

Development of a High-Performance, Environmentally Acceptable Hydraulic Fluid

Innovation and sustainability are key values at Biosynthetic Technologies (BT) that drive the strategic direction of the company's development programs. The research team at BT spends most of their time at the interface of these domains, looking for creative ways to solve the world's sustainability challenges. While most of this effort has centered on making and marketing sustainable ingredients to lubricant formulators, BT's scientists recently put their heads together to demonstrate how a collection of these sustainable ingredients could be used to make a fully functional, high-performance, environmentally acceptable hydraulic fluid.

The purpose of this initiative was to develop a commercially viable hydraulic fluid from sustainable ingredients, capable of meeting the ISO 15380 HEES standard. Ingredients with favorable environmental profiles were selected: (1) BT22, a biodegradable estolide product from Biosynthetic Technologies with high bio-content, (2) a severely hydrotreated low viscosity Group III product with good biodegradability, (3) an EcoLabel additive package from a major lubricant additive supplier, and (4) a top-treat anti-foam additive from another major additive company. A description of the components in the formulation has been documented in Table 1.

Ingredient	Company	ISO VG 68 Formulation, wt%
BT22 (Estolide)	Biosynthetic Technologies	58.50%
Group III (Severely Hydrotreated)	Major Oil Refiner	40.20%
EcoLabel Additive Package	Major Additive Company	1.25%
Anti-Foam	Major Additive Company	0.05%

Table 1. ISO VG 68 hydraulic fluid formulation details.

Basic Physicals

While an ISO 68 viscosity grade was created for the purposes of the full testing sequence, read-across compatible ISO 32 and 46 grades can also be formulated by adjusting the ratio of the base stocks. As seen in Table 2 below, the ISO 68 product meets the ISO 15380 specifications for viscosity, pour point, flash point, and water.

	Method	Unit	ISO 15380 Spec (HEES)	ISO 68 Results
BASIC PHYSICALS				
Kinematic Viscosity, 100°C	ASTM D445	cSt	7.8 min	11.1
Kinematic Viscosity, 40°C	ASTM D445	cSt	61.2 to 74.8	65.8
Kinematic Viscosity, 0°C	ASTM D445	cSt	1400 max	TBD
Viscosity Index	ASTM D2270	-	-	163
Pour Point	ASTM D97	°C	-12 max	-25
Flash Point (COC)	ASTM D92	°C	195 min	254
Density at 15°C	ASTM D1298		Report	0.8808
Color	ASTM D1500	-	Report	<1
Appearance at 25°C	Visual	-	Clear and Bright	Clear and Bright
Total Acid Number	ASTM D664	mg KOH/g	-	0.28
Water Content	ASTM D6304	ppm	1000 max	142

Table 2. Basic physical properties of the ISO 68 hydraulic fluid.

Wear, EP, and the Vickers Vane Pump Test

Perhaps some of the most interesting performance data came from the Vickers Vane Pump Test, ISO 20763, which was run at Southwest Research Institute. After the 250-hour test, the hydraulic fluid yielded a ring wear value of 1.9 mg (as compared to a spec limit of <120 mg), and a vane wear value of 3.3 mg (as compared to a spec limit of <30 mg). Being one of the most difficult tests to pass, it was impressive to see such low results reported. The vane pump data, along with other wear, weld and load data for the fluid are provided in Table 3 below.

	Method	Unit	ISO 15380 Spec (HEES)	ISO 68 Results
WEAR, EP, AND PUMP TEST				
4-Ball Wear	ASTM D4172	mm	-	0.529
4-Ball Weld	ASTM D2783	-	-	-
Weld Load	"	kgf	-	160
Last Non-Seizure Load	"	kgf	-	80
Load-Wear Index	"	kgf	-	32.84
Load-Carrying Properties (FZG A/8, 3/90)	ISO 14635-1	Stage	10 min	11
Vane Pump, Procedure A	ISO 20763	-	-	-
Ring, weight loss	"	mg	120 max	1.9
Vanes, weight loss	"	mg	30 max	3.3

Table 3. Wear, EP, Load and Vane Pump test data.

Environmental Characteristics

One of the goals in developing the hydraulic fluid was to make sure it had a favorable environmental profile, especially in the areas of biodegradability, renewable carbon content, and ecotoxicity. While these are not specified in ISO 15380, they're critical parameters to consider when designing an EAL product. The ISO 68 hydraulic fluid is biodegradable, contains 52% bio-content, and is non-toxic per the standards outlined in the table below.

	Method	Unit	ISO 15380 Spec (HEES)	ISO 68 Results
ENVIRONMENTAL CHARACTERISTICS				
Biodegradability	OECD 301B	%	-	>60%
Renewable Carbon Content	ASTM D6866	%	-	52%
EcoToxicity	OECD 201	mg/L	-	Pass
EcoToxicity	OECD 202	mg/L	-	Pass
EcoToxicity	OECD 203	mg/L	-	Pass

Table 4. Testing commonly performed to characterize environmentally acceptable lubricants.

Seal Compatibility

If a product is incompatible with the elastomers used in a hydraulic system, shrinking and/or swelling of equipment seals could occur during service. Over time, such behavior could lead to fluid leakage, increased maintenance needs, and eventually total equipment failure. The ISO 68 hydraulic fluid developed by BT was tested against HNBR and FKM 2 for 1000 hours at 100°C, and the results meet the ISO 15380 targets. In addition, BT engaged AEGIR-Marine, an OEM with a proprietary Viton+ seal technology, to run a third static compatibility test. The fluid passed all OEM targets, including those for mass, hardness, tensile strength, modulus, and elongation changes.

	Method	Unit	ISO 15380 Spec (HEES)	ISO 68 Results
SEAL COMPATIBILITY				
HNBR - 1000 hrs, 100°C	ISO 6072	-	-	-
Volume Change, %	"	%	-3 to 10	3.96
Points Hardness Change	"	-	-10 to 10	-1
Tensile Strength Change, %	"	%	30 max	-5.9
Elongation Change, %	"	%	30 max	-4.2
FKM 2 - 1000 hrs, 100°C	ISO 6072	-	-	-
Volume Change, %	"	%	-3 to 10	0.5
Points Hardness Change	"	-	-10 to 10	-5
Tensile Strength Change, %	"	%	30 max	-1.4
Elongation Change, %	"	%	30 max	13.3
AEGIR-Marine OEM Test	PRIME Viton+ Compatibility	-	-	-
Mass Change, %	"	%	-	Pass (0.65%)
Hardness Change, %	"	%	-	Pass (-3.9%)
Tensile Strength Change, %	"	%	-	Pass (-18%)
Modulus Change, %	"	%	-	Pass (-4%)
Elongation Change, %	"	%	-	Pass (7.5%)

Table 5. Elastomer compatibility testing performed with Southwest Research and AEGIR-Marine.

Oxidative and Hydrolytic Stability

Though not specified in ISO 15380, the formulation achieved high marks on RPVOT, with an oxidation induction time of 1112 minutes. Additionally, dry TOST was >2000 minutes, wet TOST was 541 minutes, and the hydrolytic stability data showed a shiny copper strip along with a nominal increase in acid value. All of these are indications that the product will have good longevity when in service, whether in the presence of oxygen radicals or water.

	Method	Unit	ISO 15380 Spec (HEES)	ISO 68 Results
OXIDATIVE AND HYDROLYTIC STABILITY				
Oxidative Stability, TOST (Dry)	ASTM D943, Dry	Hours	Report	>2000
Oxidative Stability, TOST (Wet)	ASTM D943, Wet	Hours	-	541
Oxidative Stability, RPVOT	ASTM D2272	Minutes	-	1112
Baader Test, Viscosity Increase at 40°C	DIN 51554-3	%	20 max	0.22
Hydrolytic Stability	ASTM D2619	-	-	-
Copper Weight Loss	"	mg/cm ²	-	-0.108
Copper Appearances	"	Rating	-	1b Shiny
TAN Increase in oil layer	"	mg KOH/g	-	0.01
TAN Increase in water layer	"	mg KOH/g	-	2.84

Table 6. Oxidative and hydrolytic stability data, showing the resistance of BT's hydraulic fluid to degradation by oxygen and water.

Rust and Corrosion

With respect to corrosion, the ISO 68 formulation not only passed fresh water ASTM D665A, as required by the standard, but it also passed the more rigorous salt water rust test, ASTM D665B. Additionally, on the ASTM D130 copper corrosion test, the formulation showed the least amount of tarnish possible, with a “1A” rating.

	Method	Unit	ISO 15380 Spec (HEES)	ISO 68 Results
RUST & CORROSION				
Rust Testing, A Fresh Water	ASTM D665A	-	Pass	Pass
Rust Testing, B Salt Water	ASTM D665B	-	-	Pass
Copper Corrosion	ASTM D130	-	2 max	1a

Table 7. Positive results on the formulation for both rust and corrosion.

Other Fluid Properties

The formulation developed by BT also demonstrates excellent performance in the areas of demulsibility and foam, as well. This data has been recorded in the table below.

	Method	Unit	ISO 15380 Spec (HEES)	ISO 68 Results
OTHER FLUID PROPERTIES				
Demulsibility	ASTM D1401	oil/water/em.	-	40, 40, 0 (5)
Foam	ASTM D892	-	150/0, 80/0, 150/0 max	0/0, 10/0, 0/0

Table 8. Remaining performance data on the ISO 68 hydraulic fluid, including demulsibility and foam.

Conclusion

The ISO VG 68 hydraulic fluid developed by the research team at Biosynthetic Technologies demonstrates that performance doesn’t need to be sacrificed when designing an EAL product. While the product is biodegradable, non-toxic, and contains high levels of renewable carbon, it also meets all the ISO 15380 HEES target specifications, including some of the lowest values possible on the Vickers Vane Pump Test. In addition, the product has high oxidative stability, hydrolytic stability, corrosion prevention characteristics, and is compatible with various OEM seal technologies.

Perhaps the most exciting part of this project is that this is not merely an academic or theoretical endeavor – this product is available to be commercialized today. The ingredients can be sourced from reliable suppliers, blended in standard equipment, and sold in the marketplace. If you’re interested in commercial opportunities related to manufacturing these products, or any other projects, please contact Matt Kriech at mkriech@biosynthetic.com.