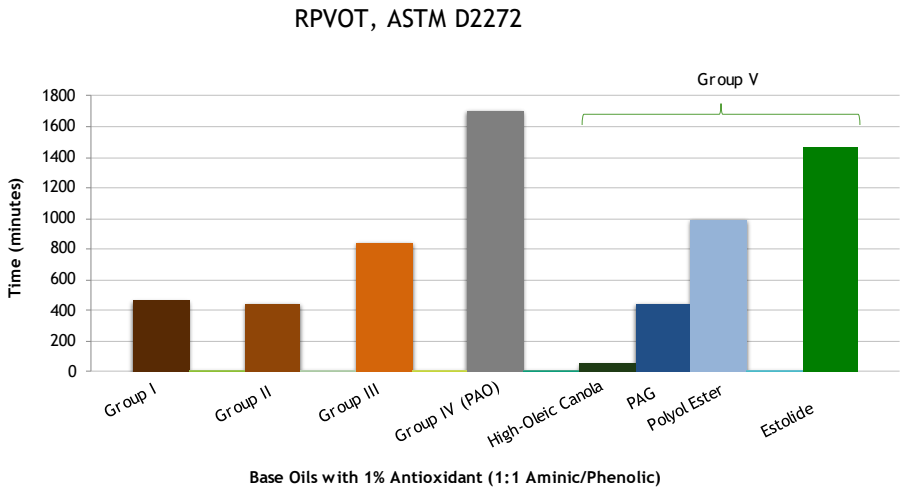
Hydrolytic Stability Torture Test



- Sample Mixed with 1% Water by Weight
- Maintained @ 180°F
- Stirred Continuously at 500 rpm
- 8 Week Study
- Modified D2618

15

Fluid Life - Oxidative Stability

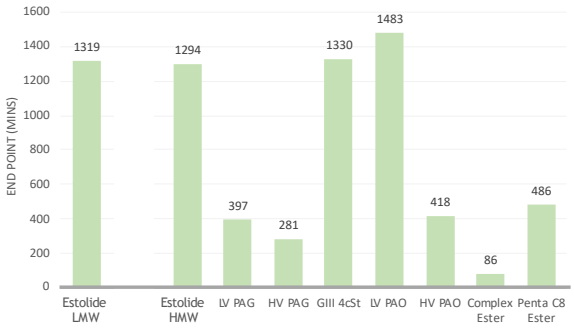


16

Oxidative Stability Study

- All materials are treated with 0.5% Phenolic and 0.5% Aminic Anti-Oxidant

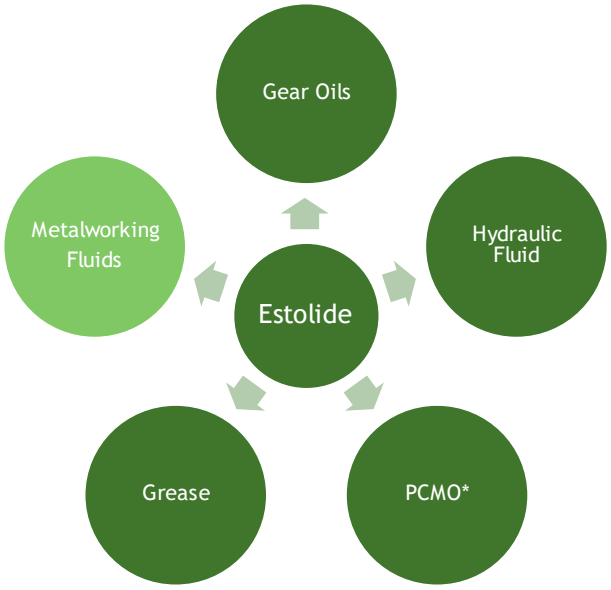
Oxidative Stability Update (mins) ASTM D2272			
Sample	KV40 cSt	KV100 cSt	End Point
Estolide LMW	4.9	23.1	1319
Estolide HMW	75.9	668.4	1294
LV PAG	3.75	16.6	397
HV PAG	72	658	281
GIII 4cSt	4.5	20.7	1330
LV PAO	3.95	17.29	1483
HV PAO	48.8	415.1	418
Complex Ester	54.1	446	86
Penta C8 Ester	5.2	25.3	486
DiEster	3.2	11.8	TBD
TMP Ester	9.4	47.1	TBD



17

Estolide Applications in Lubricants

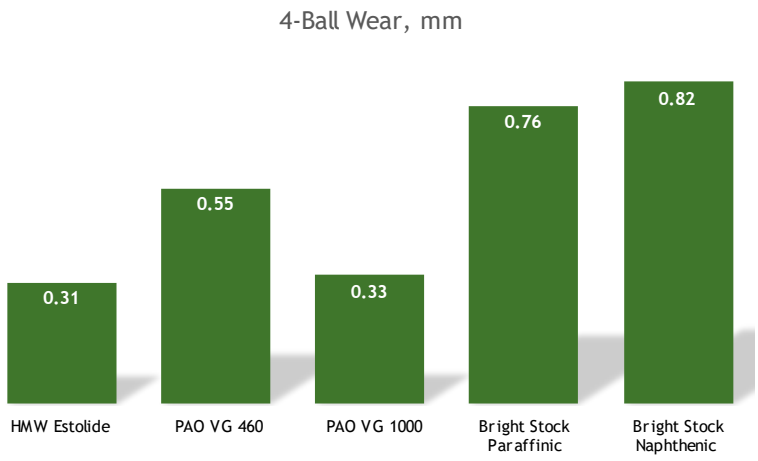
- There are many capabilities of the Estolide Technology across a wide array of applications, including:
  - Gear Oils
  - Hydraulic Fluids
  - Greases
  - Passenger Car Motor Oil (PCMO)
  - **Metalworking Fluids**



18

Wear Properties

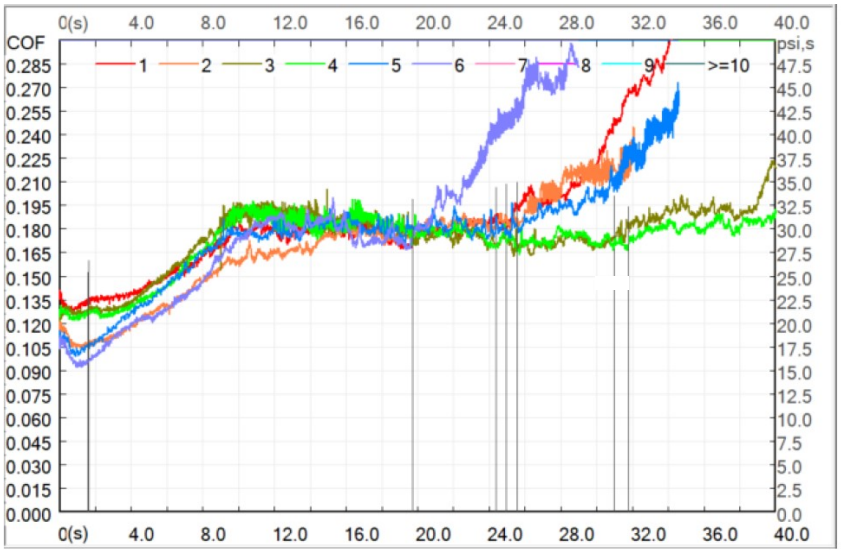
Estolides provide good wear protection



Test Method: ASTM D4172B
Conditions
- 75ºC
- 60 minutes
- Load 40 kg.
- Speed 1200 rpm

19

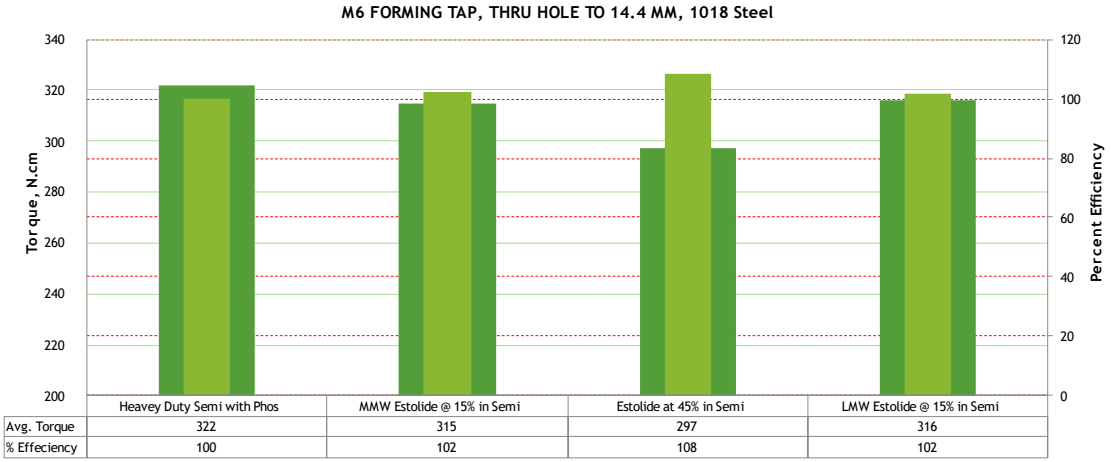
Estolide Twist Compression Test



1. Pentaerythritol Ester (15%)
2. Estolide MMW (15%)
3. Estolide HMW (15%)
4. Estolide HMW (uncapped) (15%)
5. Polymerized Ester (15%)
6. Polymerized Ester (15%)

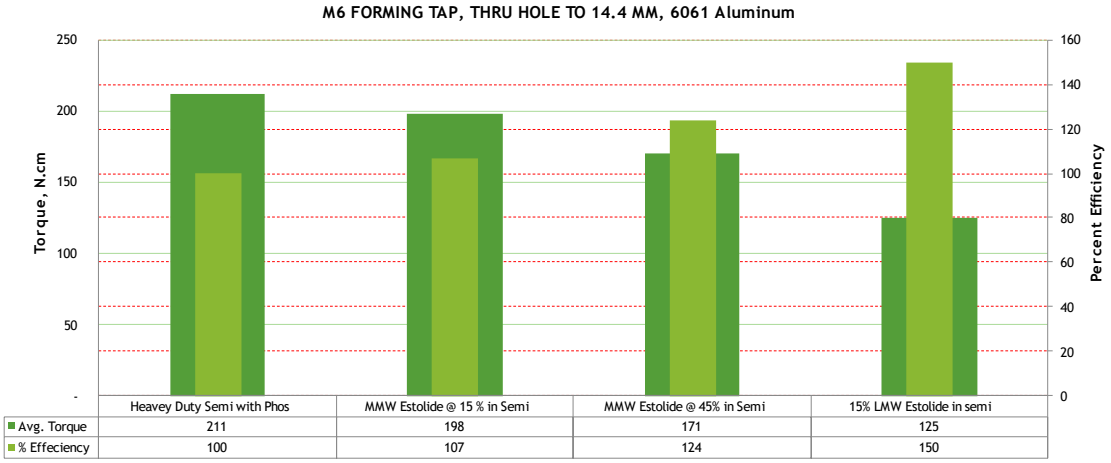
20

Micro Tap - Steel



21

Micro Tap - Aluminum



	Heavey Duty Semi with Phos	MMW Estolide @ 15 % in Semi	MMW Estolide @ 45% in Semi	15% LMW Estolide in semi
Avg. Torque	211	198	171	125
% Effeciency	100	107	124	150

BIOSYNTHETIC® TECHNOLOGIES METALWORKING ADDITIVES: BIOCEA™

Delivering Innovations for a Sustainable Future.

Biosynthetic® Technologies has developed a revolutionary new class of high-performance bio-based additives for metalworking fluids called Biocea™. These novel and, sustainable additives use the patented estolide technology and are biobased, biodegradable, non-bioaccumulative, and non-toxic.

Biocea additives deliver superior lubricity, film strength, biostability, hydrolytic stability, oxidation stability, and increased polarity on both ferrous and non-ferrous alloys. They are derived from natural oils and improve the overall quality of formulated metalworking fluid while being sustainable and environmentally friendly. Biocea additives are known to increase productivity, reduced waste and down time, and lower cost in your overall manufacturing operation.

ENVIRONMENTALLY ACCEPTABLE LUBRICANTS MARKET DRIVERS

According to a recent Kline and Company report, the global finished lubricants market in 2019 was 40.5 million tons, of which bio-lubricants accounted for less than 1% at 350,000 tons. The report stated that there are untapped growth opportunities, considering the low penetration of bio-lubricants demand in some key country markets. The U.S. is one of the fastest growing country markets, with uptake of bio-lubes expected at about a 4% CAGR from 2019 to 2024 (Kline and Company, August 5, 2020). Compare that to the global lubricants market, which according to Reportlinker, is expected to witness a downfall in 2020 with a negative growth of 0. 95% (Reportlinker, May 7, 2020). In June 2020, Genomatica reported that "Despite setbacks from the pandemic, demand for bio-lubricants should continue to grow faster than the overall global lubricants market". To leverage the pending growth of the biobased lubricant and metalworking fluid markets, lubricant manufacturers can convert their traditional formulation into environmentally acceptable formulations and thus expand their environmentally acceptable lubricants (EAL) offering and capitalize on growth patterns by utilizing the Biocea(TM) additives.

Features and Benefits

- Unparalleled lubricity
- Provide superb wear protection
- Are free of restricted chemicals
- Vegetable derived
- Excellent hydrolytic stability
- Natural detergency
- Improves overall operations in terms of uptime
- Minimizes safety risks
- Reduces overall formulation cost
- Meet the national chemical inventory requirements
- Increases operational efficiency
- Reduces cost related to maintenance
- Are REACH registered
- HX1 certified
- Show no signs of dermal irritation
- Naturally low foaming

TECHNICAL PERFORMANCE DATA

Biosynthetic Technologies' Biocea additives provide excellent lubricity, film strength and improved tool life, when compared to other lubricity additives. In addition to superior oxidative stability Biocea additives provide excellent wear protection as well as industry leading hydrolytic stability. Below, please find the ranking for the leading metalworking fluid additives performance features, and see how Biocea additives outperform the most commonly used additives available in the market today.

PERFORMANCE FEATURE	PENTAERYTHRITOL ESTER	SYNTHETIC ESTER	TMPTO	BIOCEA™ I	BIOCEA™ II	BIOCEA™ III
Lubricity	✓	✓	✓	✓	✓ ✓	✓ ✓ ✓
Film Strength	✓	✓		✓ ✓	✓ ✓ ✓	✓ ✓ ✓
Anti-Wear	—	—	—	✓ ✓	✓ ✓ ✓	✓ ✓ ✓
Improved Tool Life	✓	✓	✓ ✓	✓ ✓	✓ ✓ ✓	✓ ✓ ✓
Increased Polarity	—	✓	—	✓	✓ ✓	✓ ✓
Hydrolytic Stability	—	✓	—	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓
Molecular Weight	420.6*	295.04*	927.5*	Approx. 500	Approx. 1500	Approx. 2500

*Numbers are based on industry averages and final numbers for individual products may vary. Results listed in table may vary. Optimum blends can be created to maximize performance.

Environmental Performance Data

- High Biodegradability
- Low Bioaccumulation
- Low Toxicity
- High Bio-Content
- Rapid Breakdown
- No dermal irritation
- Low Environmental Risk
- Reduced Risk to Wildlife

Biocea additives have been evaluated through a revolutionary new method known as the CADRE Method. This is a new innovative modeling software used to safely determine skin sensitization concerns without requiring any animal testing. Biocea additives show no signs of dermal irritation or allergic sensitization. The lack of odor and skin irritation make these additives extremely suitable for metalworking fluid applications while promoting a safe work environment.

PASS	METHOD	BIOCEA™ I	BIOCEA™ II	BIOCEA™ III
Biodegradability	OECD 301B	Ultimately	Readily	Readily
Bio Content	ASTM D6866	>70%	>80%	>90%
Toxicity	OECD 201, 202, 203, 209	Pass	Pass	Pass

APPLICATIONS

Biocea additives are used in a variety of metalworking and metal forming fluid formulations for all 4 major classes of metalworking fluids: straight oil, soluble oil, semisynthetic, and synthetic metalworking fluids. Biocea additives can be used as high performance lubricity additives, that meet (and often exceed) the technology requirement needed in modern machining techniques. These novel Biocea additives are considered to be the best biobased choice for multi-purpose or general-purpose applications in neat oils, soluble oils, and semi-synthetic fluids. They have good solubility in all base oils, and easily emulsify in water-based chemistries.

ADDITIVE	GENERAL MACHINING	CUTTING AND GRINDING	FORMING
Biocea™ I	✓ ✓	✓ ✓ ✓	✓
Biocea™ II	✓ ✓ ✓	✓ ✓ ✓	✓ ✓
Biocea™ III	✓	✓ ✓	✓ ✓ ✓

Results may vary. Optimum blends can be created to maximize performance by application.

BIOSYNTHETIC TECHNOLOGIES PRODUCT NAME	INDUSTRY EQUIVALENT
BT PRA30	Polymerized Lubricant 30
BT PRA40	Polymerized Lubricant 40
BT PRA50	Polymerized Lubricant 50
BT PRA100	Polymerized Lubricant 100
BT DES	Di Ethylhexyl Sebacate
BT BHI	Bis-Hydroxyl Imidazoline
BT DSS	Di-Sodium Sebacate

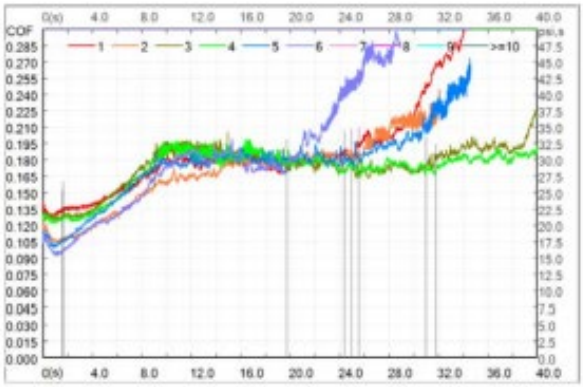
SPECIALTY CASTOR DERIVATIVES

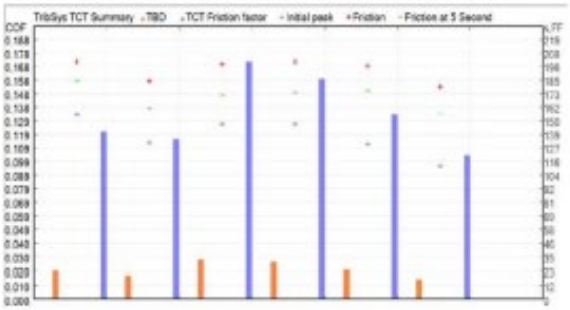
In addition to Biocea additives, Biosynthetic Technologies offers other castor derived high-performance additives that are biobased and sustainable. Our extensive bio-based product line is specifically formulated to match formulator needs and to provide solutions to the distinct challenges in the metalworking fluid market. Biosynthetic Technologies offers the following castor derivatives in their metalworking product line.

These castor derived products perform exceptionally well in a variety of functions, and often represent formulation improvements that offer greater product uniformity and cost savings.

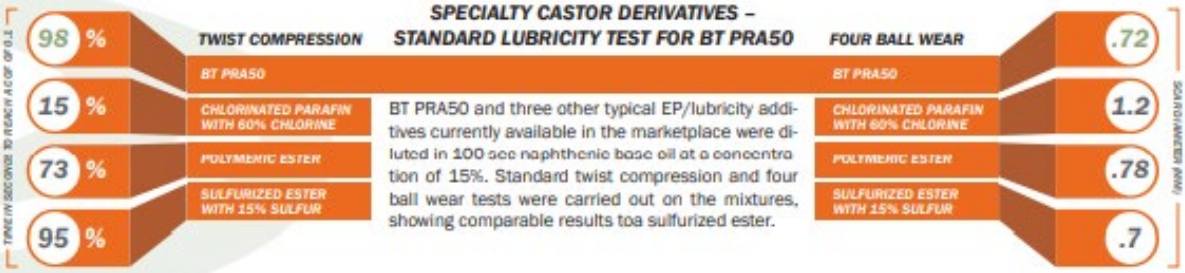
BIOCEA™ TWIST COMPRESSION TEST

During initial testing the Biocea™ products indicated superior performance when comparted to traditional technology currently available in the marketplace. Overall, the Biocea™ IIIHP (15%) showed superior performance.





SPECIALTY CASTOR DERIVATIVES – STANDARD LUBRICITY TEST FOR BT PRA50



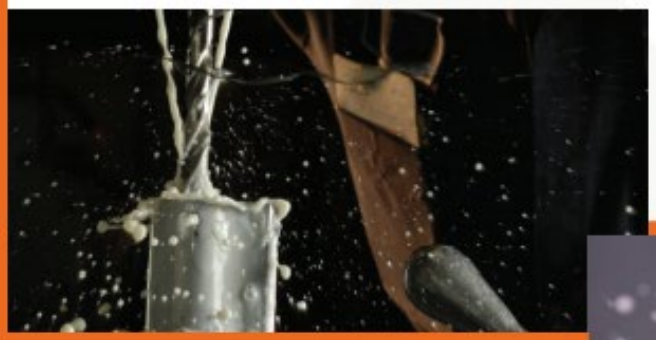
BT PRA50 and three other typical EP/lubricity additives currently available in the marketplace were diluted in 100 sec naphthenic base oil at a concentration of 15%. Standard twist compression and four ball wear tests were carried out on the mixtures, showing comparable results toa sulfurized ester.

REGISTRATION AND CERTIFICATION

At Biosynthetic Technologies we hold the appropriate certifications and registrations to certify our products do not only deliver on performance and quality but are also compliant with national and international requirements. Our Quality Assurance team stays current on the ever-evolving regulations as new legislation is passed and implemented in the industry. Our continuous improvement culture drives us, building upon our solid foundation of quality principles ensuring we meet or exceed customer expectations. All our castor oil derivatives have sales approval for US (EPA, Canada (CEPA), and Europe (REACH). Currently, we proudly maintain the following certifications for all products:

SUSTAINABILITY AND CARBON FOOTPRINT

At Biosynthetic Technologies, we understand the importance of sustainable manufacturing practices. As such sustainability through innovation is a main driver of our company's mission. We are constantly looking for ways to minimize the negative impacts on the environment while conserving energy and natural resources. Our objective is to make sustainability a point of difference for our business, and we are confident that this strategy will generate even greater benefits for the environment in which we operate, the people that we work with and the communities we are part of. Biosynthetic Technologies is committed to sustainability and clearly focused on the responsible use of natural resources in our daily business. We understand that health, environmental awareness and traceability play just as large a role for consumers as quality and efficacy. Biosynthetic® Technologies is aware of its responsibility in this business and sustainability. As such, our manufacturing facility is operating with a NEGATIVE carbon footprint!



FORMULATION ASSISTANCE

At Biosynthetic Technologies, we believe in the importance of offering superior technical support and customer service to our clients. We work closely with our partners to understand their needs and challenges and determine the best solutions to keep your businesses running smoothly. Our extensive R&D team is here to help in the creation of tailor-made ingredients to meet your specific formulation needs.

ABOUT BIOSYNTHETIC TECHNOLOGIES

Biosynthetic® Technologies manufactures a revolutionary new class of biobased synthetic compounds called Estolides that are made from organic fatty acids found in various bio-derived oils. These highly functional biosynthetic oils have numerous uses in lubricant, automotive, marine, pharma and personal care applications and can be used as the primary base oil of a formulation, a component of a base oil co-blend, or even as an additive. In addition to their high-performance properties, these renewable oils are biodegradable and nontoxic. Biosynthetic Technologies strives to make their mark on the world by delivering innovations for a sustainable future. For more information about Biosynthetic Technologies, please visit www.biosynthetic.com and follow us on LinkedIn or contact us at info@biosynthetic.com.

For more info contact us at info@biosynthetic.com or visit our website: www.biosynthetic.com
Biosynthetic Technologies, LLC. | 6320 Intech Way, Indianapolis, IN 46278 | 317-556-1050
www.linkedin.com/company/biosynthetic-technologies
2020

BIOSYNTHETIC® TECHNOLOGIES

COMMERCIAL MARKETING FORUM SESSION

Estolides - High Performance Sustainable Base Oils for Lubricant and Metalworking Formulations By Mr. Mark Miller

Biosynthetic Technologies strives to deliver innovations for a sustainable future. As such, we offer products that are bio-based, biodegradable yet deliver superior performance characteristics. In this session we'll discuss our currently product line of sustainable base oils / estolides that are made from organic fatty acids found in various bio-derived oils. In this session, we provide in depth information on estolide hydrolytic stability, oxidative stability, seal compatibility and other performance characteristics. In addition, we share our knowledge on a modified hydrolytic stability test to monitor the extensive stability of estolides versus traditional lubricant esters over a long duration of time under real world applications. This 30 minute session will be a MUST for anybody looking to develop a high performance EAL product line!

SESSION DAY & DATE: MONDAY, May 17, 2021

Biosynthetic Technologies is a US based innovative company.
Dedicated to the development of a bio -based alternative to petroleum base oils.

Our Vision
To deliver Innovative Solutions for a Sustainable Future.

Our Mission
To be the Premier Synthetic Base Fluid Supplier Across a Variety of Specialty Markets.

BIOSYNTHETIC®
TECHNOLOGIES

Estolides are the Answer for Sustainable Lubricant Base stock

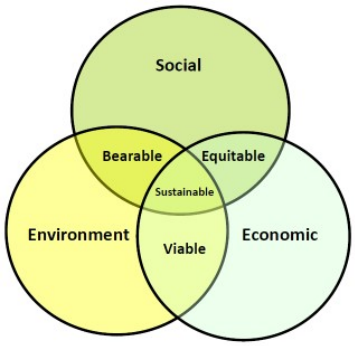
- Biodegradability
- Ecotoxicity
- Bioaccumulation
- Oxidative Stability
- Hydrolytic Stability
- Wear/Extreme Pressure Protection
- Seal/Hose/Elastomer Compatibility
- Solvency/Solubility
- Demulsibility

2

People Are Setting Higher Goals for Sustainability

- Sustainability Goal #1 Renewable
- Sustainability Goal #2 Safe for the Environment
- Sustainability Goal #3 Performance
- Sustainability Goal #4 Cost
- Sustainability Goal #5 *Carbon Footprint*
- Sustainability Goal #6 *Lifecycle Assessment*
- Sustainability Goal #7 *Social Impact*
- Sustainability Goal #8 *Economic Impact*

Products with High Bio-content
High Bio-degradability, Low Toxicity, Low Bioaccumulation
Must Be Equal Or Better Than Petroleum Based Products
Comparable or Better Price Points for Synthetics

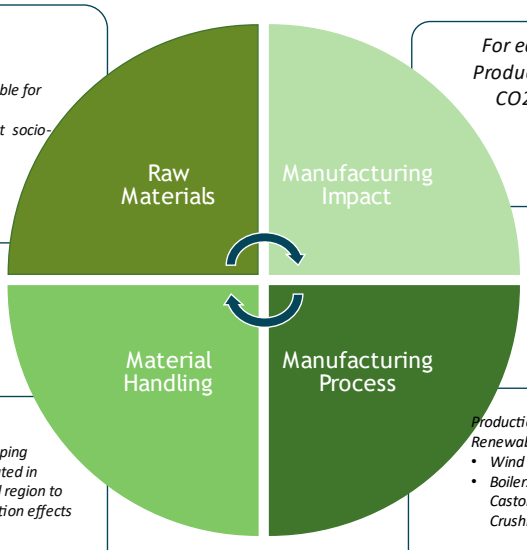


4

We Believe in Circular Sustainability

Sustainable both from an Environmental and Social Analysis:
- *Arid farmland not suitable for competing food crops*
- *Creating jobs for lowest socio-economic rungs*
- *Crop can be harvested multiple times in a single planting*

For each 1 MT of BT Product ***-9.16 Tons*** *of CO2 is absorbed.*



Sustainable Agriculture

Carbon Negative Manufacturing

Fields, crushing, processing, and shipping locations are integrated in a small geographical region to minimize transportation effects on CO2 use.

Production Facility 100% Renewable Energy
- *Wind Farm*
- *Boilers utilizing spend Castor Cake from Oil Crushing*

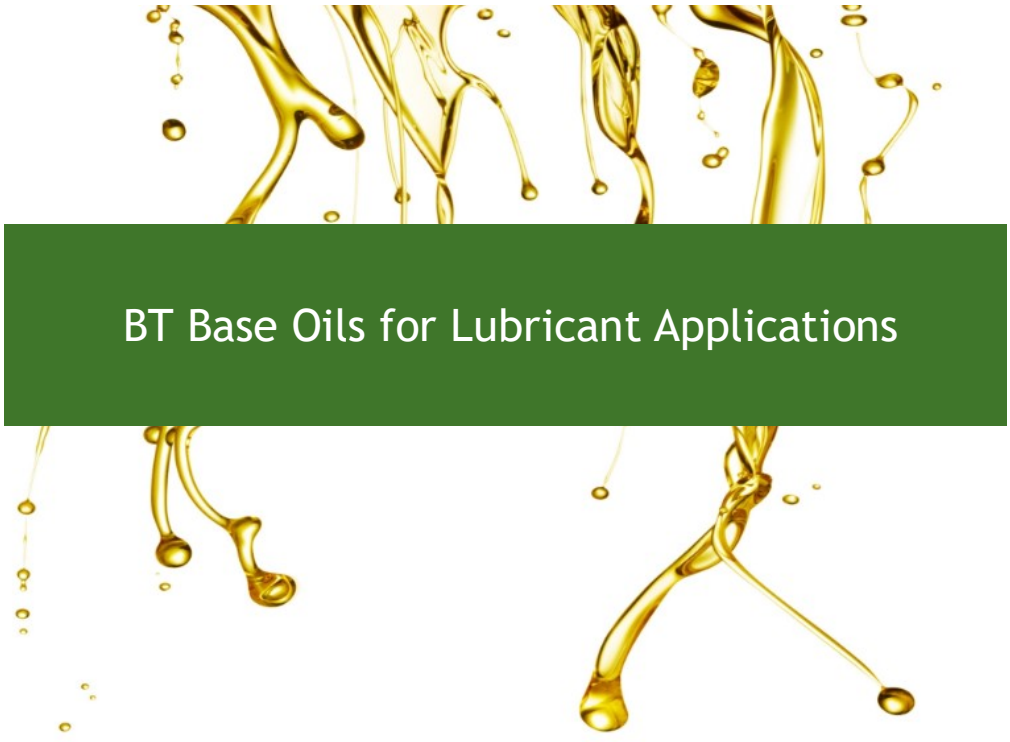
Sustainable Economically

Lifecycle study conducted by Gujarat Agriculture University, Dantiwada and Kadam Environmental consultancy laboratory, Baroda, India. A full life cycle assessment report will be delivered upon request for CO2, Water, NOx, SOx, COD, and TDS impacts from production.

5

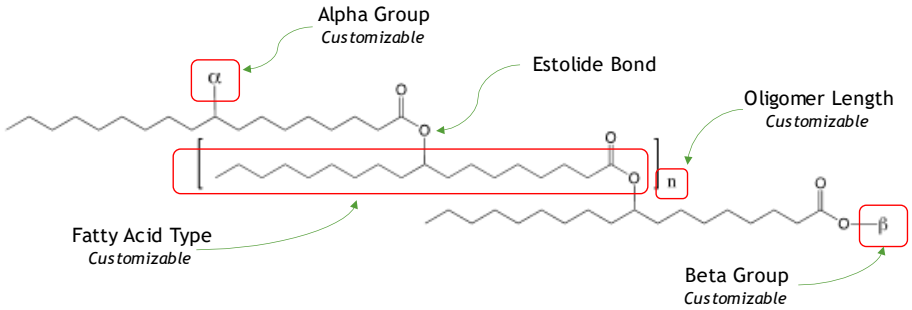
The Gold Standard for Environmental Performance

	BT4	BT22	BT75	Benchmark
Biodegradability OECD 301	88%	79%	76%	60%
Bio Content ASTM D6866	68%	86%	94%	25%
Bioaccumulation OECD107	Low Potential	Low Potential	Low Potential	Low Potential
Toxicity				
OECD 201 Alga Toxicity EC 50 mg/L	>1000	>1000	> 1000	100
OECD 202 Daphnia Toxicity EC 50 mg/L	>1000	>1000	> 1000	100
OECD 203 Fish Toxicity EC 50 mg/L	>1000	>1000	> 1000	100
OECD 209 Bacteria Toxicity EC 50 mg/L	>1000	>1000	> 1000	100



BT Base Oils for Lubricant Applications

Estolides are Highly Customizable



Synthetic Variations

- Use of different fatty acid feedstocks
- Oligomerization (n)
- Unique functional groups (α□β)

Performance Focus

- Increased or reduced viscosity
- Improved cold temperature properties
- Increased or decreased polarity
- Improved oxidative stability

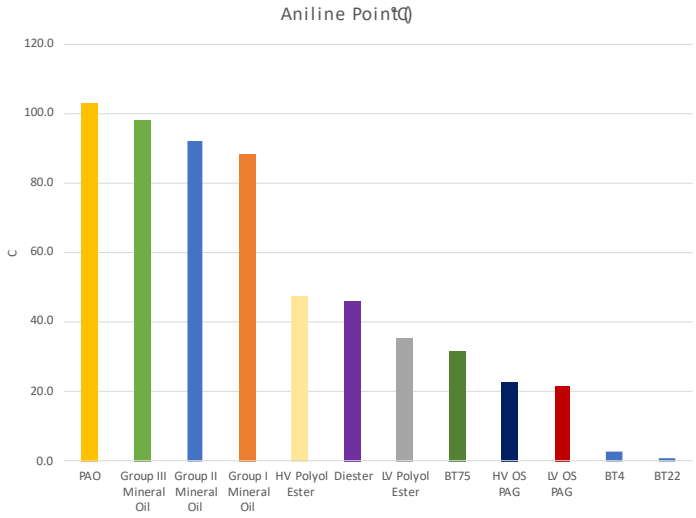
8

Easy to Formulate With

	BT4	BT22	BT75
Kinematic Viscosity @ 100°C cST	4.7	20.2	78.8
Kinematic Viscosity @ 40°C cST	20.7	137.5	695.6
Viscosity Index	152	169	197
Pour Point °C	-21 (-33)	-21	-18
Flash Point °C	242	278	288
Total Acid Number mg KOH/g	0.1	0.2	0.3
Color D1500	1	1	2
Water ppm	500 max	500 max	500 max
Specific Gravity	0.90 - 0.92	0.91 - 0.92	0.91 - 0.93
Noack %	8.3	3.4	1.5
KRL Shear Stability, 20 hours % loss	-2.07%	0.30%	0.98%

9

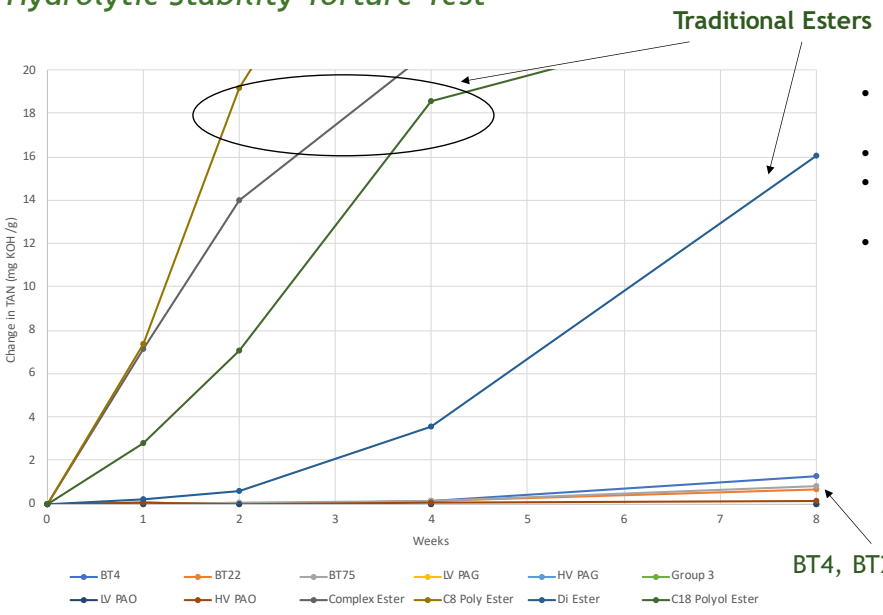
Excellent Solvency Allows Blending with Multiple Base Oils and Additives
Aniline Point – ASTM D611



Base Oil	KV 100°C (cSt)	KV 40°C (cSt)	Aniline Point (°C)
Group I Mineral Oi	6.3	50	88.1
Group II Mineral Oil	6.6	44.0	92.0
Group III Mineral Oil	6.5	37.0	98.4
PAO	7.0	38.0	102.7
LV OS PAG	6.5	28.0	21.8
HV OS PAG	12.0	150.0	22.4
Diester	5.5	28.0	46.0
LV Polyol Ester	8.8	53.0	35.4
HV Polyol Ester	17.5	178.0	47.1
BT4	4.5	22.0	2.7
BT22	22.0	150.0	0.7
BT75	75.0	680.0	31.8

10

Hydrolytic Stability Torture Test



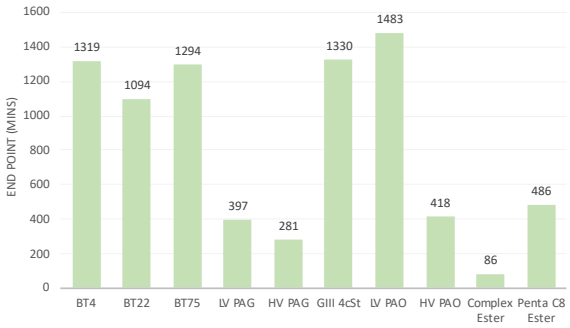
- Sample Mixed with 1% Water by Weight
- Maintained @ 180°F
- Stirred Continuously at 500 rpm
- 8 Week Study

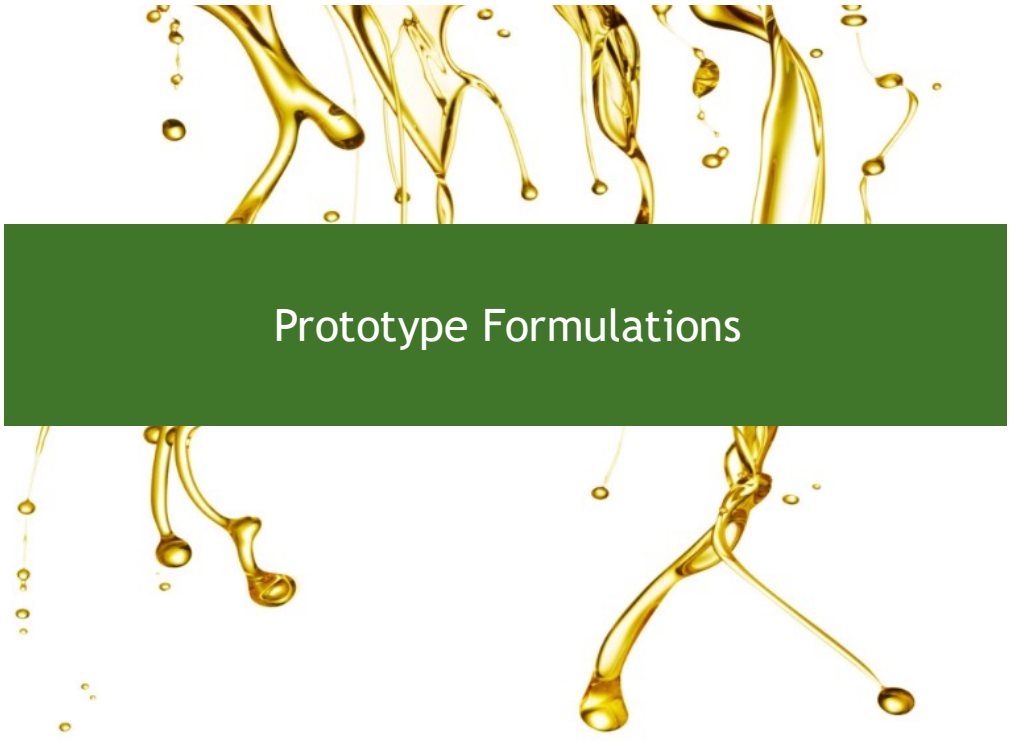
11

Best in Class Oxidative Stability

- All base oils treated with 0.5% Phenolic and 0.5% Aminic Anti -Oxidant

Oxidative Stability Update (mins) ASTM D2272			
Sample	KV40 cSt	KV100 cSt	End Point
BT4	4.9	23.1	1319
BT22	22.1	148.1	1094
BT75	75.9	668.4	1294
LV PAG	3.75	16.6	397
HV PAG	72	658	281
GIII 4cSt	4.5	20.7	1330
LV PAO	3.95	17.29	1483
HV PAO	48.8	415.1	418
Complex Ester	54.1	446	86
Penta C8 Ester	5.2	25.3	486

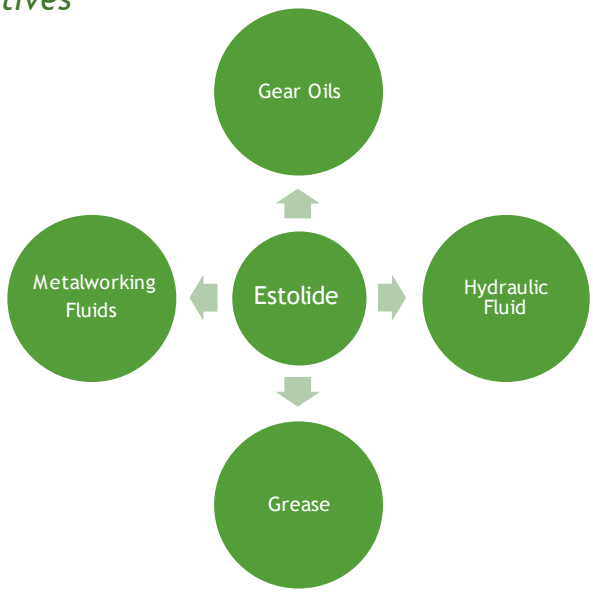




BT is a Supplier of Base Oils and Additives

- Our focus is to highlight the capabilities of the Estolide Technology across a wide array of applications
- BT's commercial goal is to supply base oils and additives into the lubricant industry, not finished formulations
- Focus on 4 Key Product Areas
  - Gear Oils
  - Hydraulic Fluids
  - Greases
  - Metalworking Fluid

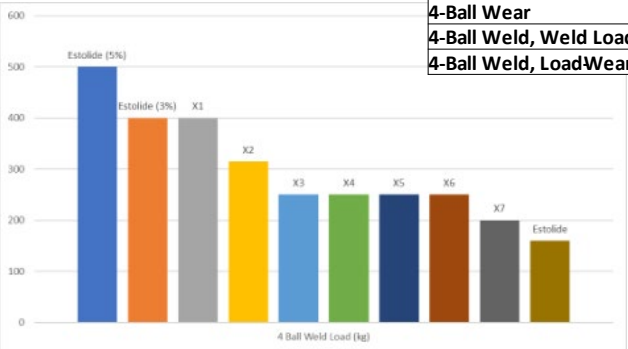
Building a solid performance database for baseoil co-blend and additive usage with Estolides



EcoLabel – ISO680 Estolide Gear Oil

Formulation	
Component	Gear Oil
Estolide	95%
Additive	5%

Performance Data	Method	Unit	ISO 680 Gear
Viscosity KV 100C	ASTM D445	cSt	**77.1**
Viscosity KV 40C	ASTM D445	cSt	**682.5**
Viscosity Index	ASTM D2270	-	**195**
Pour Point	ASTM D97	C	**-21**
Gardner Color	ASTM D1544	-	**5.5**
Water Content	ASTM D6304	wt%	**< 0.01**
4-Ball Wear	ASTM D4172	mm	**0.31**
4-Ball Weld, Weld Load	ASTM D2783	kgf	**500**
4-Ball Weld, Load-Wear Index	ASTM D2783	kgf	**42.06**

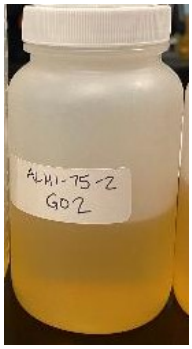


EU Ecolabel
www.ecolabel.eu

16

EcoLabel - BT75/BT22 Gear Oil

Formulations	
Component	Gear Oil
BT75	30.1%
BT22	67.0%
Additive Package	2.9%



EU Ecolabel
www.ecolabel.eu

Results	
Test	Gear Oil
Pour Point (°C)	-21
KV40 (cSt)	226.58
KV100 (cSt)	30.659
VI	178
Specific Gravity (60 °F)	0.9189
Flash Point (°C) **ASTM D92 - Flash Point, Cleveland Open Cup**	272
Four Ball Wear (Average Wear Scar) **ASTM D4172 - Four Ball Wear**	0.321
Four Ball Weld **ASTM D2783 - Four Ball Extreme Pressure - Above 400 kg**	Last Non-Seizure Load = 126 kg, Weld Point = 315 kg Load Wear Index = 59.09
Rust Testing, B Salt Water **ASTM D665 - Rust Preventing Characteristics - 4 Hours**	Pass

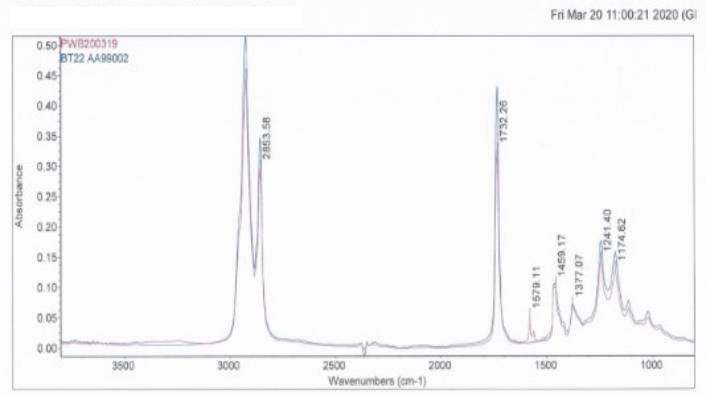
17

Gear Oil Additional Testing

Test Method	Property	DIN51517-3	China GB 5903 CKC	BT Gear Oil	Commercial A	Commercial B
ICP	Boron (ppm)	N/A	N/A	<10	<10	19
	Phosphorous (ppm)	N/A	N/A	387	701	233
	Sulfur (ppm)	N/A	N/A	4195	632	890
ASTM D2270	KV40 (cSt)	In Grade	In Grade	221.6	216.5	223.4
	KV100 (cSt)	N/A	Report	30.3	26.9	26
	VI	≤ 90	≤ 90	178	159	148
ASTM D974	TAN (mg KOH/g)	Report	N/A	0.68	1.57	0.62
ASTM D4052	Density @ 15C (kg/m3)	Report	N/A	918.1	920.1	936.8
ASTM D5950	Pour Point (C)	≤ -9	≤ -9	-21	-42	-30
ASTM D92	Flash Point (C)	≥ 200	≥ 200	260	246	300
DIN 51777-2	Water Content (%)	≤ 0.1	Trace	0.01	nd	nd
ASTM D130	Copper Corrosion	1 max	1 max	1B	1B	1A
ASTM D665A	Rust Performance	Pass	N/A	Pass	**Fail**	Pass
ASTM D1401	Demulsibility (min)	≤ (30)	N/A	42-38-00 (15)	41-36-03 (15)	**43-33-04 (60)**
Flender Foam	Volume Increase (%)	≤ 15	N/A	8	**16**	4
ISO 12152	Total Air after 5 (%)	≤ 10	N/A	5	9	3
Oxidative Stability	KV100 Change (%)	≤ 6	≤ 6	1.49	1.67	1.97
ASTM D2893	Precip # Change, mL	≤ 0.1	≤ 0.1	0	0	0

Lithium Grease

Component	%
BT22	84.8
Lithium 12-Hydroxystearate	6.3
Blachford Complex B	0.9
Vanlube 73 Super Plus	3
Irganox L57	1
NaSul 707	1.5
TPPT	1.5
Vanlube 7723	1

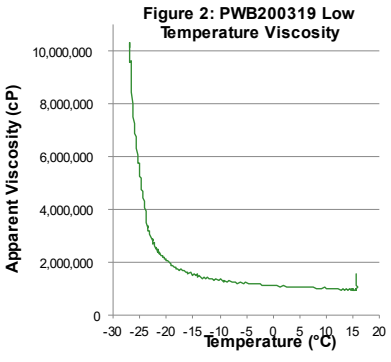


Grease was “cooked” at 220C and homogenized at 6000 psi

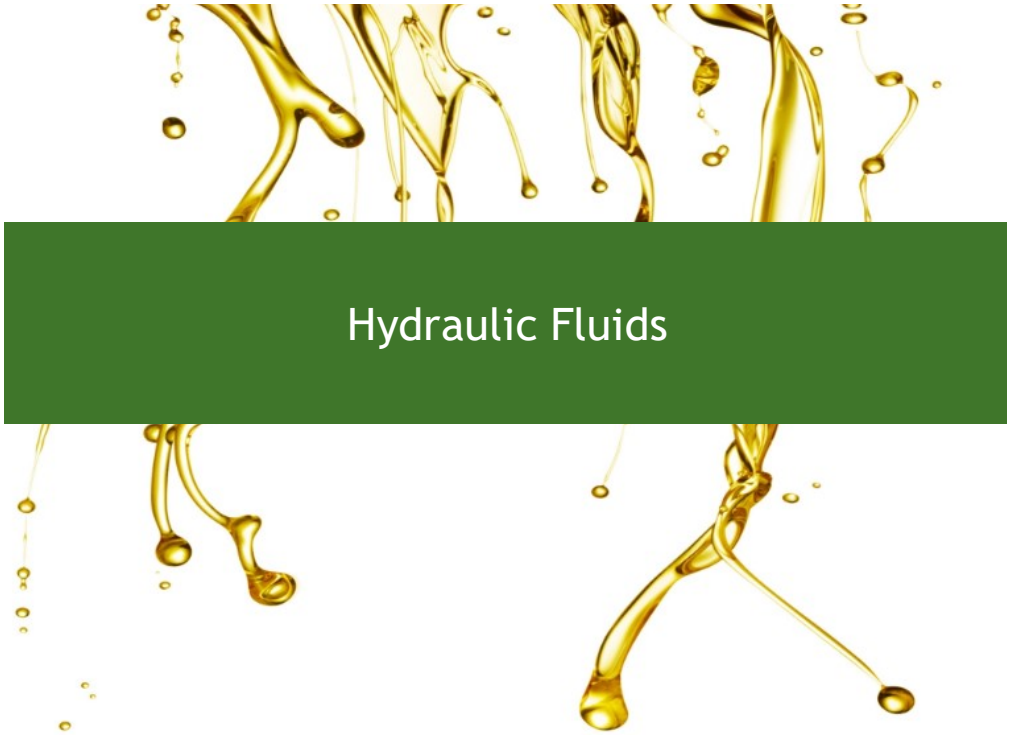
20

Lithium Grease Results

Test	Method	BT 22 Grease	GC-LB Specs
Color	Report	Tan	
Appearance	Report	Smooth	
Base Oil Four Ball Wear, 40kg 75°C, 1200 rpm, 1h, mm	ASTM D4172	0.62, 0.085 CoF	
Unworked Penetration, 1/10th mm	ASTM D217	271	
Worked Penetration, 60x, 1/10th mm	ASTM D217	276	220-340*
NLGI Grade	ASTM D217	2	
Prolonged Worked Penetration, 10,000, 1/10th m	ASTM D217	342	
Worked Penetration, 10,000x	ASTM D217	321	
Oil Separation, 24h at 100C,%	ASTM D6184	0.95	
Evaporation, 24h, 100°C, %	CTM-1	0.71	
Dropping Point,°C	ASTM D2265	249	150 min
Water Washout, 38°C, %	ASTM D1264	4.75	
Four Ball Wear, 40kg 75°C, 1200 rpm, 1h, mm	ASTM D2266	0.42, 0.072 CoF	0.6 max
Chemistry	FT-IR	See Figure 1	
Low Temperature Apparent Viscosity,-C Spindle, Inception Point,°C	CTM-4 (Brookfield)	-23 See Figure 2	
Oxidation Induction Time, 180C, min	ASTM D5483 Modified	No Exotherm	
Four Ball Extreme Pressure, Weld, kg	ASTM D2596	>250 <315	200 min



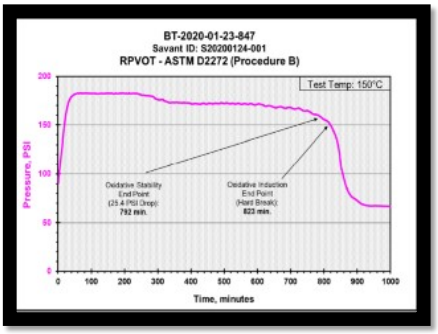
21



Hydraulic Fluids

Hydraulic Formulation #1 ISO46 – PAO BLEND

Formulation	
Component	Hydraulic
BT22	68.43%
PAO 2 cSt	30.75%
Additive	0.82%



Test	Hydraulic
Pour Point (°C)	-32
KV40 (cSt)	44.41
KV100 (cSt)	8.813
VI	182.9
Specific Gravity (60°F)	0.8763
Flash Point (°C) ASTM D92- Flash Point, Cleveland Open Cup	174
Oxidative Stability (RPVOT) ASTM D2272- Rotating Pressure Vessel Oxidation Test (RPVOT) Method B- End of Test/Hard Break	Oxidative Stabilty End Point = 792 minutes, Oxidative Induction En Point = 823 minutes
Hydrolytic Stability ASTM D2619- Hydrolytic Stability of Hydraulic Fluids	Weight change of copp panel (mg/cm²) = 0.00, Appearance of coppe panel = 1B Change in Acid Numbe 0.060 mg KOH/g Totally acidity of the water layer (mg KOH) = 0.010

Hydraulic Formulation #2 ISO46 - Group III BLEND

Formulation	
Component	Hydraulic
BT22	39.68%
4 cSt Group III	59.4%
Additive	0.92%

Environmental Performance		
Biodegradability	OECD 301B	75%
Ecotoxicity		
Pseudokirchneriella subcapitata	OECD 201, 100 ppm for 72 hrs	Not acutely toxic
Daphnia magna	OECD 202, 100 ppm for 48 hrs	Not acutely toxic
Pimephales promelas	OECD 203, 100 ppm for 96 hrs	Not acutely toxic

Performance Data	Method	Unit	ISO 46 Hydraulic
Viscosity KV 100C	ASTM D445	cSt	**8.43**
Viscosity KV 40C	ASTM D445	cSt	**46.0**
Viscosity Index	ASTM D2270	-	**162**
Pour Point	ASTM D97	C	**-26**
Flash Point (COC)	ASTM D92	C	**224**
Total Acid Number	ASTM D664	mg KOH/g	**0.39**
Color	ASTM D1500	-	**<1**
Gardner Color	ASTM D1544	-	**5.5**
Water Content	ASTM D6304	wt%	**< 0.01**
Rust Testing, A Fresh Water	ASTM D665	-	**Pass**
Rust Testing, B Salt Water	ASTM D665	-	**Pass**
Copper Corrosion	ASTM D130	Rating	**1a**
Demulsibility	ASTM D1401	-	**40, 40, 0 (15)- Pass**
Foam	ASTM D892	-	**0/0, 0/0, 0/0**
4-Ball Wear	ASTM D4172	mm	**0.413**
4-Ball Weld, Weld Load	ASTM D2783	kgf	**160**
4-Ball Weld, Last Non-Seizure Load	ASTM D2783	kgf	**100**
4-Ball Weld, Load-Wear Index	ASTM D2783	kgf	**39.96**
Hydrolytic Stability			
TAN Increase in oil lay	ASTM D2619	mg KOH/g	**0.24**
TAN Increase in water lay	ASTM D2619	mg KOH/g	**0.63**
Oxidative Stability, RPVOT	ASTM D2272	min	**584**

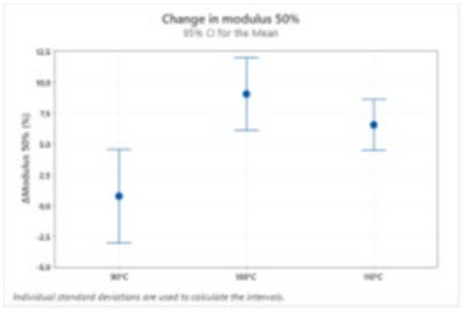
24

Hydraulic Formulation #3 ISO 68 - Group III BLEND

Formulation	
Component	Hydraulic
Estolide	58.5%
4 cSt Group III	40.2%
Additive	1.3%

Environmental Performance		
Biodegradability	OECD 301B	77%
Ecotoxicity		
Pseudokirchneriella subcapitata	OECD 201, 100 ppm for 72 hrs	Not acutely toxic
Daphnia magna	OECD 202, 100 ppm for 48 hrs	Not acutely toxic
Pimephales promelas	OECD 203, 100 ppm for 96 hrs	Not acutely toxic

Performance Data	Method	Unit	ISO 68 Hydraulic
Viscosity KV 100C	ASTM D445	cSt	**11.1**
Viscosity KV 40C	ASTM D445	cSt	**65.8**
Viscosity Index	ASTM D2270	-	**163**
Pour Point	ASTM D97	C	**-26**
Gardner Color	ASTM D1544	-	**4.2**
Water Content	ASTM D6304	wt%	**< 0.01**
Rust Testing, A Fresh Water	ASTM D665	-	**Pass**
Rust Testing, B Salt Water	ASTM D665	-	**Pass**
Demulsibility	ASTM D1401	-	**40, 40, 0 (5)- Pass**
Foam	ASTM D892	-	**0/0, 10/0, 0/0**



AEGIR Marine

Approved

25

ISO 68 HF Results

Performance Data	Method	Unit	ISO 68 (BT22, VHVI4)
Viscosity KV 100 °C	ASTM D445	cSt	11.1
Viscosity KV 40 °C	ASTM D445	cSt	65.8
Viscosity Index	ASTM D2270	-	163
Pour Point	ASTM D97	C	-25
Flash Point (PM)	ASTM D92	C	213
Total Acid Number	ASTM D664	mg KOH/g	0.28
Gardner Color	ASTM D1544	-	4.2
Water Content	ASTM D6304	wt%	142
Rust Testing, A Fresh Water	ASTM D665	-	Pass
Rust Testing, B Salt Water	ASTM D665	-	Pass
Copper Corrosion	ASTM D130	Rating	1A
Demulsibility	ASTM D1401	-	40, 40, 0 (5)
Foam	ASTM D892	-	0/0, 10/0, 0/0
4-Ball Wear	ASTM D4172	mm	0.529
4-Ball Weld, Weld Load	ASTM D2783	kgf	160
4-Ball Weld, Last Non- Seizure Load	ASTM D2783	kgf	80
4-Ball Weld, Load -Wear Index	ASTM D2783	kgf	32.84
Hydrolytic Stability	ASTM D2619	-	
Copper Weight Loss	ASTM D2619	mg/cm2	-0.108
Copper Appearances	ASTM D2619	Rating	1b Shiny
TAN Increase in oil layer	ASTM D2619	mg KOH/g	0.01
TAN Increase in water layer	ASTM D2619	mg KOH/g	2.84
Oxidative Stability, RPVOT	ASTM D2272	-	
Oxidative Stability End Point	ASTM D2272	min	1112
Oxidative Induction End Point	ASTM D2272	min	1219

26

Metal Working

Biocea™ Additives for Metalworking Fluids

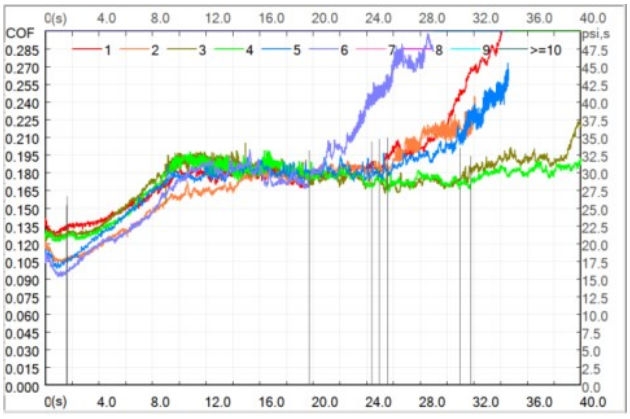
Additive	General Machining	Cutting and Grinding	Forming
Biocea™ I	✓✓	✓✓✓	✓
Biocea™ II	✓✓✓	✓✓✓	✓✓
Biocea™ III	✓	✓✓	✓✓✓

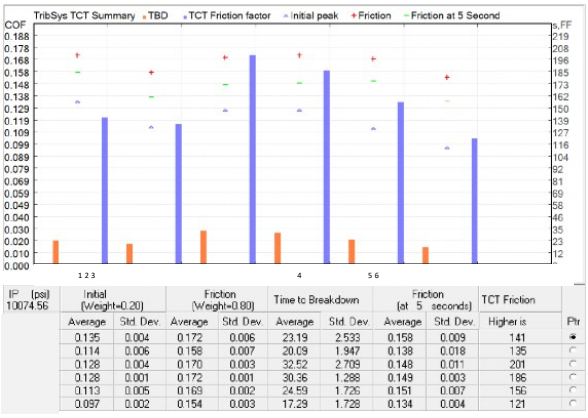
*Results may vary. Optimum blends can be created to maximize performance by application.

Performance Feature	*Pentaerythritol Ester*	*Synthetic Ester*	*TMPTO*	*Biocea™ I*	*Biocea™ II*	*Biocea™ III*
Lubricity	✓	✓	✓	✓	✓✓	✓✓✓
Film Strength	✓	✓	✓	✓✓	✓✓✓	✓✓✓
Anti-Wear	-	-	-	✓✓	✓✓✓	✓✓✓
Improved Tool Life	✓	✓	✓✓	✓✓	✓✓✓	✓✓✓
Increased Polarity	-	✓	-	✓	✓✓	✓✓
Hydrolytic Stability	-	✓	-	✓✓✓	✓✓✓	✓✓✓
Molecular Weight	420.6*	295.04*	927.5*	455	1462	2680

*Numbers are based on industry averages and final numbers for individual products may vary.
Results listed in table may vary. Optimum blends can be created to maximize performance.

Biocea™ Twist Compression Test





IP (psi) 10074.56	Initial (Weight=0.20)		Friction (Weight=0.80)		Time to Breakdown		Friction (at 5 seconds)		TCT Friction	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Higher is	Pr
	0.135	0.004	0.172	0.006	23.19	2.533	0.158	0.009	141	
	0.114	0.006	0.158	0.007	20.09	1.947	0.138	0.018	135	
	0.128	0.004	0.170	0.003	32.52	2.709	0.148	0.011	201	
	0.128	0.001	0.172	0.001	30.36	1.288	0.149	0.003	186	
	0.113	0.005	0.169	0.002	24.59	1.726	0.151	0.007	156	
	0.097	0.002	0.154	0.003	17.29	1.728	0.134	0.004	121	

1. Pentaerythritol Ester (15%)
2. Biocea II (15%)
3. Biocea™ III (15%)
4. Biocea™ IIIHP (15%)
5. BT-PRA50 (15%)
6. BT-PRA100 (15%)

- During initial testing, the Biocea ™ products indicated superior performance when compared to traditional technology currently available in the marketplace.
- Overall, the Biocea™ IIIHP (15%) showed superior performance of all additives tested so far.

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LIFE CYCLE ASSESSMENT INFORMATION

Biosynthetic® Technologies offers a wide range of specialty oleo chemicals with numerous uses in industrial lubricant, metalworking, marine, and personal care applications. Our patented Estolide technology products can be used as the primary base oil and/or an additive. Our extensive oleo chemical commodities product line are feedstock agnostic but feature quality sustainable feedstocks such as; castor, soybean and many others. In addition to their high-performance properties our oleo solutions are: Biodegradable, Sustainable, Renewable, Non-bioaccumulative, and Non-toxic.

At Biosynthetic® Technologies, we understand the importance of sustainable manufacturing practices. We are constantly looking for ways to minimize the negative impacts on the environment while conserving energy and natural resources. Our objective is to make sustainability a point of difference for our business, and we are confident that this strategy will generate even greater benefits for the environment in which we operate, the people that we work with and the communities we are part of. Biosynthetic® Technologies is committed to sustainability and clearly focused on the responsible use of natural resources in our daily business. As such, our manufacturing facility is operating with a NEGATIVE carbon footprint!

At Biosynthetic® Technologies, we can proudly say that our sustainable base oils are produced in a negative carbon output manufacturing facility. A life cycle study of our manufacturing facility and all its processes has confirmed a NEGATIVE carbon footprint; cradle to crate!

Biosynthetic Technologies' base stocks are derived from oleo chemicals, predominantly free fatty acids from oils sources like High Oleic Soy Oil and Castor Oil. We have completed Life Cycle Assessments of our Castor derived Estolides in conjunction with the Gujarat Agriculture University, our manufacturing partner, and the Dantiwada and Kadam Environmental consultancy laboratory and found our molecules to be sustainable both from an Environmental standpoint where we looked at CO2, NOx, Sox, TDS, and other key environmental impacts, but also from a social capacity as well.
Biosynthetic Technologies Estolides provide farmers with a pathway out of poverty, they don't compete with food crops, and no forest habitat is destroyed or altered for the planting of the crops. In addition, the region where we manufacture Estolides, is highly optimized geographically, logistically, and uses the full waste streams from Castor Oil production. For example, we use the spent cake from the Castor crush to fire the boilers that generate the steam for our Estolide synthesis. In the end we have shown when accounting for the CO2 uptake of the entire Castor Plant our products leave the gate of our manufacturing facility in a carbon negative state.

The previously mentioned life-cycle study illustrates the positive environmental aspects and impacts of utilizing a biobased material. It is also recognized that the composition and manufacturing of Biosynthetic Technologies base oils will evolve over time as part of a continual improvement process, but these changes are not expected to significantly change the overall environmental impact profile. The important advantage of our manufacturing process is that our feedstock, in plant format, absorbs carbon dioxide, thereby reducing greenhouse gas accumulations in the atmosphere.

The life cycle study for Biosynthetic® Technologies base oils was conducted to trace out the environmental effect of our products. All stages in the life cycle of a product area were analyzed: raw material acquisition, manufacture, transportation, and its uses. For each of our products, we produced material and energy flows including the environmental inputs of water, energy, land resources and outputs such as emission to the air, water effluent, and solid and liquid waste. They were then examined on the following 10 Environmental impacts:

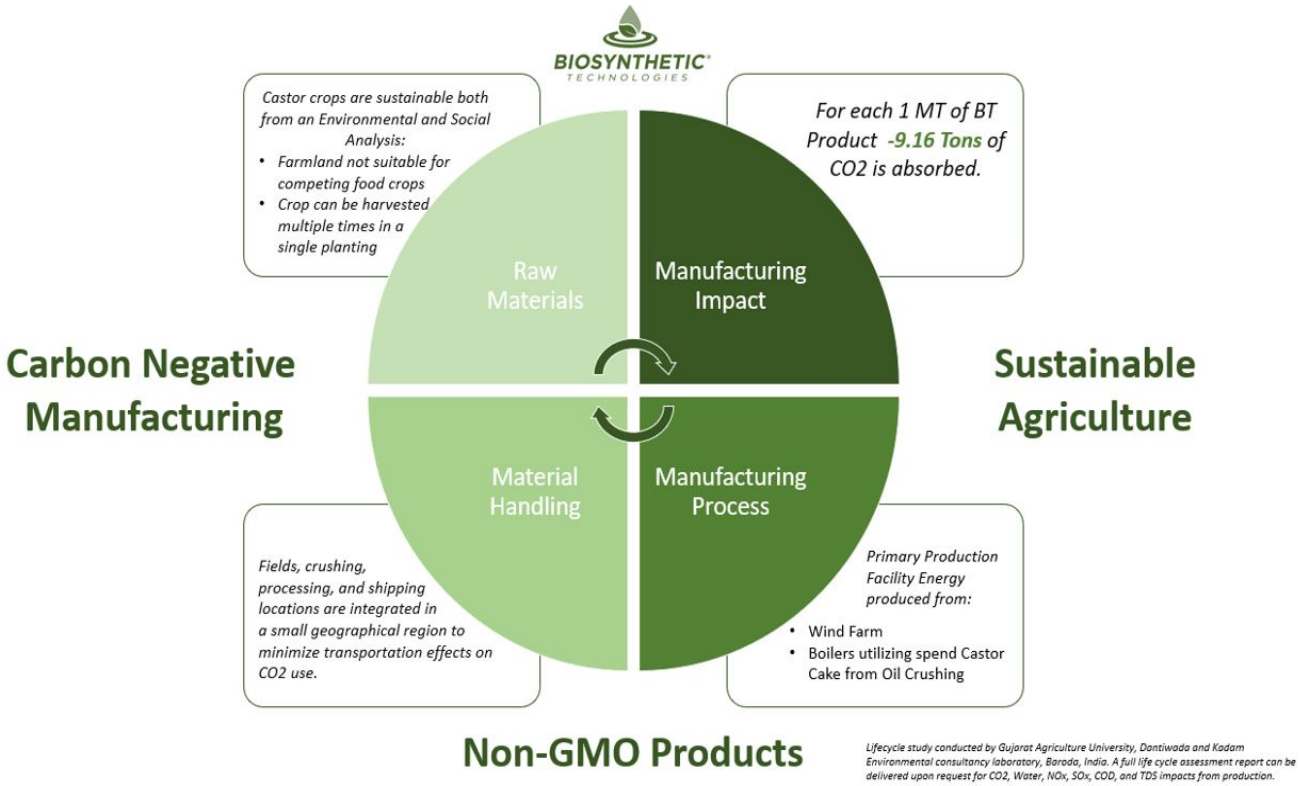
1. Global warming potential – CO2, CH4, N2O
2. Acidification potential – SOx, NOx,
3. Fossil fuel depletion – coal, oil usage
4. Habitat alteration – virgin land area consumed
5. Criteria air pollutants – SOx, NOx and particulates
6. Human health – carcinogens
7. Smog – NOx equivalents
8. Ecological toxicity – aquatic and soil toxics, e.g., heavy metals
9. Water intake – consumptive water use
10. Indoor air quality – volatiles released within 72 hours

Details	Seed Farming	Seed Transportation	Seed Crushing	Oil Refining	Oil Transportation	Estolide Production	Subtotal	Steam Production	Wind Power Generation	Total
Water (m3)	9,400.000	-	-	-	-	0.150	9,400.150	-	-	9,400.150
Electricity (KWh)	-	-	91.000	-	-	725.000	816.000	-	-	816.000
Steam (Tonne)	-	-	0.413	0.590	-	3.460	4.463	-	-	4.463
CO2 (Tonne)	(17.300)	0.074	-	-	0.088	-	(17.138)	7.976	-	**(9.162)**
Nox (kg)	-	1.870	-	-	0.225	-	2.095	0.965	-	3.060
Sox (kg)	-	0.065	-	-	0.008	-	0.073	0.068	2.786	2.927
Eflluent (Tonne)	-	-	-	-	-	0.225	0.225	-	-	0.225
COD (ppm)	-	-	-	-	-	50.000	50.000	-	-	50.000
TDS (ppm)	-	-	-	-	-	1,200.000	1,200.000	-	-	1,200.000

In addition, our manufacturing facility generates 100 % of its electrical energy from windmills. All by products flowing from our production processes are used or sold as fertilizer, fuel, sweeteners and blending agents, food grade lubricants but also as raw materials for other product such as soaps, detergents, fining agents etc. The conclusion from the life cycle study is that the net carbon absorption after the production of the Biosynthetic® Technologies base oils is -9.1644. Regarding the environmental performance of our products (with all environmental impacts being given equal weighting) the most significant impact was noted for:

1. Negative effect on Global warming
2. Reduced CO2 production
3. Reduction in Smog formation
4. Reduced Eutrophication
5. Reduction in Ecological toxicity

Biosynthetic® Technologies is among a growing number of innovative companies focused on restoring the balance and stabilizing our global climate through carbon-negative manufacturing.



Carbon Negative Manufacturing

Sustainable Agriculture

Non-GMO Products

Lifecycle study conducted by Gujarat Agriculture University, Dantiwada and Kadam Environmental consultancy laboratory, Baroda, India. A full life cycle assessment report can be delivered upon request for CO2, Water, NOx, SOx, COD, and TDS impacts from production.

CERTIFICATIONS AND REGISTRATIONS

Certification is a key strategy in further enhancing Biosynthetic® Technologies into a world class producer of sustainable and high-performance base oils. At Biosynthetic® Technologies we hold the appropriate certifications and registrations to certify our products do not deliver on performance and quality but are also compliant with national and international requirements. Please visit www.biosynthetic.com to download certification letters etc.

Product	US	Canada	Europe, REACH	Environmental Claims		Food Contact	
	Approval	Approval	Approval	Eco Label LuSC List	BioPreferred	HX-1 InS	HX-1 NSF
BT4	✓	✓	✓	✓	68% Biocontent	✓	✓
BT22	✓	✓	✓	✓	86% Biocontent	✓	✓
BT75	✓	✓	✓	✓	94% Biocontent	✓	✓

Product	US	Canada	Europe, REACH	Environmental Claims		Food Contact	
	Approval	Approval	Approval	Eco Label LuSC List	BioPreferred	HX-1 InS	HX-1 NSF
Biocea™ I	✓	✓	✓	✓	68% Biocontent	✓	✓
Biocea™ II	✓	✓	✓	✓	86% Biocontent	✓	✓
Biocea™ III	✓	✓	✓	✓	94% Biocontent	✓	✓

INS and NSF HX-1

Our products are registered with INS Services and NSF as an HX-1 ingredient for use in H1 lubricants with incidental food contact. H1 fluids are widely used in and around food processing areas as well as in pharmaceutical and other applications. The HX-1 certification for our BioEstolides™ and sustainable base oils allows lubricant manufacturers to formulate environmentally friendly H1 lubricants with high performance characteristics such as excellent oxidative stability and superior hydrolytic stability.

Kosher

Kosher is derived from a Hebrew word and means “right and proper.” Some may also define it as “suitable and pure.” It also means fit to eat. In order for a food to be considered kosher, each stage of the food’s production, handling and manufacturing must adhere to strict biblical laws, which dictate the foods a Jewish person can consume and the way they have been prepared. These standards have their origins in Jewish law. Those who consume kosher food have made a pledge to eat foods that have been prepared in a clean environment and to consume pure foods. In summary, if a food or chemical is kosher, it will have been prepared in accordance with Jewish food laws. Our products are kosher certified.

Halal
Halal is an Arabic word that means what is permitted in Islam, usually used to refer to dietary instructions. Halal-certified products have been approved by a certifying body. Certification indicates that there are no prohibited or unlawful ingredients contained within the food. They would have undergone a strict certification system to ensure that they meet these standards. Our products are manufactured in a facility that has been granted a halal certificate. In addition, all our products are halal certified.

Vegan
The Certified Vegan Logo is a registered trademark, similar in nature to the kosher mark, for products that do not contain animal products or byproducts and that have not been tested on animals. Our products are vegan certified.

ISO 14001 – Environmental Monitoring and Measurement
The standards and tools defined in ISO 14001 help organizations successfully manage their environmental responsibilities.

ISO 9001 – Quality Management Systems
This standard sets out a clear criterion for the requirements of a quality management system. The aim of this standard is to aid efficiency and enhance customer satisfaction. Each organization is expected to set out their own quality and customer satisfaction standards. Once these have been defined, the organization strives to improve their performance in accordance with the standards it has set out. Download the applicable information here.

Good Manufacturing Practices
Good Manufacturing Practice Regulations, or GMP, is a system that ensures consistency and quality of produced and controlled products. The regulations can be legally enforced and ensure that industry sectors such as packers, manufacturers and producers are actively involved in ensuring the purity, safety and effectiveness of the items they produce.
All our manufacturing facilities have systems in place and that it complies with Good Manufacturing Practice Regulations, ensuring both quality and consistency. Certification reduces the risk of contamination during manufacturing and provides consumers with the assurance that the product is safe and effective.

SAMPLING INFORMATION

To request a sample of any of our products please visit:

https://www.biosynthetic.com/products/

Upon completion of the online sample request form, the customer will receive an email from us with tracking information. Samples will be shipped within 3 business days.

An email will be shared with the customer upon shipment, containing the details of the sample request as well as the tracking number. For more information, please contact:

Base Oil Samples (BT Products):
Mike Woodfall | mwoodfall@biosynthetic.com | (832) 702-9286

Additive Samples (Biocea™ Products):
Jeffrey Mackey | jmackey@biosynthetic.com | (317) 656-9510

Specialty Castor Derivatives Samples :
Jeffrey Mackey | jmackey@biosynthetic.com | (317) 656-9510

Our standard sample size is 10 oz. Larger samples sizes are available upon request.

https://www.biosynthetic.com/products/

CONTACT INFORMATION

Mark Miller: CEO

Mark Miller is the CEO of Biosynthetic Technologies (BT), an Indianapolis-based company that provides high performance, renewable, non-toxic, biodegradable petroleum replacement. Prior to BT, he co-founded and was CEO of Terresolve Technologies, Ltd. A globally recognized environmentally safe chemical products company. He has engineered, sold and marketed environmentally acceptable lubricants and base oils for over 30 years. Mr. Miller is Vice Chair of ASTM Subcommittee D02.12 on Environmental Standards for Lubricants and the 2022 Technical Editor for STLE's TLT magazine. He has a B.S. in Chemical Engineering from Tufts University and an M.B.A. from Manhattan College and is the Entrepreneur-in-Residence and a business professor at The Ramapo College of New Jersey. Mark also sits on the Board for The National Foundation For Animal Rescue (NAFFAR) and he and his wife, Shari, have adopted more than their share of homeless critters.

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Matt Kriech: COO

Along with being COO of Biosynthetic Technologies, Dr. Kriech supports Heritage Research Group and The Heritage Group in evaluation of potential new projects and investments. Prior to his current role, he led the transition team for THG- The Center and worked for Asphalt Materials Inc. in developing predictive economic models. He has also served as General Manager of PIZO and Supply Chain Manager, Tolling Manager, and Business Excellence leader for Monument Chemical. Matt received his B.A. from Wabash College in 2000 and his Ph. D. from the University of Utah in 2005, where he studies protein-lipid interactions using non-linear optical spectroscopy. Prior to returning to Indiana, he worked for ATK as a "Rocket Scientist" in Utah, helping to test and develop state of the art rocket propellants. Matt serves on local charity boards for cancer and diabetes. In his spare time, he enjoys outdoor activities, spending time with his family, and brewing beer as owner of Wabash Brewing.

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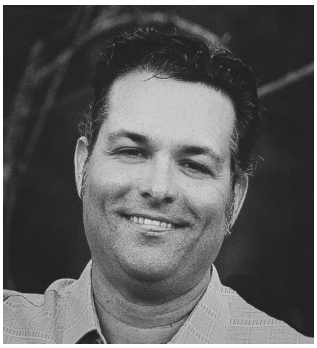

Mike "Woody" is the Sales and Commercial Leader for Biosynthetic Technologies, as such he looks forward to helping customers innovate in the growing sustainable lubricant marketplace. Mike received a BS Chemical Engineering from the University of Illinois. His career in lubricants started at the D.A. Stuart Company where he first worked with vegetable oils in Lubricant formulations. Since then his experience in the Lubricant Industry has allowed him to represent companies such as Cargill, Afton Chemical, Bunge, and Monson. This experience has helped build a foundation of knowledge in both fuel and lubricant additive technology, while continuing to bring renewable solutions to formulators. He is currently serving as a Board Member with the STLE Houston Section and enjoys volunteering in the outdoors with his local BSA Troop.

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Julie Austin: R&D

Julie is a highly valued, integral part of Biosynthetic Technologies R&D Team bringing 20 years of chemistry research experience. Julie earned a B.S. in Chemistry with a focus in Environmental Biology. Beginning her career at Reilly Industries, she worked in exploratory research and development of pyridine-based derivatives. Following, she joined Great Lakes Chemical for 13 years as the lead researcher on various projects that were piloted and commercially developed as flame retardants for thermoplastic resins and thermoset foams. In 2014, Julie was recruited by The Heritage Group and began working with Calumet Chemical on developing new transformer oils, improving cold flow properties of B100, and researching new technology for supply chain issues as well as working with other THG groups on organic synthesis processes prior to joining Biosynthetic Technologies in 2018. Julie is a 25+ year member of the American Chemical Society. With a desire to stimulate young minds in the fields of STEM, she has assisted with many Children's Science Camps and Festivals over the years. With her husband Craig, Julie lives in Fountain Square where they enjoy spending time with friends at local music venues and restaurants, walking and biking the Cultural Trail, and working to improve their local community.

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Debby Neubauer:
Marketing &
Personal Care Lead

Debby Neubauer is a B2B Marketing professional with over 20 years of experience in sales and marketing that spans a wide range of industries. From Caskets to oil and college textbooks to print-work, Debby has seen it all.. even got some t-shirts! For the last 12 year she has run the marketing department for both B2B and B2C divisions, including brands such as, Batestville, Penreco, Royal Purple and Bel-Ray. Debby holds a bachelor's degree From the Haarlem Business School in the Netherlands and an MBA from Southern Illinois University at Edwardsville. Did we mention that Debby is Dutch? Why does that matter? Well, it means that she's a bit mischievous and direct, is pretty witty and a little cheeky. She also considers herself an unofficial black licorice taste tester … and a really slow runner. Debby's journey to excellence has been fueled with an unrelenting passion for learning. When not working, Debby can be found with either a good book, in the middle of a Netflix binge watch, travelling or a combination of the three!

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Mr. Thompson oversees the development of innovative chemistries from lab to commercial scale. Prior, Travis held various project roles in the areas of product development, process design and manufacturing.
Travis received a B.S. from the University of California Irvine and is names on 35+ US patents in the fields of organic chemistry, formulation chemistry and process engineering. In addition, he has authored a number of articles in industry-leading publications on topics ranging from chemical biology to sustainable chemistries. Travis currently resides in Anaheim, California with his kids. In his free time, he enjoys running, reading, hiking, and snowboarding.

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Dr. Marlon Lutz:
Process Chemist

Dr. Lutz brings 17 years of chemistry experience including 6 years dedicated to Estolide synthesis and product development. He is responsible for researching and commercializing our bio based products using Estolide technology. Dr. Lutz has a strong passion for chemistry where he excels in developing novel molecules and improving chemical processes with an emphasis on incorporating greener methods. Dr. Lutz graduated from Loyola University Chicago with a Ph. D. in Organic Chemistry and an emphasis in synthetic methodology and medicinal and supramolecular chemistry. In addition, Marlon spent over a decade at Regis Technologies in Chicago where he developed novel synthetic routes for active pharmaceutical ingredients and fine/specialty chemicals, optimized processes, and translated this information to develop safe, scalable and robust processes under cGMP regulations. Marlon holds over 25 publications in peer-reviewed journals/books and is named on 14 U.S. patents in the fields of organic chemistry, process chemistry, medicinal chemistry, supramolecular chemistry, and novel cancer therapeutic agents. In his spare time, Marlon enjoys making wine with his wife for their winery, playing sports and his guitar. He also enjoys being outdoors with his wife and their four children whether it is camping, fishing, or just being on the water.

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Jeffrey Mackey:
Application and
Commercialization Lead

Jeff Mackey has been active in the metalworking industry for almost 30 years beginning at Van Straaten/Castrol in R&D. He later moved to Fuchs Lubricant Company where he held several technical roles including R&D Manager for metalworking fluids. Jeff expanded his career in metalworking and industrial additive sales working for Lubrizol Corporation and later Afton Chemical Corporation where he managed the CTS group for metalworking. Prior to Biosynthetic Technologies, Jeff was Vice President of Marketing and Business Development for Yushiro Manufacturing Americas, Inc. where he focused on new market development and M&A activities. Jeff has held several committee positions over the years including past Chair of the Metalworking committee for ILMA, Past Chair for STLE's CMFS committee, and is currently Vice -Chair for STLE's LORV section. Jeff lives in the Indianapolis area with his wife and three children and enjoys golf, volleyball, and spending time with his family.

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Alex Kitchel:
Lab Technician

Alex's work focuses on the use of additives in oils and additional work on the hydrolytic stability of these oils. Prior to BT, Alex worked at Pace Analytical where he worked to determine pollutant and contaminant levels in water and soil samples.
Alex received his B.A. from Hanover College in Biology and History. His work in Biology focuses on ecology and conservation with experience in Thailand where he completed studies on coral bleaching and its effects on marine species richness and evenness. In Alex's free time he enjoys playing sports, working out, reading, hiking, and scuba diving.

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LINKS AND OTHER INFORMATION

Please check out our website for additional information. Here are some of the links:

- Base Oil Applications — Applications - Biosynthetic
- Estolide Technology — Estolides - Biosynthetic
- SDS Information — Safety Data Sheets - Biosynthetic
- TDS Information — Technical Data Sheets - Biosynthetic
- Certification — Certifications - Biosynthetic
- Sample Order Form — Sample Request Form - Biosynthetic

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