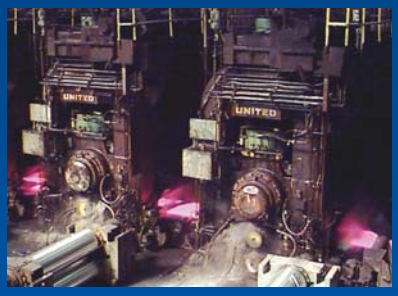
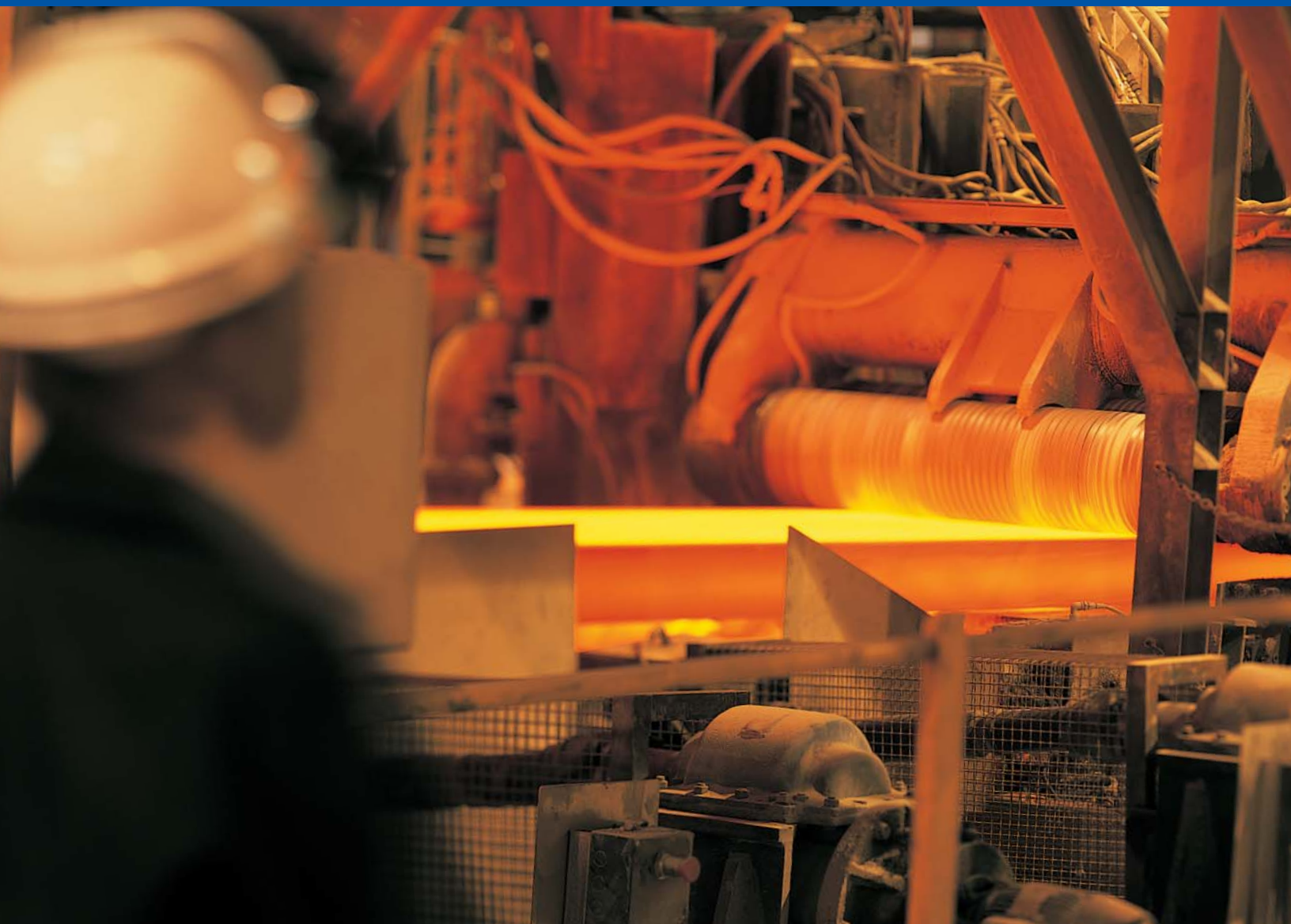
American Chemical Technologies, Inc.

EcoSafe® FR

Fire Resistant and Readily Biodegradable Hydraulic Fluids HFDU/HEPG



Formulated for Use in High Performance Hydraulic and Hydrostatic Drive Systems



EcoSafe® FR Hydraulic

A Breakthrough in Performance and Protection for High Performance Hydraulic Systems

EcoSafe® FR fluids represent a significant advancement in fire-resistant hydraulic fluid technology. These fully synthetic formulations deliver performance superior to premium anti-wear mineral oils, and offer significant performance and environmental advantages over other fluid options – including other synthetics. EcoSafe® FR fluids are used in industrial and mobile equipment, including high-pressure systems, hydrostatic drives, systems with servo valves, and all robotics.

EcoSafe® FR fluids are based on a very high VI, polyether polyol base stock combined with a non-metallic additive package. Unlike phosphate and polyol ester-based fluids, they do not break down when exposed to water, minimizing potential for fluid degradation and system damage. As a result, fluid changeout intervals are extended under even the most severe operating conditions.

EcoSafe® FR fluids are classified as FM Approved industrial fluids by Factory Mutual and meet stringent criteria for biodegradability and low toxicity.

Performance Advantages

Excellent Lubricity – EcoSafe® FR fluids offer excellent lubricity, for outstanding pump life under the most severe conditions. The fluids meet or exceed the pump performance of premium, anti-wear mineral oils, even at 5,500 psi (380 bar) operating pressure. Shear stability is excellent. And all three grades earn a 12-stage rating in the FZG Gear Test, demonstrating high level protection against wear and scuffing.

Hydrolytic Stability – Unlike phosphate esters, polyol esters and vegetable oils, EcoSafe® FR fluids will not break down and react with water, minimizing fluid degradation and acid formation that can damage and eventually destroy hydraulic pumps.

Non-Sludge or Varnish Forming – The fluids are oxidatively stable and will not degrade to form varnish or sludge, contributing to long-term system cleanliness while extending maintenance intervals and overall service life.

High Temperature Stability – EcoSafe® FR fluids are very stable at high temperatures and resistant to thermal degradation up to 120°C (250°F).

All-Weather Service – The high viscosity indices of EcoSafe® FR fluids enable them to handle wide temperature extremes. The fluids also have low pour points necessary for cold weather start up.

Material Compatibility – EcoSafe® FR fluids are completely compatible with commonly used seals, hoses and metals. Detailed compatibility data is available upon request.

Detergency – EcoSafe® FR fluids are natural detergents, so systems remain clean…free of staining or sticky residue.

Fire Resistance – EcoSafe® FR fluids are classified as FM Approved industrial fluids by Factory Mutual.

Biodegradable/Low Toxicity – EcoSafe® FR fluids are classified as "readily biodegradable" and environmental impact is low if the products are spilled. EcoSafe® FR fluids also satisfy stringent criteria for toxicity.

EcoSafe® FR fluids meet or surpass Bosch-Rexroth, Sauer-Danfoss, Denison, Parker, Oilgear, and Eaton (formerly Vickers) specifications.

Unmatched by Other Fluids

EcoSafe® FR fluids do not have the drawbacks of other synthetic fluids, mineral oils and vegetable oils…

- Polyol esters (including vegetable oils, which are naturally occurring polyol esters) hydrolyze in the presence of water to form acid. Fluids with increased acidity attack hose linings and o-rings, and leach the alloy from brass components, resulting in premature component failure. Polyol esters also contain some degree of unsaturation, which reduces their thermal and oxidative stability. The end result is the formation of sludge and varnish from insoluble degradation byproducts.
- Phosphate esters also hydrolyze in the presence of water. This reaction accelerates with increasing temperatures and is catalyzed by the presence of strong acids. Since this hydrolysis forms strong acids the reaction is said to be autocatalytic. Metals such as copper, some copper alloys and lead act as pro-oxidation catalysts which will also accelerate this reaction. Phosphate ester fluids represent a human health hazard because a major decomposition by-product is highly toxic.

Fluids

Typical Performance Properties*

Rexroth 1,100 Hour Endurance Test (2600 rpm, 85°C [185°F], 380 bar)	Pass
Brugger Value (DIN 51347)	>40 N/mm^2
Vickers 104C Vane Pump Test, ASTM D2882	
(2000 psi, 1200 rpm, 100 hours, 65°C [150°F], 7.5 gpm, 3.5 gallon sample)	<5mg total wear
Four Ball Wear, ASTM D2266 (1800 rpm, 1 hour, 75°C (167°F), 40 kg load)	0.35 mm
Four Square Gear Test (FZG) (1760 rpm, 90°C [194°F], 1600 ml sample)	Pass, all 12 stages
Eaton Corporation 35VQ25 (formerly Vickers)	
Industrial (I-286-S), Mobile (M-2950-S)	Pass
Turbine Oil Stability Test, ASTM D943	
(95°C [203°F], iron and copper catalysts, 60 mls water) Time to 2.0 Acid Number Increase	>2,000 hours
Seal Compatibility (1,000 hours @ 100°C [212°F]) Buna-n, Viton, Polyurethane (@60°C), EPR, Butyl, PTFE	Pass
OECD Ready Biodegradability Test Method 301 B, 28 days, Requirement: >60%	70.9%

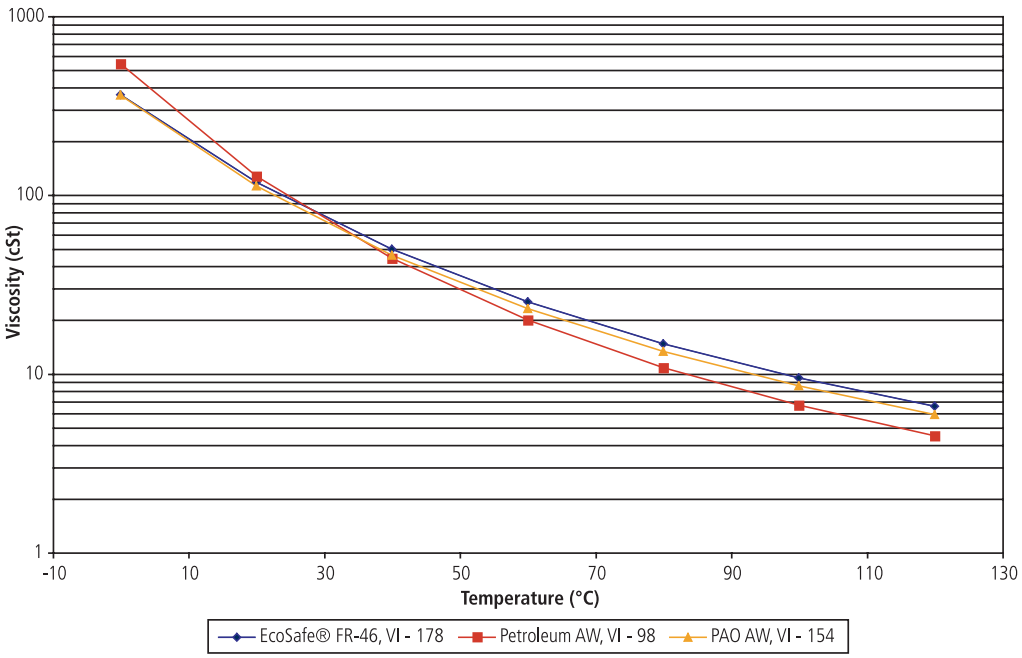
*Typical properties, not to be construed as specifications.

Typical Physical Properties*

	EcoSafe® FR-46	EcoSafe® FR-68	EcoSafe® FR-100
Viscosity @ cSt @ 40°C (100°F, SUS)	48.9 (250)	69 (350)	94.8 (480)
Viscosity @ cSt @ 100°C (210°F, SUS)	9.35 (57.5)	12.6 (69.8)	16.8 (86.6)
Viscosity Index	178	185	192
Pour Point, °C (°F)	-48 (-55)	-45 (-50)	-40 (-40)
Density (lbs/gal) @ 60°C (140°F)	8.19	8.21	8.25
FM Approved	Yes	Yes	Yes

*Typical properties, not to be construed as specifications.

Kinematic Viscosity Comparison

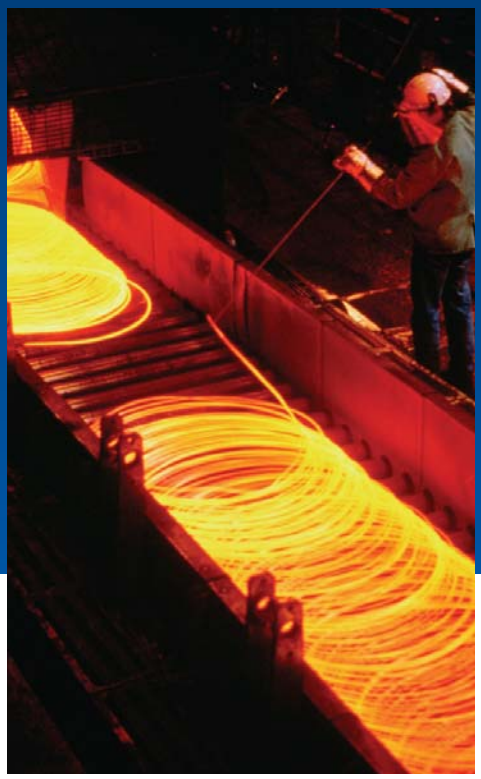


Superior Oxidative Stability

Results of controlled fluid tests show the superior stability of PAG-based fluids such as EcoSafe® FR fluids compared to PAOs (synthetic hydrocarbons). After 2500 hours at 120°C, the PAO produced significant deposits, which could result in operational problems in hydraulic systems. In contrast, the vial containing the PAG-based fluid was virtually free of deposits.

EcoSafe® FR

Hydraulic Fluids



A Global Source for Premium Fluids and Lubricants

American Chemical Technologies, Inc. (ACT) provides premium industrial lubricants and metalworking fluids to a wide range of industries. Founded more than 30 years ago in the U.S., ACT has grown to become an international supplier of highly specialized products for industry and markets through a global network. Our commitment to advanced technology and personal service continues today as we set new standards for product performance and customer satisfaction.

Call On Us for Total Support

We want your experience with our products to be successful. ACT supports its products with a full range of sales, technical, and customer service support, including information and/or assistance to help you with product selection, handling, maintenance, and disposal. Our Check-Mate hydraulic fluid monitoring program is designed to enable users to maintain fluid quality while monitoring the condition of all system components. Call ACT today for expert fluids and lubricants support.

To Learn More Call: 1-800-938-0101

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Ask About the Full Line of Fluids and Lubricants from ACT

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- UCON™ Trident™ Water Soluble Anhydrous Hydraulic Fluids
- Neptune® Gear Oils
- EcoGear® Gear Oils

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

EcoSafe® FR-46, FR-68, and FR-100

Fire Resistant & Readily Biodegradable Hydraulic Fluids

DESCRIPTION:

EcoSafe® FR fluids are fully synthetic, non-aqueous hydraulic fluids that are Factory Mutual Approved industrial fluids. They can be used in industrial, marine and mobile equipment, including high-pressure systems, systems with servo valves and all robotics. **EcoSafe® FR** fluids are formulated from a very high VI, fully synthetic basestock coupled with a patented non-metallic additive package providing the properties demanded by today's high performance hydraulic systems while at the same time satisfying the stringent criteria for biodegradability and toxicity. All three viscosity grades achieved a 12-stage rating in the FZG Gear Test demonstrating a high level of protection against wear and scuffing. **EcoSafe® FR** fluids also have excellent low temperature properties, good shear stability and are resistant to oxidative and thermal degradation. **EcoSafe® FR** fluids meet or surpass Bosch-Rexroth, Sauer-Danfoss, Denison, Parker and Eaton (formerly Vickers) specifications.

Typical performance properties are listed in Table 1 with seal compatibility data appearing in Tables 2 and 3. The increased performance which **EcoSafe® FR** fluids provide results in extended pump service life with reduced downtime along with lower maintenance costs. These fluids meet, or exceed, the pump performance of premium, anti-wear mineral oils, even at the 6,500 psi (450 bar) operating pressure. ***Additional bonus features include:*** non-sludge/varnish forming, high viscosity index, low pour point, excellent heat transfer, low foaming and complete compatibility with commonly used seals, hoses and metals.

If you want to add **EcoSafe® FR** fluids to a hydraulic system, call us and we will advise you regarding compatibility and solubility. Most "oil soluble" additives are not soluble in **EcoSafe® FR** fluids thus requiring a thorough and detailed plan prior to conversion. A separate information sheet '*Converting Hydraulic Systems to EcoSafe® FR Fluids*' is available upon request. Your American Chemical Technology representative is also trained and experienced in all aspects of conversion assistance.

TABLE 1: TYPICAL PERFORMANCE PROPERTIES

Four-Ball Wear	ASTM D4172	0.35 mm
Vickers 104C Vane Pump 2,000 psi, 100 hours, 150°F, 7.5 gpm, 1,200rpm 3.5 gal. sample	ASTM D2882	<10 mg Total Wear *
Four Square Gear Test 194 °F, 1,760 rpm, 1,600 ml sample, 12 stages	FZG	Pass, all 12 stages
Turbine Oil Stability Test 95 °C, iron and copper catalysts, 60 mls water) Time to 2.0 Acid Number increase	ASTM D943	>2,000 hours

*Results of 1.2 and 1.7 mg's Total Wear obtained by UEC (USX Engineers & Consultants, Inc.)

EcoSafe® FR-46, FR-68, and FR-100

TABLE 2: SEAL COMPATIBILITY WITH ECOSAFE® FLUIDS

Original Physical Properties	N4180 A80 LL-885	N4274 A85 LL-885	E4183 A80 LL-885	V4208 A90 LL-885	P4300 A90 LL-885	P4301 A90 LL-885	P4615 A90 LL-885
Hardness, Shore A., pts.	78	80	80	88	94	94	96
Tensile Strength, psi	2,308	3,273	1,953	2,177	8.056	9,159	8000
Elongation, %	260	170	180	150	560	500	540
EcoSafe® FR Fluids							
168 Hrs. @ 100 ℃							
Hardness Change, pts.	- 3	+ 2	0	- 5	- 2	- 4	- 1
Tensile Change, %	+ 8	+ 7	+ 1	- 13	+ 23	- 18	- 4
Elongation Change, %	- 19	+ 24	- 17	+ 7	+ 21	+ 4	+ 11
Volume Change, %	+ 4	- 1	- 2	+ 1	+ 7	+ 7	+ 5

KEY: N4180A80 Nitrile; P4300A90 Polyurethane; N4274A85 Nitroxile; P4301A90 Polyurethane (water resistant); E4183A80 Ethylene-Propylene; P4615A90 Molythane; V4208A90 Fluorocarbon (Viton)

Performed by: Parker Hanniffin GmbH Prädifa – Packing Division

TABLE 3: SEAL COMPATIBILITY WITH ECOSAFE® FLUIDS (Continued)

Test Method - DIN 53 521

	NBR-1 (Buna-N)	**FKM-2 (Viton®)**	**Polyurethane P 5000**
Temperature, °C	100	100	60
Time, hours	1,000	1,000	1,000
Hardness Change, Pts.	-5	-3	-2
Modulus Change, %	+29.5	+4.7	-8.6
Tensile Change, %	-11.9	-5.8	+13.2
Elongation Change, %	-31.5	+6.8	+15.7
Weight Change, %	+9.0	+0.7	+3.9
Volume Change, %	+10.8	+1.5	+4.7

Performed by: Parker Hanniffin GmbH Prädifa – Packing Division

TABLE 4: ENVIRONMENTAL DATA:

Ready Biodegradability, 28 days	OECD 301B	70.9%
Ready Biodegradability, 28 days	OECD 301F	88.0%
Fish Acute Toxicity 96 hour LC50 for rainbow trout, Oncorhynchus mykiss	OECD 203	"practically non-toxic"

Note: 60% biodegradation within 28 days is required to be classified as a "readily biodegradable" hydraulic fluid.

EcoSafe® FR-46, FR-68, and FR-100

STORAGE AND HANDLING:

We believe **EcoSafe® FR** fluids have a low degree of hazard when used as intended. They are stable, non-corrosive and have high flash point materials that are compatible with nearly all commonly used materials in standard hydraulic systems. As with all products of this type, we recommend that good hygiene practices be observed, including: (1) avoid prolonged skin contact, (2) provide adequate ventilation, (3) do not ingest; and that all OSHA Standards pertaining to products of this type be observed.

PROPERTIES:

	Test Method	**ESFR-46**	**ESFR-68**	**ESFR-100**
Viscosity @ 40ºC	ASTM D445	50.0 cSt	68.0 cSt	100.0 cSt
Viscosity @ 100ºC	ASTM D445	9.6 cSt	12.2 cSt	16.6 cSt
Viscosity @ 100ºF	ASTM D445	250 SUS	350 SUS	480 SUS
Viscosity @ 210ºF	ASTM D445	57.5 SUS	69.8 SUS	86.6 SUS
Viscosity Index	ASTM D2270	173	180	193
Pour Point	ASTM D97	-42°C (-44°F)	-39°C (-38°F)	-34°C (-30°F)
Air Release	ASTM D3427			
@ 50°C		3.0 min	5.5 min	
@ 75°C				4.0 min
Specific Gravity @ 25°C	ASTM D1298	0.985 g/cm^3	0.990 g/cm^3	0.992 g/cm^3
Density @ 77°F	ASTM D1298	8.19 lbs/gal.	8.23 lbs/gal.	8.25 lbs/gal.
Flash Point	ASTM D92	279°C (534°F)	281°C (538°F)	281°C (538°F)
Fire Point	ASTM D92	315°C (599°F)	319°C (606°F)	319°C (606°F)

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

EcoSafe® FR Fluids

Useful Data for Deciding upon Disposal Methods

DESCRIPTION:

EcoSafe® FR-46 and EcoSafe® FR-68 are new, non-aqueous polyether polyol hydraulic fluids that are approved as "less hazardous hydraulic fluids" by Factory Mutual Research.

Although the fluids are classified as "less hazardous", EcoSafe® FR fluid, like all organic materials, will burn when subjected to extreme conditions. Therefore, incineration was investigated as a possible method of disposal. Based on the following BTU value data and the fact that EcoSafe® FR fluids (virgin material) contain no metals or halogens, they are candidates for a fuels blending program:

EcoSafe® FR-46	12,863 BTU
EcoSafe® FR-68	12,745 BTU

In addition, analysis of EcoSafe® FR-46 water extractables was done to examine the impact on wastewater streams. This was done by thoroughly mixing EcoSafe® FR-46 with water in a 1:1 ratio, then allowing separation to occur for 8, 16 and 24 hours. The following is the analytical data* on the aqueous phase:

	TOC mg/l	BOD mg/l	COD mg/l
After 8 hours	3,925	37	13,920
After 16 hours	4,551	72	16,234
After 24 hours	4,053	288	14,853

TOC = Total Organic Carbon
BOD = 5 day Biological Oxygen Demand
COD = Chemical Oxygen Demand

*Data supplied by Galbraith Laboratories, Inc., Knoxville, TN

American Chemical Technologies is committed to the principles of "Responsible Care" for products it manufactures and markets. It is in this spirit that we share the data contained in this bulletin.

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

EcoSafe® FR Hydraulic Fluids

Hydraulic Pump - Wear Data

DESCRIPTION:

EcoSafe® FR fire resistant hydraulic fluids have been extensively tested in various pumps under a variety of conditions. The following chart shows some of the data that has been obtained over the last several years of development of these products. All 104C tests were run via ASTM D7043 (D2882) at 2,000 psi for the duration listed. Wear data is reported in mg. of weight loss for the total of the cam ring and vanes.

Product	Run Date	Test Site	Pump	Temp (F)	Duration (hours)	Wear (mg)
FR-46	01/16/87	OLIN	104C	150	100	1.2
FR-46 [1]	01/21/87	OLIN	104C	150	100	9.4
FR-68	04/20/87	OLIN	104C	150	280	16.5
FR-46	02/13/89	UEC	104C	150	100	1.2
FR-46	03/26/90	OLIN	104C	170	90	1.0
FR-68	040/6/90	OLIN	104C	170	680	1.8
FR-46 [2]	10/19/90	TH D	35VQ25	200	50	44.3
					50	56.5
					50	22.5
					50	24.6
FR-68 [3]	01/09/90	OLIN	104C	150	98	8.5
FR-46	10/27/94	UEC	104C	150	100	1.7
FR-68	10/16/06	Clark	104C	175	100	2.8
FR-46	01/30/14	Clark	104C	150	100	4.1
FR-46	03/26/14	Clark	104C	150	100	2.3

[1] Run was made with 0.75% water added to the fluid.

[2] Complies with approval criteria M-2952-S of the Vickers System. Test run in Darmstadt, Germany (tested at 3,000 psi).

[3] 1:1 mixture of EcoSafe® FR-68 (50%) and Polyol Ester (50%).

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

EcoSafe® Fluids

"Check-Mate" Hydraulic Fluid Monitoring Program

DESCRIPTION:

It is a hard fact of life that industrial hydraulic and circulating systems exist in atmospheres that are anything but clean. Moreover, modern production demands tax these systems to their limits and, all too frequently, beyond their limits. While industry as a whole has made great strides in recent years to implement sound preventative maintenance programs dealing with hydraulic circuits and their components, far too little emphasis has been placed on proper hydraulic fluid maintenance.

A hydraulic fluid is a system component as much as the valves, pumps, motors, seals or any other system component. It is the one component of a hydraulic system, which comes into intimate contact with all other system components. It must be maintained by systematic fluid monitoring. This monitoring, besides maintaining fluid quality, is a powerful diagnostic tool, which if used properly, can give the consumer an excellent fingerprint of the condition of all hydraulic system components.

American Chemical Technologies (ACT) is a major supplier of industrial hydraulic fluids. Therefore, we are vitally interested in seeing users of these fluids put into effect some form of a scheduled or systematic fluid inspection program. ACT feels this to be a necessity, and it should be an integral part of any existing maintenance program. Fluid maintenance must be considered because certain things do happen to hydraulic fluids after they are charged into a circuit and the fluid is the one system component that is in contact with all other system components.

- The viscosity and TAN (total acid number) levels change.
- The fluid gets dirty or contaminated with particulate matter such as dirt, wear particles and other foreign material.

In view of this, the fluid user must have some means to determine the condition of in-service fluids with respect to TAN levels, viscosity changes and source
& level of contamination. Systematic analysis or fluid monitoring can only achieve this.

ACT is pleased to offer users of EcoSafe® a fluid monitoring program available only to ACT customers.

The ACT program is a meaningful laboratory analysis of in-service fluids on a systematic and scheduled basis. It is conducted in a laboratory, not at the machine site.

If an ACT customer avails himself of this program, each machine or circuit on the monitoring program is sampled and analyzed on a scheduled basis and the following data is supplied for each unit:

- A viscosity determination
- TAN levels
- ISO particle count
- Percentage of tramp oils
- Our comments and recommendations
- Other tests if necessary

ACT is proud to offer this approach to sensible hydraulic system maintenance. It is designed to supplement existing maintenance programs and help you, the customer, in maximizing product and minimizing maintenance cost. Unscheduled downtime is expensive and often unnecessary. Minor problems can be detected by fluid monitoring before they become major and costly failures.

DO YOU KNOW THE CONDITION OF YOUR HYDRAULIC FLUIDS RIGHT NOW?

For further details, consult your ACT representative at (800) 938-0101

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

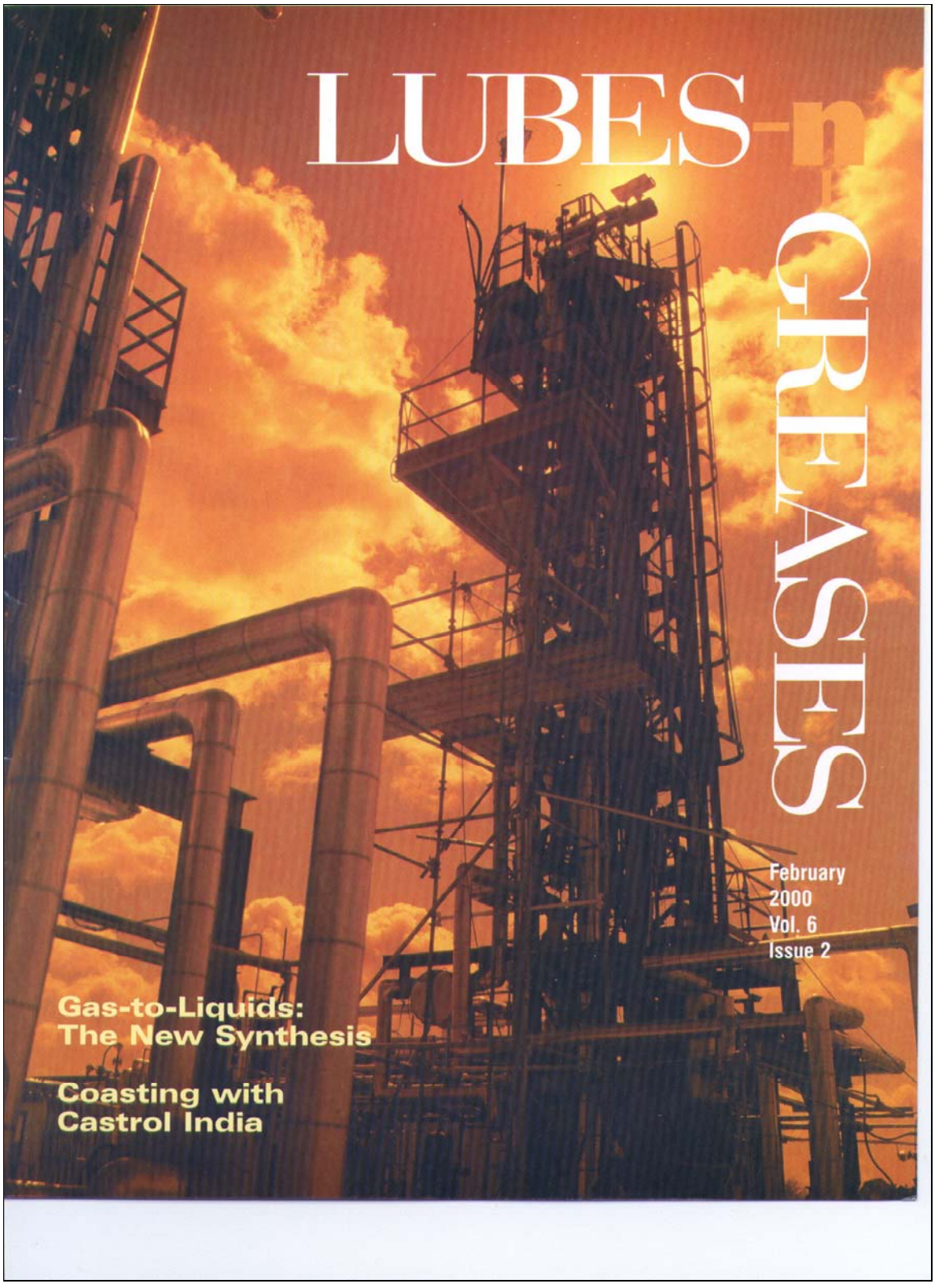
EcoSafe®

Cross Reference

DESCRIPTION:

Competitive product Cross-Reference list

POLYETHER POLYOL	ECOSAFE® FR-46	ECOSAFE® FR-68	ECOSAFE® FR-100
POLYOL ESTER	Quaker Quintrolubric 822-220 Quaker Quintolubric 888-46 Houghton Cosmolubric HF-122 D.A. Stuart Dasco FR355-2	Quaker Quintrolubric 822-300 Quaker Quintolubric 888-68 Houghton Cosmolubric HF-130 D.A. Stuart Dasco FR355-3	Quaker Quintrolubric 882-450 Houghton Cosmolubric HF-144
Phosphate Ester	Fyrquel 150 HoughtoSafe 1110,1114LT,1115,1120 MetSafe FR-310	Fyrquel 200 HoughtoSafe 1130	Fyrquel 300 HoughtoSafe 1055
Phosphate Ester/Oil Blends	Houghton-Vital MetSafe FR 303-46	MetSafe FR 303-68	
Vegetable Oil	Houghton Cosmolubric B-220	Houghton Cosmolubric B-230	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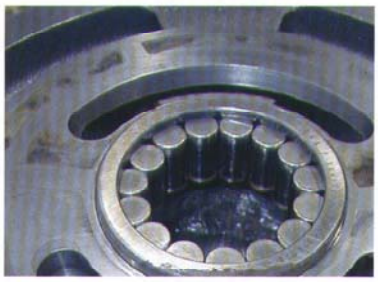
Gas-to-Liquids:
The New Synthesis
Coasting with
Castrol India

The Next Big Fire-Safe Fluid?



BY LISA TOCCI

At Rexroth Industrial Hydraulics in Bethlehem, Pa., eight people gathered around a workbench last September. They had flown in from Indiana, from Michigan, from South Carolina, to watch the teardown of a $12,000 piston pump that had arrived a few days earlier, on leave from its strenuous duties at a Midwestern steel mill. They wanted to see what no laboratory test could show absolutely: whether the costly fire-resistant, synthetic hydraulic fluid used in the pump had protected it from the harsh conditions of life in a steel mill.

Joe Burke of Bethlehem Steel's Burns Harbor 160-inch plate mill in Chesterton, Ind., was on hand to witness the teardown, along with plate mill general foreman Bob Petrusha; the suppliers of the fluid; its inventor; a visitor from *Lubes'n'Greases*; and of course employees of Rexroth itself.

"This pump operates in one of the most vulnerable, agitated systems there is," Burke remarked. The hydraulic pump, one of four that power the mill's automatic gage control system, turns at 1,100 rpm, developing 5,000 psi of pressure against its lens plate.

Burke and Petrusha seemed assured that the teardown would confirm the performance of EcoSafe, the trademarked synthetic fluid now used in their hydraulic system. But before trying it, Burns

Harbor was at its wit's end. The axial piston pumps, installed in 1991, were rated to last 20,000 hours, "but we were getting a maximum of 3,800 hours on a pump, and some averaged only 2,200 hours," Burke said.

From its inception, the system had used a fire-resistant polyol ester based fluid, but even draining and refilling the system with fresh fluid—twice—didn't seem to help, as acids in the system raged out of control.

"We blew out 48 pumps and had to replace over 30 of them," Petrusha recalled. "We couldn't even keep spares in stock, they blew out so fast." Directional and servo valves also needed constant maintenance and replacement, as sludge, varnish and rust plagued the system.

"We tried other pumps, too, but the other manufacturer kept seeing the same problems," added Burke.

Finally, in 1997, it was decided to try EcoSafe, a patented product based on polyether polyol (PEP). First, the 3,000-ton leveler and its 2,000-gallon reservoir were flushed and converted to EcoSafe. Success! The leveler system's pump and valve failures virtually disappeared. Acid levels dropped significantly, too, and stayed stable. Five months later the entire 1,800-gallon hydraulic control system was converted to the PEP fluid.

PHOTO OPPORTUNITY

Now in Bethlehem, this pump from the mill would be torn down for scrutiny, having accumulated about 8,300 hours of trouble-free operation. This actually was the third time the pump would be torn down, and its internal condition eyeballed.

As Burke, Petrusha and others watched, Don Johnson, a technician and 10-year Rexroth veteran, dismantled the piston pump. It was free of corrosion. Grinning, he laid the internal parts one by one on the countertop. Parts were wiped clean and scrutinized for signs of wear or discoloration. Brass-shoed pistons were handed around and appraised coolly. Cameras appeared and the pump parts and housing were photographed as intently as models for a Sports Illustrated swimsuit issue.

Happily snapping pictures were Kevin Kovanda and his brother Ross Kovanda of American Chemical Technologies Inc. in Wixom, Mich. Exclusive suppliers of EcoSafe hydraulic fluid, they had a lot riding on this teardown, and were ebullient at what they were seeing.

Wielding his own camera was Charlie Fey, Rexroth Industrial Hydraulics' national service manager. Fey admitted that Burns Harbor's 48 pump failures in seven years—including 35 catastrophic ones—had stymied him. Rexroth had worked diligently with the fluid supplier and with Burns Harbor to find the underlying root cause of the failures, without finding a solution.

That was the point where ACT got involved. Kevin and Ross Kovanda persuaded Burke and Petrusha to try ACT's polyether polyol fluid, and even bought the Rexroth Series 30 pump for the field trial. (ACT has a second trial under way at Burns Harbor using a Dennison pump, as well.) "I was a little leery when they first put the fluid in, not having any experience with it, but after the first and second teardowns, all indicators proved the fluid was working very well in our pump," Fey said.

"Using this new fluid has saved the plant $20,000 a month just in repair costs," and that doesn't include the savings in downtime...

Synthetic hydraulic fluid has shielded the components of this sensitive piston pump (above and left), from the harshness of life in an Indiana plate mill.

Joe Burke said EcoSafe costs about $1.50 more per gallon than the polyol ester fluid used before. So the initial cost was a bit daunting. The old fluid, however, had been very hydrophilic, and had "huge acid problems" as a result. "Typically, the TAN would be around 5.0 or 6.0, and we had to dump it if it got to 7.0. But this EcoSafe stuff is very hydrophobic and TAN has been no problem. It stays around 0.5.

"Using this new fluid has saved the plant $20,000 a month just in repair costs," he added. And that doesn't include the savings in downtime, which cost the mill $10,500 per hour.

A CHEMICAL SOLUTION

Perhaps the happiest witness to the teardown was Phil Miller, the inventor of the PEP based EcoSafe fluid and vice president, technical services, of Gateway Additive Co. in Spartanburg, S.C. He invented the technology while employed at Olin Corp., patented it in 1992,

and then saw it sold to Gateway along with Olin's functional fluid additives line. Gateway shopped the technology around but found no interest from hydraulic fluid makers, large and small, who had their own established products. It finally inked a U.S. marketing deal with ACT.

Kevin Kovanda, president of ACT, said EcoSafe represents a new generation of fire-resistant chemistry: "Water glycols were invented in the 1950s, followed by phosphate esters in the 1960s, and polyol esters in the 1970s. So this is the first truly new fire-resistant fluid since then."

Miller explained that PEPs offer great hydrolytic stability. Hydrolysis is the chemical process of breaking down and reacting with water. Hydrolytic stability is the tendency to resist this reaction—a very desirable property if the fluid is to be used in a steel mill, where hot and cold rolling operations create extremely wet environments.

PEPs are the reaction products of an alcohol (usually butanol) and an expoxide like propylene oxide. This is not a reversible reaction, said Miller, and since no water is formed, hydrolysis should not occur. Adding more units of propylene oxide to the alcohol molecule will increase the polymer's molecular weight and viscosity.

The polymers have inherently good lubricity, plus good oxidation stability, so they do not cause varnishing, sticky residue or staining. Detergency is also excellent, Miller said, so systems run clean. Additives contribute corrosion protection and antiwear capabilities, for both ferrous and nonferrous metals.

"In two years, we've only sold about 5,000 gallons of this fluid to Bethlehem Steel. Essentially, it's just initial fill, and then it just lasts and lasts."

ACT's Kevin Kovanda (left) watches Don Johnson of Rexroth at the September teardown. At press time, the pump had gone 12,000 hours on EcoSafe fluid. Next teardown is slated for 20,000 hours.

Because the reaction that creates a PEP cannot be reversed, it offers strong advantages over polyol esters, said Miller. Polyol esters can be broken down by water—hydrolysis—and then revert back to alcohol and acid.

Phosphate esters, another widely used fire-resistant base for hydraulic fluids, also are subject to hydrolysis at high temperatures, he observed, and can form gelatinous substances, even semi-solid gels that clog hydraulic systems. This situation occurred twice in 1992 at a continuous casting operation; in both cases, production was idled for several expensive days.

TACKLING THE COMPETITION

EcoSafe rates as a Group 2 fluid in fire-resistance tests by Factory Mutual Research Corp., rather than the higher Group 1 level. "Any liquid will burn under the right conditions," Miller said, explaining that Factory Mutual tests only new fluids, not fluids that have been in service for a while. Tests done on used fluid actually show that EcoSafe retains its fire-resistance significantly longer than polyol ester fluids, he said.

About 500,000 gallons of EcoSafe fluid are in service now, a mere ripple in the ocean of 17 million gallons of fire-resistant hydraulic fluid sold each year in the United States.

The fluid's durability, added Kevin Kovanda, has a drawback: "In two years, we've only sold about 5,000 gallons of this fluid to Bethlehem Steel. Essentially, it's just initial fill, and then it just lasts and lasts."

Offering condition monitoring services for the fluid, and expanding its use, are how ACT hopes to grow. It sells EcoSafe in the United States, France and Belgium, and recently added Mexico to its territory. It now has a fistful of other successful case histories dating back to 1990: at a brass casting plant, in a high speed rod mill, in steel mill track loaders, in the wheel loaders used for digging out slag pits.

ACT has worked hard to get EcoSafe into users' hands—and with enough success that other fluid suppliers began to sit up and take notice. Some of the companies which rejected the technology when it was first offered are now clamoring for a piece of the action—and find ACT and Gateway (now owned by Lubrizol) solidly allied in the U.S. market.

Other vendors are not standing still, of course, and competing products are coming on fast. Still, "Kevin and his company are the ones who took the risk and are making this a commercial success, and so we'll be staying with them," Miller said. "Other U.S. hydraulic fluid sellers may want it now, but they can't have it." ▮

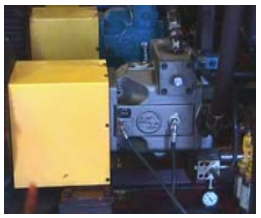
PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

TYPICAL WEAR PERFORMANCE CHARACTERISTICS for *EcoSafe® FR*

Rexroth 1,100 hour Endurance Test (2600 rpm, 85°C, 380 bar)		Pass
Denison HF-0 Approval to 160°F (71°C)		Pass
Vickers 104C Vane Pump Test, ASTM D2882 (2000 psi, 100 hours, 150°F, 7.5 gpm, 1200 rpm, 3.5 gallon sample)		< 5 mg Total Wear
TUHH Report – Flywheel Test (300 hours, 3000 rpm, 90°C, 420 bar)		Pass
Four Ball Wear, ASTM D2266 (1800 rpm, 1 hour, 167°F, 40 kg load)		0.35 mm
Four Square Gear Test (FZG) (194°F, 1760 rpm, 1600 ml sample)		Pass, all 12 stages
Eaton Corporation 35VQ25 (formerly Vickers)		
Industrial	I-286-S	Pass Mobile Equipment
	M-2950-S	Pass

ECOSAFE® CHEMICAL STRUCTURE

FEATURES:

1. Polyether chemistry
2. Fully saturated molecule
3. Excellent lubricant
4. Natural Detergent
5. High viscosity index
6. Low pour point
7. Readily biodegradable
8. Low BTU value

BENEFITS:

1. Hydrolytic stability/Non-reversible
2. Superior oxidation resistance
3. Outstanding pump life under the most severe conditions
4. System Cleanliness
5. Capable of handling wide temperature extremes
6. Excellent for cold temperature applications
7. Low environmental impact if spilled
8. Low energy release when burned

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

TYPICAL OXIDATION RESISTANCE PROPERTIES

	Polyol Ester	Natural Triglycerides	Phosphate Ester	EcoSafe® FR
TOST, ASTM D943 – Modified (Wet) (95°C, iron and copper catalysts, 60 mls water)				
PASS/FAIL	**FAIL**	**FAIL**	**FAIL**	**PASS**
Hours	500	500	840	> 2,000
Initial TAN	2.84	0.95	0.06	0.25
TAN @ completion	32.93	36.68	2.44	2.21
TAN INCREASE	**30.09**	**35.73**	**2.38**	**1.96**

	Polyol Ester	Natural Triglycerides	Phosphate Ester	EcoSafe® FR
TOST, ASTM D943 – Modified (Dry) (95°C, iron and copper catalysts)				
PASS/FAIL	**FAIL**	**FAIL**	**FAIL**	**PASS**
Hours	1512	500	1680	> 2,000
Initial TAN	2.84	0.95	0.06	0.25
TAN @ completion	5.18	7.70	2.44	0.31
TAN INCREASE	**2.34**	**6.75**	**2.48**	**0.06**

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

EcoSafe®

Typical Environmental Properties

EPA 410.4 Chemical Oxygen Demand (COD)

EcoSafe® FR-46 — 2180 mg O_2/g

EPA 405.1 Biological Oxygen Demand (BOD)

EcoSafe® FR-46 — BOD_5 — 1450 mg O_2/g (67%)

OECD Biodegradability Test

		301B	301F	
EcoSafe® FR-46	28 day	70.9%	88.0%	"readily biodegradable"

A result of > 60% is required to be classified as "readily biodegradable"

OECD Method 203, Acute Aquatic Toxicity Test

(96 hour LC_{50} for rainbow trout, Oncorhynchus mykiss)	"practically non-toxic"
(96 hour LC_{50} for fatheat minnow, Pimephales promelas)	"slightly toxic"
(24 hour LC_{50} for daphnids, ceriodaphnia dubia)	"slightly toxic"

EcoSafe® and EcoGear® are manufactured from CAS# equivalent base-stocks with similar performance additives. EcoGear® is is expected to have less biodegradability and lower aquatic toxicity than EcoSafe®.

In addition, analysis of EcoSafe® water extractables was done to examine the impact of waste-water streams. This was done by thoroughly mixing EcoSafe® with water in a 1:1 ratio, then allowing separation to occur for 8, 16, and 24 hours. The following analytical data was obtained from the aqueous phase:

	TOC mg/L	BOD_5 mg/L	COD mg/L
After 8 hours	3925	37	13,920
After 16 hours	4551	72	16,234
After 24 hours	4053	288	14,853

TOC = Total organic carbon, BOD_5 = 5 day biological oxygen demand, COD = chemical oxygen demand

There are two methodologies that the EPA approves for determine the amount of organics eluted into a wastestream. EPA 1664A described the Hexane Extraction Method (HEM) as the amount of total organics eluted and the Silica Gel Treatment – Hexane Extraction Method (SGT-HEM) is the amount of non-polar organics. If EcoSafe® is present in the water then it is a part, but not necessarily all of HEM minus SGT-HEM. Just as the polyethers that are used to manufacture EcoSafe® are excluded from being an oil by the USCG, the EPA 1664A allows for the exclusion of polar organics from the testing protocols.

Technical Paper

Polyether Polyol: An Interim Look Inside the Lead Pump on a Hydraulic Automatic Gauge Control System©

This paper introduces a new generation, fire-resistant hydraulic fluid: polyether polyol. This paper highlights the internal inspection of a variable displacement, axial piston pump that has operated for 4,000 hours at 345 bar (5,000 psi). The fluid is used in the lead pump operating on the Hydraulic Automatic Gauge Control system at Bethlehem Steel's 160" Plate Mill in Burns Harbor, Indiana.

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Bethlehem, Pennsylvania

KEY WORDS

Hydraulics; Pistons; Synthetic Base Oils

INTRODUCTION

Bethlehem Steel's Burns Harbor Division is the premier steel plate producer in the world. It produces in excess of 1,000,000 tons per year on the most sophisticated equipment in the industry. Each stage of production is monitored and computer controlled.

Slab reduction starts with a reversing, roughing mill. This process rolls the slab to its desired width. The plate continues on to the reversing, finishing mill where it is rolled to its final thickness. It is here that the Hydraulic Automatic Gauge Control (HAGC) comes into play (see Fig. 1), the most advanced thickness control system in the steel business. Ninety-three continuous, on-line isotope gauge sensors automatically measure thickness over the entire width and length of the plate. This data is fed to the HAGC, which continuously adjusts the mill rolls while the plate is in the mill. Such corrections require an actuator that is capable of making precise adjustments, while under load, to compensate for mill variations. See Table 1 for a description of the HAGC system specifications.

Tight gauge control minimizes in-plate gauge variation, which increases yield and reduces weight variation. Control of gauge variation is critical for producers that must meet "precise weight" plate orders. These weight constraints are constantly being demanded in the ship building and transportation industries.

The HAGC system was installed at Burns Harbor in December 1991. The original fluid used was a polyol ester. Over the next six years the system experienced 35 catastrophic pump failures, with no single pump ever-obtaining 4000 hours. During this period, 3800 hours was the most time ever logged on one pump. Also, two different sources of polyol ester fluid had been used

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May 23-27, 1999
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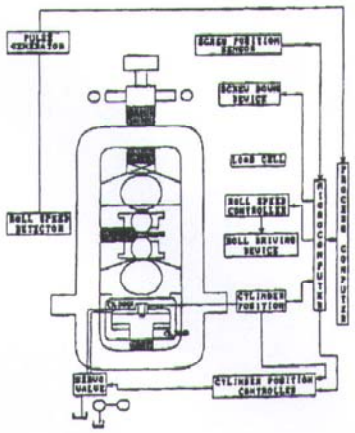

Fig. 1—Schematic of hydraulic AGC system.

during this time. Each supplier had to drain and re-fill the system twice because of a high Acid Number in the fluid (in excess of 5.0 mg KOH/g fluid). There had also been premature failure of servo valves due to sludge, varnish and rust formation from the polyol ester fluid.

The system was converted to polyether polyol on April 18, 1998. New axial piston pumps were installed on the system. A Rexroth pump was configured to be the lead pump with a Denison pump supplying back-up flow. By the end of October 1998, slightly in excess of 4000 hours had been logged on each pump. Both pumps were pulled and submitted to the manufacturer for inspection. This paper highlights the inspection of the lead pump.

FLUID DESCRIPTION

A basis for understanding some of the critical properties of polyether polyol hydraulic fluid can be obtained by examining its chemistry. These synthetic base "oils" are the reaction products of an alcohol, most commonly butanol, represented as R-OH, and an epoxide, most commonly propylene oxide, represented as $\underbrace{CH_2 - CH - CH_3}_{O}$:

$$R - OH + {}_n\underbrace{CH_2 - CH - CH_3}_{O} \rightarrow R - O - [CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - O]_n - H$$

A designed synthetic molecule is obtained by controlling the number of repeating propylene oxide units (n) added onto the alcohol. This number will determine the polymer's molecular weight and viscosity.

One major advantage offered by polyether polyol is its hydrolytic stability, i.e. its tendency to resist chemical reaction with water. Since most steel mill equipment operates in a humid atmosphere, moisture can be drawn into the fluid as the reservoir breathes. As cylinders extend and retract, the piston rod can also draw in moisture from the air. In both instances, water (moisture) ingress's into the hydraulic system setting up a possible reaction with the fluid. The reaction by-products of this hydrolysis form acids that can contribute to corrosion, rapid increases in acid number, and eventual equipment downtime. This advantage is in stark contrast to ester-based fluids where hydrolysis may be a problem in the presence of water *(1)*, and in the case of phosphate esters, gelatinous by-products can form if a sufficient amount of water is present. Figure 2 highlights the superior oxidation and hydrolytic performance of polyether polyol *vs.* commercial polyol ester and natural triglyceride (vegetable oil esters) fluids.

Polyether polyol also has inherently good lubricity *(2)*. This is illustrated in Fig. 3, which shows four-ball wear data

TABLE 1—HYDRAULIC AUTOMATIC GAUGE CONTROL SYSTEM SPECIFICATIONS

Hydraulic Pump Supply Technical Data	
Pump type	Pressure Compensated, variable volume, axial piston
Pump model	Rexroth - AA4VSO250 Series 30 Denison - P16
Pumps in system	4
Pumps in operation	2
Operating pressure	330 - 345 bar (4800 - 5000 psi)
Rated supply	208 liters @ 345 bar (55 gpm @ 5000 psi)
Operating temperature	35 - 41°C (95 - 105°F)
Case drain temperature	55 - 66°C (130 - 150°F)
AC motor size	150 Kw (200 HP)
Shaft speed	1200 rpm
System volume	6800 liters (1800 gallons)
Cylinder Technical Data	
Piston diameter	111.76 (44 in.)
Area	9807 sq. cm (1520 sq. in.)
Piston rod diameter	104.14 cm (41 in.)
Area	8517 sq. cm (1320 sq. in.)
Piston stroke	4.45 cm (1.75 in.)
Designed maximum force per cylinder	3,438,288 kg (7,580,000 lbs.)
Valves, Filtration, Elastomers	
Cylinder valve type	High response servo
Servo valve model	Bosch - NG16
Pressure filter	Parker, 3 micron absolute
Polishing filter	Parker, 3 micron absolute
Pre-charge filter	Parker, 10 micron absolute
ISO 4406 cleanliness	14/12 (NAS 6)
Seal type	Buna N
Hose type	Buna N

TOST, ASTM D943-Modified (without water)
(95°C, Iron and copper catalysts)

	Polyol Ester	Natural Triglycerides	Phosphate Ester	Polyether Polyol
Pass/Fail*	Fail	Fail	Fail	Pass
Hours	1512	500	1680	> 2000
Initial TAN	2.84	0.95	0.06	0.25
TAN @ completion	5.18	7.70	2.54	0.31
TAN increase	2.34	6.75	2.48	0.06

TOST, ASTM D943
(95°C, iron and copper catalysts, 60 mls water)

Pass/Fail*	Fail	Fail	Fail	Pass
Hours	500	500	840	> 2000
Initial TAN	2.84	0.95	0.06	0.25
TAN @ completion	32.93	36.68	2.44	2.21
TAN increase	30.09	35.73	2.38	1.96

** 2000 hours or 2.0 change in acid number.*

Fig. 2—Comparative turbine oil stability data.

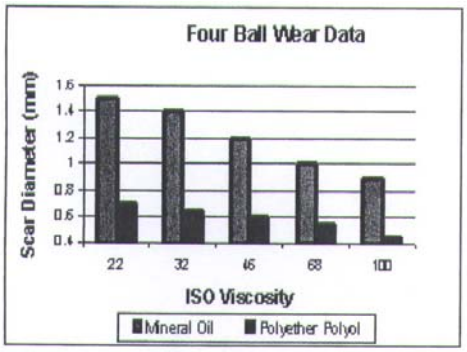

Fig. 3—Four-ball wear data.

obtained for petroleum oil and polyether polyol base fluids (without additives) over the same viscosity range. Since polyether polyol fluids are completely saturated (<1 iodine value), they have good oxidation stability and do not cause varnishes, sticky residues or staining of pump components. They also have excellent detergency, which contributes to system cleanliness. This detergency is at least in part due to the fact that these polyols act as solvents for their own decomposition products. This solvency prevents deposits by keeping them in solution. Additives for corrosion protection (both ferrous and non-ferrous metals) and further enhancements of its oxidation stability and anti-wear properties are used to obtain the finished hydraulic fluid.

Typical physical properties for three fully formulated polyether polyols are shown in Table 2. Performance highlights for these three viscosity grades are summarized in Tables 3, 4 and 5.

TABLE 2—TYPICAL FLUID PROPERTIES OF POLYETHER POLYOL

TEST	VISCOSITY GRADE		
Property			
Viscosity:	ISO-46	ISO-68	ISO-100
@ 100°F, SUS	230	310	480
@ 40°C, cSt	46	68	100
@ 210°F, SUS	53.3	65.3	86.0
@ 100°C, cSt	8.9	12.1	17.2
Viscosity Index	185	189	196
Pour point, °C (°F)	-48 (-55)	-46(-50)	-40(-40)
Density @ 60° (°F), lb/gal	8.25	8.27	8.29
Acid number, mg KOH/gm (max.)	0.4	0.4	0.4
Factory Mutual Approved	Yes	Yes	Yes
Flash point, °C (°F), COC	274(525)	302(575)	329(625)
Foam test, ASTM D892	Pass	Pass	Pass
Copper corrosion, ASTM D130	Pass	Pass	Pass

TABLE 3—TYPICAL WEAR PERFORMANCE PROPERTIES OF POLYETHER POLYOL

TEST	RESULT	
Vickers 104C Vane Pump Test, ASTM D2882 (138 bar, 100 hours, 65.6°C, 28.4 liters/minute 1200 rpm, 13.2 liter sample)	< 5 mg Total Wear	
Four Ball Wear, ASTM D 2266 (1800 rpm, 1 hour, 75°C, 40 kg load)	0.35 mm	
Four Square Gear Test (FZG) (90°C, 1760 rpm, 1600 ml sample)	Pass, all 12 stages	
Vickers 35VQ25; Industrial	I-286-S	Pass
Mobile Equipment	M-2950-S	Pass

PUMP INSPECTION

As seen in Fig. 4, the Rexroth, variable displacement, axial piston pump operated at 345 bar (5000 psi) for 4000 hours. Typical surface conditions and flatness are approximately 5 µm for optimum pump performance. Any significant increase in these clearances will lead to loss of volumetric efficiency, local heat build up, and eventually pump failure. Also piston bore concentricity and straightness are extremely important for high-pressure piston pumps. The critical lubrication points, for this style piston pump, are summarized below:

1. Wear (swash) plate and piston shoes
2. Barrel end and valve plate
3. Pistons and piston bores
4. Front and rear bearings
5. Shaft seal

(Continued on next page)

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Table 4—Additional Oxidation REsistance Properties of Polyether Polyol

Test	Result
Universal Oxidation Glassware (135°C, steel and copper catalysts) Time to 0.5 increase in acid number	200 hr
RBOT, ASTM D2272 Minutes @ 150°C	420

Table 5—Typical Environemtal Properties of Polyether Polyol

Test	Result
OECD Ready Biodegradability Test Method 301B, 28 days	70.9
OECD Ready Biodegradability Test Method 301F, 28 days	83.4
OECD Method 203, Fish Acute Toxicity Test (96 hour LC50 for rainbow trout, Oncorhynchus mykiss)	"practivally non-toxic"

Inspection of Wear (Swash) Plate and Piston Shoes

In the area between the wear (swash) plate and piston shoes, a fluid's lubricating properties as well as its long-term corrosion resistance are of equal importance. This interface is under extremely high pressure, within the load zone of the pump, and also is a contact area between two dissimilar metals. The wear plate is comprised of a carbon steel alloy and the piston shoe is manufactured from a hard brass alloy. Any breakdown in the lubricating film would quickly wear the softer brass metal, disturbing the pressure balance between the piston shoe and the opposite pressure side of the piston, eventually resulting in pump failure. At the same time, if the fluid has poor oxidation or hydrolytic stability, acids can be created in the fluid that will leach various alloys from the brass resulting in premature shoe failure. Further breakdown of an unstable fluid will eventually form deposits that act as a "lapping" compound on the metal surfaces. Both conditions end in premature pump failure either due to excessive case drain (loss of volumetric efficiency) or catastrophic failure.

Inspection of the piston shoes shows them to be in excellent condition. The wear (swash) plate looks normal, except for some light running marks. See Fig. 5.

Inspection of Barrel End and Valve Plate

Again the authors are dealing with an interface of dissimilar metals. Lubrication is not as critical an issue since the full pump flow passes through this area, making it easy to build up a good fluid film. A more sensitive issue is fluid cleanliness as any metal removed reduces the pump's efficiency due to internal leakage. This leakage can be directly related to particulate contamination or the eventual erosion caused as the fluid flows through the metal fatigued area. A fluid's ability to dissipate air is also important in this region. This is the area where the fluid is ported from an inlet condition to a high-pressure condition. Any air bubbles present during this transition could result in cavitation of the metal surfaces. This scenario would also reduce the efficiency of the pump and result in premature failure. Finally, corrosion resistance would again be of paramount importance. Any attack of the brass or pitting of the metal surfaces would again create internal leakage.

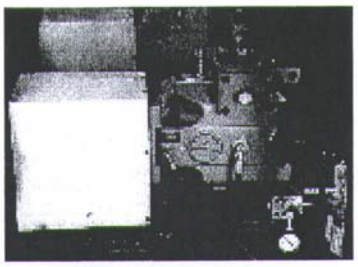

Fig. 4—Model AA4VS0250 Series 30.

Fig. 5—Wear (swash) plate and piston shoe.

The valve plate was in normal condition. The barrel end was in normal condition, however, as you can see in Fig. 6, there are small triangular areas of metal erosion. This is common for this series pump and has been reengineered in the current Series 30 pump. The triangular, metal erosion is the result of fluid being trapped, under high pressure, as the barrel rotates against the stationary valve plate. The barrel carries this pressurized fluid until it reaches the inlet port (low or zero pressure) where it immediately "jet streams" out across the metal surface causing erosion. The condition of this barrel end is equivalent to that of a pump that has operated on mineral oil under the same conditions over the same time period. See Fig. 6.

INSPECTION OF PISTONS AND PISTON BORES

This is again an area of dissimilar metals; carbon steel alloy piston and a brass alloy lined piston bore. Similar to the barrel end and valve plate, lubrication is not the only

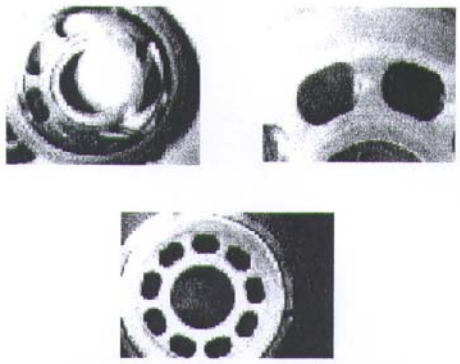

Fig. 6—Barrel end and valve plate.

Fig. 7—Piston and piston bore.

critical element. Proper lubrication assures that the piston slides smoothly within the bore. It is also important as pistons always spin within their bores as a result of mass forces, even at "zero" displacement. In theory, the mating surfaces are separated by a hydrodynamic fluid film and do not touch. However, the heat generated from internal friction within the lubricating film can lead to viscosity breakdown and penetration of the fluid film. Particulate contamination can also rupture this fluid film causing metal-to-metal contact and the generation of unwanted heat. All in all, lubrication, fluid cleanliness, and corrosion resistance help to maintain the tolerances between the piston and bore and thus their portion of the overall efficiency of the pump.

Pistons and bores were in excellent condition with only slight scratches from particulate contamination. See Fig. 7.

Inspection of Front and Rear Bearings

The bearings within this pump are lubricated entirely by circulating case fluid via the internal leakage within the pump. Both bearings are cylindrical roller bearings designed to handle a maximum amount of radial loading. The drive shaft end OD is utilized as the inner-bearing race. This design allows for the highest load carrying bearing given the space constraints imposed by the inlet and outlet kidneys. At the same time, this design provides sufficient shaft diameter to allow for full, through drive capability in case of a tandem pump arrangement. Along with load carrying ability, fluid cleanliness is of critical importance in this area. Excessive particulate contamination and/or wear metal from within the

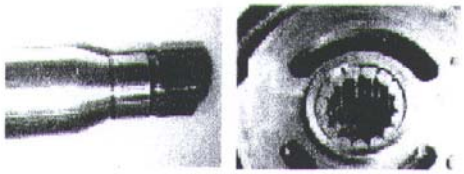

Fig. 8—Rear bearing and mating shaft surface.

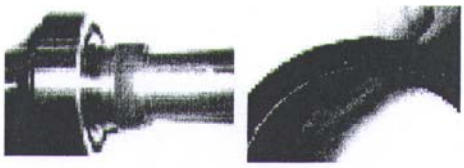

Fig. 9—Shaft seal and ceramic bushing.

pump will be flushed through the bearings as the fluid flows to the case drain, resulting in bearing failure.

Inspection of the front and rear bearings shows them to be in good condition with only slight running marks. The appearance of the drive shaft OD (inner bearing race) confirms this as it shows only slight marks.

Inspection of Shaft Seal

This pump employed a BAFSL style, single reinforced lip, spring loaded shaft seal. It was comprised of FPM (fluorocarbon rubber). This seal is designed to allow a minute amount of fluid leakage without causing visible drops. This leakage is necessary for fluid to lubricate the seal lip as the shaft spins. A fluid with excellent oxidation resistance is also required for long-term seal life. As previously discussed the oxidation by-products that result from an unstable fluid will form deposits within the pump. These deposits will act as a lapping compound on the seal lip resulting in excessive leakage and premature failure.

Inspection of the shaft seal and ceramic bushing showed no deposits and the seal lip was in excellent condition. There was no visible shaft seal leakage during the 4000 hours of operation.

CONCLUSION

After 4000 hours it can be concluded that the fluid provides excellent lubrication properties, at least as good as running on conventional mineral fluids. Further inspections are scheduled at longer running intervals to judge the long-term stability of the fluid.

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IRON AND STEEL ENGINEER

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DECEMBER 1998

Polyether polyol, a new generation hydraulic fluid, has led to major increases in the operating life of equipment in the steel industry by solving problems associated with pumps and valves. Field experience and results are discussed.

Field experience with a new generation polyether polyol hydraulic fluid

Kevin P. Kovanda, President, American Chemical Technologies, Inc., Wixom, Mich., and **Philip R. Miller**, Vice President—Technical Services, Gateway Additive Co., Spartanburg, S. C.

EVERY steel mill is faced with competition from the globalization of the steel supply base. To meet this challenge, steel mills are re-evaluating, re-engineering and modernizing equipment. In an effort to remain cost competitive, the industry is increasingly using fluid power (hydraulics) for the accuracy, versatility, speed and repeatability it offers.

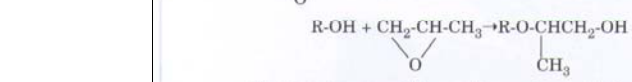
To reduce capital expenditures, current hydraulic systems are smaller in size, generate higher pressures and function on lower fluid volume coupled with higher flow rates. These conditions have placed increased importance on the hydraulic fluid. They have resulted in higher oxidation rates because of elevated operating temperatures and shorter resonance time in the reservoir, hydrolytic instability from moisture in the fluid, and heat generated from the continuous shear through tight tolerance pumps and valves. The problem is magnified further when it is recognized that the last significant, fully synthetic, fire-resistant hydraulic fluids were introduced over 25 years ago.

Over the last several years, a new generation hydraulic fluid, polyether polyol, has provided superior performance and long-term stability.

Fluid description

A description of the chemistry of polyether polyol provides a basis for understanding some of its critical properties.

Polyether polyols are the reaction products of an alcohol, most commonly butanol, represented as R-OH, and an epoxide, most commonly propylene oxide, represented as $CH_2\text{-}CH\text{-}CH_3$:



$$R\text{-}OH + CH_2\text{-}CH\text{-}CH_3 \rightarrow R\text{-}O\text{-}CHCH_2\text{-}OH$$

This is not a reversible reaction and no water is formed: the implication is that hydrolysis will not occur. A designed synthetic molecule is obtained by controlling the number of repeating units of propylene oxide added onto the alcohol. This number will determine the polymer's molecular weight and viscosity.

Polyether polyols have inherently good lubricity. This is illustrated in Fig. 1, which shows four-ball wear data obtained for mineral oil and polyether polyol base fluids (without additives) over the same viscosity range. Since polyether polyols are completely saturated (<1 iodine value), they have good oxidation stability and do not cause varnishes, sticky residues or staining of pump components. They also have excellent detergency, which contributes to system cleanliness. Additives for corrosion protection (both ferrous and nonferrous metals) and further enhancements of its oxidation stability and anti-wear properties are used to obtain the finished hydraulic fluid.

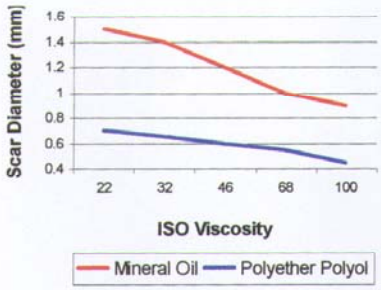


Fig. 1 — Four-ball wear data.

Typical physical properties of polyether polyols formulated to give three viscosity levels are shown in Table I. Performance highlights are summarized in Table II.

Properties of polyether polyol, polyol ester and phosphate ester

Polyol ester fluids are the reaction product between an alcohol, most commonly trimethylol propane (TMP), represented as R-OH, and an acid, commonly oleic acid, represented as R'-COOH:

$$R\text{-}OH + R'\text{-}COOH \rightleftarrows R\text{-}OOC\text{-}R' + H_2O$$

This is a reversible reaction since water can react with the ester to revert back to the alcohol and acid. This process is called hydrolysis.

TABLE I Typical fluid properties of polyether polyol

	Viscosity grade		
Property	**ISO-46**	**ISO-68**	**ISO-100**
Viscosity			
100°F, SUS	230	310	480
40°C, cSt	46	68	100
210°F, SUS	53.3	65.3	86.0
100°C, cSt	8.9	12.1	17.2
Viscosity index	185	189	196
Pour point, °F	–55	–50	–40
Density at 60°C, lb/gal	8.25	8.27	8.29
Acid number, mg KOH/gm (max.)	0.4	0.4	0.4
Factory Mutual approved	Yes	Yes	Yes
Flash point, COC, °F	470	520	570
Foam test, ASTM D892	Pass	Pass	Pass
Copper corrosion, ASTM D130	Pass	Pass	Pass

TABLE II Typical performance properties of polyether polyol

Test	Result
Vickers 104C Vane Pump Test, ASTM D2882 (2000 psi, 100 hr, 150°F, 7.5 gpm, 1200 rpm, 3.5-gal sample)	<5 mg total wear
Four Ball Wear, ASTM D2266 (1800 rpm, 1 hr, 167°F, 40-kg load)	0.35 mm
Four Square Gear Test (FZG) (194°F, 1760 rpm, 1600-ml sample, 12 stages)	Pass, all 12 stages
Oxidation (Universal Oxidation Glassware) (135°C, steel and copper catalysts) Time to 0.5 TAN increase	200 hr

Phosphate esters are reaction products of an aromatic, or aryl compound such as phenol or cresol, represented as Ar-OH, with most commonly, $POCl_3$ (phosphorus oxychloride):

$$3\ Ar\text{-}OH + POCl_3 \rightarrow (Ar\text{-}O)_3\text{-}P\text{-}OH + 3Cl.$$

Although this is not a reversible reaction, it is susceptible to hydrolysis at elevated temperatures and can form gelatinous by-products if a sufficient amount of water is present. These by-products will form semi-solid gels. This situation occurred twice in 1992 at a continuous casting operation. In both instances production was idled for several days.

Hydrolytic stability is the tendency of a fluid to resist chemical reaction with water. It is a major advantage offered by the polyether polyol hydraulic fluid. Fluid levels change in the normal operation of the hydraulic system causing the reservoir to breathe. In hot and cold rolling operations, cylinders are constantly functioning in wet environments. In both instances there is an ingress of water (moisture) into the system. The water reacts with the polyol ester or phosphate ester, producing a free acid. This acid can eventually cause corrosion and downtime.

Several other key properties of the fluids are summarized in Table III. Numerical values on a scale from 1 (poor) to 5 (excellent) were assigned for each property for each fluid type. Most values are quantitative comparisons, but some are subjective in nature. This was done numerically so that properties could be weighted, since not all properties are necessarily equally important in every application.

Field experience

Olin Brass casting plant, East Alton, Ill. — The Olin Brass casting plant was the first industrial site for beta testing the polyether polyol hydraulic fluid. The test began Oct. 1, 1990 and ran for approximately 14 months. Hydraulic system specifications follow:

TABLE III Rating of fluid types
Ratings: 1 (poor) to 5 (excellent)

Property	Phosphate ester	Polyol ester	Polyether polyol
Hydrolytic stability	4	3	5
Chemical stability	4	3	5
Oxidative stability	4	3	5
Seal compatibility	2	4	5
Anti-wear	4	3	5
Environmental impact	2	5	4
Viscosity index	2	4	5
Demulsibility	4	3	2
Varnishes and residues	4	3	5
Inherent fire resistance	5	3	4
Long-term fire resistance	5	2	3
Heat release on burning	4	3	5
Combustion product toxicity	1	4	5
Price	2	5	4

Previous fluid	Polyol ester
ISO viscosity grade	68
Fluid service life	18 months
Pump mfg./type	Vickers, vane
Pump model No.	V2234-5-11W
Flow rate	17 gpm
Shaft speed	1200 rpm
Reservoir size	250 gal
Pressure	800 psi
Operating temperature	110-120°F
Seal material	Viton

The fluid conversion was accomplished by draining the system and refilling with polyether polyol fluid having an ISO viscosity grade of 46. It was estimated that a few gallons of the polyol ester remained in the cylinders. During the 14-month trial, no problems were encountered and no fluid makeup was necessary. The previously used polyol ester required makeup at the rate of approximately 25 gal/month (450 gal over its 18-month service life). Since the level of copper was of concern with the polyol ester fluid, a metals analysis was conducted at various times during the trial. The test data are shown in Table IV.

TABLE IV Test results with polyol ester and polyether polyol at Olin Brass

	Polyol ester		Polyether polyol			
Time in operation, weeks	New	83	New	8	26	48
Metal contamination, *ppm						
Iron	N/T	28	<10	<10	<10	15
Copper	N/T	56	<5	<5	<5	<5
Zinc	N/T	40	<1	<1	<1	<1
Nickel	N/T	3	N/D	N/D	N/D	N/D
Calcium	N/T	<5	N/D	N/D	N/D	7

*N/T Not tested, N/D None Detected

International Mill Service, Inc. (IMS) Gary, Ind. — IMS operates a fleet of six CAT 992C wheel loaders for digging out slag pits. In 1992, the company sought a fire-resistant hydraulic fluid to replace the polyol ester fluid currently in use. Anticipating longer component life, the polyol ester fluid had been previously selected over a water-glycol fluid. Since the polyol ester fluid was unable to provide acceptable pump life because of a varnish buildup around the pistons, a trial was established using polyether polyol fluid. The machine ran for almost 9000 hours with polyether polyol fluid on a used set of pumps, before a failure occurred. This same machine had not run for more than 2000 hours on the polyol ester fluid without a pump failure. Hydraulic specifications for the wheel loader are:

Pump type	Hydraulic, axial piston, Steering, gear
Flow rate	Hydraulic (2), 120 gpm Steering, 188 gpm
Reservoir volume	140 gal
Operating pressure	Hydraulic, 3250 psi Steering, 2500 psi
Shaft speed	2000 rpm

In 1993, the testing of polyether polyol fluid was expanded to include all the pit loaders. Results have been similar to or better than those of the initial trial.

Also in 1993, the polyether polyol fluid was used in a 990 CAT. All original pumps ran until rebuild with just over 16,000 hours on them.

Since 1992, the pumps on all mobile equipment operating with the polyether polyol fluid have consistently averaged 12,000 to 14,000 hours.

In Dec. 1997, the use of polyether polyol was further expanded to the first of 13 Kress slab haulers. Historically, the constant pressure pumps on this equipment only last for 7000 to 8000 hours on polyol ester fluid. Currently, one unit has accumulated 3300 hours.

U.S. Steel, Edgar Thomson Works, Braddock, Pa. — In July 1995, the decision was made to begin converting all mobile equipment from polyol ester fluid (ISO viscosity grade 68) to a polyether polyol fluid. The first piece of equipment converted was a Kress slab hauler. The pump specifications are summarized in Table V.

TABLE V Slab hauler pump specifications

Manufacturer	Type	Quantity	Pressure, psi	Speed, rpm	Volume, gpm
Tyrone	Gear	2	2500	2000	78.5
Rexroth	Axial piston	4	Front 2500, rear 2000	2000	30.2

The first set of pumps ran for 3763 hours before failure. This failure occurred because of a dry start-up after the suction filter was changed. The next set of pumps has accumulated 5572 hours, as of June 23, 1998, and was still running. The previous pump life with polyol ester fluid was approximately 3000 hours. A second Kress slab hauler was converted in July 1996 and, as of June 23, 1998, the pumps have run for 7605 hours.

Discussions with maintenance personnel indicate that there has not been a fluid-related problem with the hydraulics since converting to the polyether polyol fluid. Also, filter changes have been extended to 1500 hours from 1000 hours. This extension has been possible because routine sample analysis has indicated no abnormal conditions, no evidence of sludge or varnish in the system and overall trouble-free operation of the hydraulics.

This plant also operates two Gradall XL5210s for ladle and furnace deskulling. The first unit was purchased on Dec. 12, 1995. The pumps operated for 2735 hours until a fluid leak caused them to run dry on June 19, 1998. A second unit was purchased on Feb. 1, 1998, and has accumulated 551 hours as of June 19, 1998. The Gradall XL5210 has the following operating specifications:

Operating pressure	4500 psi
Flow rate	120 gpm
Operating temperature	100°F above ambient
Shaft speed	2300 rpm
Pumps	Rexroth (2), bent axis, variable displacement

High speed rod mill — In March 1996, polyether polyol fluid was chosen for the initial operation of a new bar mill. The four main hydraulic systems integral to the mill's operation are: cold billet handling (designated FF); roughing mill train (designated AA); pouring reel outlet (designated EE); and reforming (designated DD).

The hydraulic system specifications for all four systems can be summarized as:

Pressure	1500-2100 psi
Flow rate	60-75 gpm
Shaft speed	1800 rpm
Temperature	95-110°F
Pump type	Vickers vane
Filtration	12 micron absolute
Fluid cleanliness	ISO 15/12 or less
Close tolerance valves	Proportional

There have been no pump failures over the mill's two and a half years of operation. The trend in TAN levels since the mill was commissioned is illustrated in Fig. 2.

As a result of this successful implementation, the manufacturer of the high speed rod mill has replaced polyol ester with polyether polyol as the approved, fire-resistant hydraulic fluid for all future installations. Since this approval, there have been two additional successful installations: one in Canada and one in the U.S.

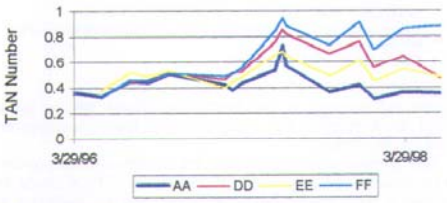


Fig. 2 — High speed rod mill TAN levels.

Caterpillar, Inc. track loaders — Polyether polyol had been used successfully for over two years on the Caterpillar 973 steel mill track loader bucket hydraulic system at U.S. Steel, Edgar Thomson Works when fluid consolidation was examined. One potential area considered was the use of polyether polyol both as a hydraulic fluid and as a hydrostatic transmission fluid. (Assurances were received from the Caterpillar dealer that the use of polyether polyol would not void the manufacturer's warranty.) Three 973 track loaders were converted on Aug. 25, 1997.

The track loader hydrostatic drive provides variable machine speeds up to 6.4 mph, forward or reverse. Additional specifications are:

- Each track is driven by a separate hydraulic circuit consisting of one variable-displacement piston pump, connected by Caterpillar's XT-6 hydraulic hose and couplings to a variable-displacement piston motor.
- Two drive pumps; variable-displacement, slipper-axial Caterpillar piston pumps driven from engine flywheel by single shaft and simple splitter box.
- Two track motors; two position variable-displacement, link-type Caterpillar piston motors.
- Full flow filtering of hydrostatic drive system oil.
- Relief valve settings; 5510 psi/380 bar/38,000 kPa.
- System flow rate; 110 gpm.

The systems were converted by simply draining the Caterpillar TO-4 mineral oil and adding polyether polyol to the system. The level of oil contamination during this test is summarized in Table VI together with cumulative machine hours and the results of a wear metals analysis.

Bethlehem Steel Corp., Burns Harbor, Ind. — Excessive pump losses on the Hydraulic Automatic Gage Control (HAGC) system and excessive TAN levels in the 3000-ton leveler main reservoir and bulk storage tank

TABLE VI Oil contamination test results with track loaders

Condition	Track loader										Fluid	
	No. 685*			No. 686			No. 687			No. 688	Polyether Polyol	Cat. TO-4 Oil
Date:	8/25/97	2/4/98	6/19/98	8/25/98	2/4/98	6/19/98	8/25/97	2/4/98	6/19/98	6/23/98	–	–
Oil, %	24.07	17.00	N/T	6.62	0.00	9.4	53.50	17.00	15.7	37.4	New	New
Duration												
Hours	1110	1325	1365	45	207	292	522	1012	1395	279	–	–
Hours cumulative***	NA	215	255	N/A	162**	85	N/A	490	873	279	–	–
Metal content, ppm+												
Phosphorus	590	570	N/T	550	590	642	620	610	620	771	590	1000
Sulfur	2200	1400	N/T	1500	1300	1000	2000	1300	1200	2800	1500	7000
Calcium	45	<100	N/T	8	<100	44	640	120	186	137	N/D	1100
Copper	64	N/D	N/T	8	N/D	36	16	N/D	51	66	N/D	6
Zinc	94	<100	N/T	13	<100	14	240	110	86	254	N/D	1100
Chlorine	N/D	N/D	N/T	N/D	N/D	17	N/D	N/D	4	15	N/D	67
Magnesium	N/D	N/D	N/T	N/D	N/D	22	N/D	N/D	111	15	N/D	350
Iron	N/D	N/D	N/T	N/D	N/D	56	N/D	N/D	70	7	N/D	N/D

* Unit No. 685 traded in on unit No. 688 in 1998.
** Transmission failed on 1/30/98. Transmission rebuilt prior to test. Failure considered mechanical, not fluid related.
*** N/A Not applicable.
+ N/T Not tested, N/D Not detected.

were experienced at the Bethlehem Steel 160-in. plate mill. Both systems had operated from their inception on polyol ester fluid.

The decision was made to convert the leveler and pre-leveler system first, because of the increase of TAN levels, to above 9. The conversion was made over the weekend of Dec. 13, 1997, and a two-step flushing procedure was followed. The first step was to drain the polyol ester fluid and flush the system with a mineral oil flushing fluid. Because of the intricacy of the system valving and the fact that the piping could not be thoroughly drained at the start, arrangements were made to cycle the system for several hours with the mineral oil flush. The second step was to drain this fluid and then flush with the polyether polyol fluid. Arrangements were again made to have the system cycled for several hours. This material was then drained, the reservoirs opened and inspected, and all filter elements changed prior to the addition of the final charge of fluid. A trace dye added to the mineral oil flushing fluid indicated that the level of mineral oil contamination remaining in the system was less than 5%. Consequently, the level of polyol ester remaining in the system was less than 0.5%. At the time of start-up the TAN number had been changed from 9.48 to 0.47. System specifications for the 3000-ton leveler and pre-leveler are:

Date placed in service	July 1996
Operating pressure	3650 psi
Operating temperature	95-105°F
System volume	2000 gal
Flow rate	100 gpm
Pump mfg./type	Parker, axial piston
Pump model No.	PV180 and PV130
Shaft speed	1200 rpm
Pumps on system	6
Seal material	Buna N
Hose material	Buna N
Close tolerance valves	Rexroth servo
Valve model No.	4WRDE16-125L-51/6L-1579/V
Pressure filter	Parker, 3 micron absolute
Polishing filter	Parker, 2 micron absolute
Typical fluid cleanliness	ISO 14/12, NAS 6

When operating with polyol ester, the fluid had to be drained and refilled twice because of high TAN values. Water ingress was suspected, however, leaks were not found. During the same time period, the system experienced five pump failures with an average life of 1000 to 1500 hr/pump. Servo and directional valve problems were a constant maintenance item.

Since the conversion to polyether polyol, the pumps have accumulated an average of 4500 hours (as of July 15, 1998), and only one valve and one pump have been changed. The pump failure was caused by a piston splitting in half. The TAN levels experienced since the conversion are shown in Fig. 3.

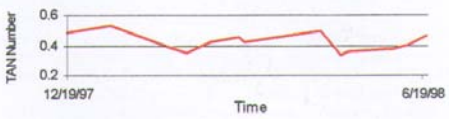


Fig. 3 — TAN levels following conversion of 3000-ton leveler to polyether polyol.

Based on the successes at the 3000-ton leveler, the HAGC system was scheduled for conversion during the weekend of April 18, 1998. The same two-step flushing procedure was followed, with similar results. System specifications for the HAGC system are:

Date placed in service	Dec. 1991
Operating pressure	4800-5000 psi
Operating temperature	95-105°F
Case drain temperature	130-150°F
System volume	1800 gal
Flow rate	100 gpm
Pump mfg./type	Rexroth, axial piston Denison, axial piston
Pump model No.	Rexroth- AA4VSO250, Series 30 Denison-P16
Shaft speed	1200 rpm
Pumps in system	4
Seal material	Buna N

Hose material	Buna N
Close tolerance valves	Moog servo Bosch servo
Valve model No.	Moog-79 Bosch-NG-16
Pressure filter	Parker, 3 micron absolute
Polishing filter	Parker, 3 micron absolute
Pre-charge filter	Parker, 10 micron absolute
Typical fluid cleanliness	ISO 14/12, NAS 6

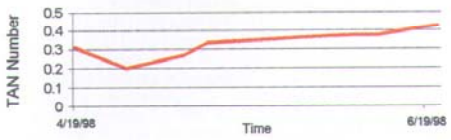


Fig. 4 — TAN levels following conversion of HAGC system to polyether polyol.

Since the system was installed in 1991, there had been 35 catastrophic pump failures. Two different sources of polyol ester fluid were used during this period and it was necessary to drain and refill the system twice because of high TAN levels. In one instance, the polyol ester fluid lasted only four months before it had to be discarded because of a rapid increase in TAN level. Average pump life over the last six years had been 3000 to 4000 hours. There had also been servovalve problems caused by sludge, varnish and rust formation from the polyol ester fluid.

As of July 15, 1998, there are approximately 1750 hours on the polyether polyol fluid without incident. Fluid cleanliness has continued to trend at the ISO 14/12, NAS 6 level. The trend in the TAN levels is illustrated in Fig. 4.

Summary

A new generation hydraulic fluid, polyether polylol, has solved many problems associated with pumps and valves together with dramatic extensions of operating life compared with polyol ester and phosphate ester fluids.

Polyether polyol is a Factory Mutual approved fire-resistant hydraulic fluid.

Field experience and performance results obtained in the steel industry with mobile equipment are discussed. ▲

For More Information Please Contact:

American Chemical Technologies, Inc.
485 E. Van Riper Rd.
Fowlerville, MI 48836
Phone: (517) 223-0300 / (800) 938-0101
Fax: (517) 223-1703

PRODUCT INFORMATION

A PRODUCT OF AMERICAN CHEMICAL TECHNOLOGIES, INC.

Seal Compatibility

When converting systems from either phosphate ester or polyol ester to an EcoSafe® product, differences in compatibility should be taken into consideration during the conversion process. These are general guidelines that represent expected results from quality manufactured elastomers.

	Phosphate Ester	Polyol Ester	EcoSafe®
EPR (EPDM)	**R**	**U**	**S**
Viton® (FKM)	**S**	**S**	**R (performance)**
Buna-N	**U**	**R**	**R (cost)**
Butyl	**S**	**S**	**S**
Silicone	**U**	**R**	**U**
Neoprene (polychloroprene)	**U**	**U**	**S**
Teflon®	**S**	**R**	**S**
Urethane	**U**	**S**	**S**

R = Recommended (primary factor)
S = Satisfactory
U = Unsatisfactory

SAFETY DATA SHEET

AMERICAN CHEMICAL TECHNOLOGIES, INC.

This SDS conforms to the GHS, ISO 11014-1, and ANSI Z400.1
This SDS complies with 29 CFR 1910.1200
Prepared according to EU Directive 1907/2006/EC

SECTION 1 – CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name: EcoSafe® FR-46
Product Code: ESFR-46

Product Type: Polyether Polyol Lubricant
Recommended Use: Hydraulic fluid

Manufacturer/Supplier:
American Chemical Technologies, Inc.
485 E. Van Riper Road, Fowlerville, MI 48836
Office: 517-223-0300 Fax: 517-223-1703

Emergency Spill Information:
INFOTRAC 1-800-535-5053 (US & Canada)
INFOTRAC 1-352-323-3500 (International)
24 HOURS/DAY, 7 DAYS/WEEK

SECTION 2 – HAZARDS IDENTIFICATION

GHS Product Classification: None

Emergency Overview: This product has been evaluated and does not require any hazard warning on the label under OSHA criteria. The product does not require a hazard warning label in accordance with GHS criteria according to REGULATION (EC) No 1272/2008.

Risk Phrases: None

Safety Phrases: S3/14, S14, S26, S27/28, S29/35, S36/37, S36/39, S40, S43, S57, S62, S63

HMIS Code: (Health:1) (Flammability:1) (Reactivity:0) (Protection: B)

NFPA Code: (Health:1) (Flammability:1) (Reactivity:0)

WHMIS Code: None

SECTION 3 – COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS#	EC#	Range % by wt.
Polyether polyol	Proprietary	Not known	90% - 100%
Phenothiazine	92-84-2	202-196-5	0.1% - 0.9%

SECTION 4 – FIRST AID MEASURES

Eye: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

Skin: After contact with skin, take off immediately all contaminated clothing, wash immediately with plenty of soap and water.

Inhalation: In case of accident by inhalation: remove casualty to fresh air and keep at rest.

Ingestion: If swallowed, do not induce vomiting: seek medical advice immediately.

Symptoms/effects: Mild irritation may occur with overexposure.

Special treatment: Treat symptomatically.

SECTION 5 – FIRE FIGHTING MEASURES

Suitable Extinguishing Media: In case of fire use dry chemical, carbon dioxide, foam, steam, or water fog. Water can be used to cool and protect exposed material.

Unsuitable Extinguishing Media: Never use water.

Specific Hazards: Keep away from extreme heat and open flames.

Hazardous Combustion Products: Incomplete combustion results in oxides of carbon.

Fire Fighting Equipment: Fire fighters should wear an approved self-contained breathing apparatus.

SECTION 6 – ACCIDENTAL RELEASE MEASURES

Personal precautions: Wear suitable protective clothing and gloves.

Environmental precautions: Use appropriate containment to avoid environmental contamination. Do not empty into drains; dispose of this material and its container in a safe way.

Methods and materials for cleanup: To clean the floor and all objects contaminated by this material use an inert absorbent material.

SECTION 7 – HANDLING AND STORAGE

Handling: Keep containers closed when not in use. Wash thoroughly after handling. Empty container contains product residue which may exhibit hazards of product.

Storage: No special storage precautions required.

SECTION 8 – EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure limits:

Component	CAS#	Country	Long Term (8 Hours TWA)	Short Term (15 min)
Phenothiazine	92-84-2	USA	5 mg/m^3 (skin)	None

Engineering Controls: Use local exhaust ventilation to control mists or vapors.

Protective Equipment: Wear suitable protective clothing, gloves and eye/face protection.

SECTION 9 – CHEMICAL AND PHYSICAL PROPERTIES

Appearance	: Clear blue liquid	
Odor	: Mild	
Odor Threshold	: Not determined	
pH	: Not applicable	Method: ASTM D1293
Melting Point / Freezing Point	: Pour Point -42°C (-44°F)	
Initial Boiling Point	: Not determined	
Flash Point	: 274 °C (525°F)	Method: ASTM D92
Evaporation Rate	: Not determined	
Flammability	: Not flammable	
Upper/Lower Explosive Limits	: Not determined	
Vapor Pressure	: <0.5 mm Hg @ 37.8 °C	Method: ASTM D5191
Vapor Density	: Not determined	
Specific Gravity	: 0.988 @ 25°C	Method: ASTM D1475
Solubility in Water	: <1g/100g @ 25 °C	
Partition Coefficient	: log $P_{ow} \geq 2.90$	Method: OECD 117
Autoignition Temperature	: 382 °C (720 °F)	Method: ASTM E659
Decomposition Temperature	: 226 °C (439 °F)	Method: ASTM E2550
Viscosity	: 50.0 cSt @ 40°C	Method: ASTM D445

SECTION 10 – STABILITY AND REACTIVITY

Chemical Stability: Material is normally stable at moderately elevated temperatures and pressures.

Hazardous Reactions: None.

Conditions to Avoid: None identified

Materials to Avoid: Keep away from chlorine, fluorine, and other strong oxidizers.

Hazardous Decomposition Products: Material does not have explosive properties.

SECTION 11 – TOXICOLOGICAL INFORMATION

Eye Contact: Mildly irritating to eyes.

Skin Contact: Mildly irritating to skin.

Inhalation: Mildly irritating to respiratory system.

Ingestion: Slightly harmful if swallowed.

Primary Routes of Entry: None identified.

- ACUTE EXPOSURE --

Dermal Toxicity	The LD50 in rabbits is > 2000 mg/Kg. Based on data from components or similar materials.
Inhalation Toxicity	No data available to indicate product or components may be a toxic inhalation hazard.
Oral Toxicity	The LD50 in rats is between 2000 mg/kg and 5000 mg/kg. Based on data from components or similar materials. Swallowing material may cause irritation of the gastrointestinal lining, nausea, vomiting, diarrhea, and abdominal pain.
Dermal Sensitization	No data available to indicate product or components may be a skin sensitizer.
Inhalation Sensitization	No data available to indicate product or components may be respiratory sensitizers.

-- CHRONIC EXPOSURE --

Chronic Toxicity	No data available to indicate product or components present at greater than 1% are chronic health hazards.
Carcinogenicity	No data available to indicate any components present at greater than 0.1% may present a carcinogenic hazard.
Mutagenicity	No data available to indicate product or any components present at greater than 0.1% are mutagenic or genotoxic.
Reproductive Toxicity	No data available to indicate either product or components present at greater than 0.1% that may cause reproductive toxicity.
Teratogenicity	No data available to indicate product or any components contained at greater than 0.1% may cause birth defects.

SECTION 12 – ECOLOGICAL INFORMATION

-- ENVIRONMENTAL TOXICITY --

Fish Toxicity: LC_{50} = 23.7 mg/L (Pimephales promelas, 96 Hr., OECD 203)

Invertebrate Toxicity: LC_{50} = 18.6 mg/L (Daphnia magna, 48 Hr., OECD 202)

Vascular Plant Toxicity: Not determined.

Algae Toxicity: Not determined.

Bacteria Toxicity: Not determined.

-- ENVIRONMENTAL FATE --

Persistence and Degradability: 87.8% OECD301B 28 days
BOD_5 = 1.3 mg O_2/g; COD = 2180 mg O_2/g (0.06%)

Bioaccumulative Potential: 1 - 10% of the components potentially bioconcentrate, based on octanol/water coefficients.

Mobility in soil: Not determined.

Other Adverse Effects: None identified.

Water Hazard Class WGK 1: Slightly water polluting substance

SECTION 13 – DISPOSAL INFORMATION

Do not empty into drains; dispose of this material and its container as non-hazardous waste.

This material, if discarded, is not a hazardous waste under RCRA Regulation 40 CFR 261. This material, if discarded, should be considered a European non-hazardous waste in accordance with Directive 91/689/EC.

European Waste Catalog Code (EWC-code): 13 01 12

SECTION 14 – TRANSPORTATION INFORMATION

UN Number	Not regulated.
UN Proper Shipping Name:	Not regulated.
Transport Hazard Class	Not regulated.
Package Group	Not regulated.
Marine Pollutant	No
Special Precautions	None.

SECTION 15 – REGULATORY INFORMATION

-- Global Chemical Inventories --

USA	All components of this material are on the US TSCA Inventory or are exempt.
EEC	All components are in compliance with the EC 7th Amendment Directive 92/32/EEC.
Canada	All components of this material are DSL listed or are exempt.
Japan	All components are in compliance with the Chemical Substances Control Law of Japan.
Australia	All components are in compliance with chemical notification requirements in Australia.
Korea	All components are in compliance in Korea.
Philippines	All components are in compliance with the Philippines Toxic Substances and Hazardous and Nuclear Wastes Control Act of 1990 (R.A. 6969).
China	All components of this product are listed on the Inventory of Existing Chemical Substances in China.

-- Other U.S. Federal Regulations --

EPA 550-B-01-003 This product does not contain greater than 1.0% of any chemical substances (0.1% for carcinogens) listed on the Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA) and Clean Air Act Section 112(r): EPCRA Section 302 Extremely Hazardous Substances, CERCLA Hazardous Substances, EPCRA Section 313 Toxic Chemicals, CAA 112(r) Regulated Chemicals For Accidental Release Prevention.

SARA 311 Classifications

Fire Hazard	No
Sudden Release of Pressure Hazard	No
Reactive Hazard	No
Immediate (Acute) Hazard	No
Delayed (Chronic) Hazard	No

-- State Regulations --

Cal. Prop. 65 This product does not intentionally contain any chemicals known by the State of California to cause cancer and/or birth defects. Moreover, American Chemical Technologies does not routinely analyze its products for impurities which may be such chemicals.

-- Other / International --

Harmonized Tariff Schedule Number 3403.99.0000

SECTION 16 – OTHER INFORMATION

Label text:
Handling: Keep containers closed when not in use. Wash thoroughly after handling. Empty container contains product residue which may exhibit hazards of product.
First Aid:
Eye: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
Skin: After contact with skin, take off immediately all contaminated clothing , wash immediately with plenty of soap and water.
Inhalation: In case of accident by inhalation: remove casualty to fresh air and keep at rest.
Ingestion: If swallowed, do not induce vomiting: seek medical advice immediately.
Fire: In case of fire use dry chemical, carbon dioxide, foam, steam, or water fog. Water can be used to cool and protect exposed material.
Spill or Leak: To clean the floor and all objects contaminated by this material use an inert absorbent material.

Prepared By: Mark D. Latunski
Date Revised: 28 April 2014
Supersedes: 21 February 2014
Date Prepared: 19 January 2001

The information provided herein is believed to be accurate to the best of the company's knowledge as of the date of its issue. We do not warrant or guarantee the information provided and will not be held liable for any loss or damage from its use.

Date Translated: 28 April 2014

This SDS originated in English. Context errors associated with the translation to other languages are avoided to the best of our ability. If the translation is unclear, please reference the English version.

SAFETY DATA SHEET

AMERICAN CHEMICAL TECHNOLOGIES, INC.

This SDS conforms to the GHS, ISO 11014-1, and ANSI Z400.1
This SDS complies with 29 CFR 1910.1200
Prepared according to EU Directive 1907/2006/EC

SECTION 1 – CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name: EcoSafe® FR-68
Product Code: ESFR-68

Product Type: Polyether Polyol Lubricant
Recommended Use: Hydraulic fluid

Manufacturer/Supplier:
American Chemical Technologies, Inc.
485 E. Van Riper Road, Fowlerville, MI 48836
Office: 517-223-0300 Fax: 517-223-1703

Emergency Spill Information:
INFOTRAC 1-800-535-5053 (US & Canada)
INFOTRAC 1-352-323-3500 (International)
24 HOURS/DAY, 7 DAYS/WEEK

SECTION 2 – HAZARDS IDENTIFICATION

GHS Product Classification: None

Emergency Overview: This product has been evaluated and does not require any hazard warning on the label under OSHA criteria. The product does not require a hazard warning label in accordance with GHS criteria according to REGULATION (EC) No 1272/2008.

Risk Phrases: None

Safety Phrases: S3/14, S14, S26, S27/28, S29/35, S36/37, S36/39, S40, S43, S57, S63, S62

HMIS Code: (Health:1) (Flammability:1) (Physical Hazard:0) (Protection: B)

NFPA Code: (Health:1) (Flammability:1) (Reactivity:0)

WHMIS Code: None

SECTION 3 – COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS#	EC#	Range % by wt.
Polyether polyol	Proprietary	Not known	90% - 100%
Phenothiazine	92-84-2	202-196-5	0.1% - 0.9%

SECTION 4 – FIRST AID MEASURES

Eye: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

Skin: After contact with skin, take off immediately all contaminated clothing, wash immediately with plenty of soap and water.

Inhalation: In case of accident by inhalation: remove casualty to fresh air and keep at rest.

Ingestion: If swallowed, do not induce vomiting: seek medical advice immediately.

Symptoms/effects: Mild irritation may occur with overexposure.

Special treatment: Treat symptomatically.

SECTION 5 – FIRE FIGHTING MEASURES

Suitable Extinguishing Media: In case of fire use dry chemical, carbon dioxide, foam, steam, or water fog. Water can be used to cool and protect exposed material.

Unsuitable Extinguishing Media: Never use water.

Specific Hazards: Keep away from extreme heat and open flames.

Hazardous Combustion Products: Incomplete combustion results in oxides of carbon.

Fire Fighting Equipment: Fire fighters should wear an approved self-contained breathing apparatus.

SECTION 6 – ACCIDENTAL RELEASE MEASURES

Personal precautions: Wear suitable protective clothing and gloves.

Environmental precautions: Use appropriate containment to avoid environmental contamination. Do not empty into drains; dispose of this material and its container in a safe way.

Methods and materials for cleanup: To clean the floor and all objects contaminated by this material use an inert absorbent material.

SECTION 7 – HANDLING AND STORAGE

Handling: Keep containers closed when not in use. Wash thoroughly after handling. Empty container contains product residue which may exhibit hazards of product.

Storage: No special storage precautions required.

SECTION 8 – EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure limits:

Component	CAS#	Country	Long Term (8 Hours TWA)	Short Term (15 min)
Phenothiazine	92-84-2	USA	5 mg/m^3 (skin)	None

Engineering Controls: Use local exhaust ventilation to control mists or vapors.

Protective Equipment: Wear suitable protective clothing, gloves and eye/face protection.

SECTION 9 – CHEMICAL AND PHYSICAL PROPERTIES

Appearance	: Clear blue liquid	
Odor	: Mild	
Odor Threshold	: Not determined	
pH	: Not applicable	Method: ASTM D1293
Melting Point / Freezing Point	: Pour Point -39°C (-38°F)	
Initial Boiling Point	: Not determined	
Flash Point	: 307 °C (585°F)	Method: ASTM D92
Evaporation Rate	: Not determined	
Flammability	: Not flammable	
Upper/Lower Explosive Limits	: Not determined	
Vapor Pressure	: Not determined	Method: ASTM D5482
Vapor Density	: Not determined	
Specific Gravity	: 0.986 @ 25°C	Method: ASTM D1475
Solubility in Water	: <1g/100g @ 25 °C	
Partition Coefficient	: Not determined	Method: ASTM E1147
Autoignition Temperature	: 382 °C (720 °F)	Method: ASTM E659
Decomposition Temperature	: Not determined	Method: ASTM E2550
Viscosity	: 68.0 cSt @ 40°C	Method: ASTM D445

SECTION 10 – STABILITY AND REACTIVITY

Chemical Stability: Material is normally stable at moderately elevated temperatures and pressures.

Hazardous Reactions: None.

Conditions to Avoid: None identified

Materials to Avoid: Keep away from chlorine, fluorine, and other strong oxidizers.

Hazardous Decomposition Products: Material does not have explosive properties.

SECTION 11 – TOXICOLOGICAL INFORMATION

Eye Contact: Mildly irritating to eyes.

Skin Contact: Mildly irritating to skin.

Inhalation: Mildly irritating to respiratory system.

Ingestion: Slightly harmful if swallowed.

Primary Routes of Entry: None identified.

- ACUTE EXPOSURE --

Dermal Toxicity	The LD50 in rabbits is > 2000 mg/Kg. Based on data from components or similar materials.
Inhalation Toxicity	No data available to indicate product or components may be a toxic inhalation hazard.
Oral Toxicity	The LD50 in rats is between 2000 mg/kg and 5000 mg/kg. Based on data from components or similar materials. Swallowing material may cause irritation of the gastrointestinal lining, nausea, vomiting, diarrhea, and abdominal pain.
Dermal Sensitization	No data available to indicate product or components may be a skin sensitizer.
Inhalation Sensitization	No data available to indicate product or components may be respiratory sensitizers.

-- CHRONIC EXPOSURE --

Chronic Toxicity	No data available to indicate product or components present at greater than 1% are chronic health hazards.
Carcinogenicity	No data available to indicate any components present at greater than 0.1% may present a carcinogenic hazard.
Mutagenicity	No data available to indicate product or any components present at greater than 0.1% are mutagenic or genotoxic.
Reproductive Toxicity	No data available to indicate either product or components present at greater than 0.1% that may cause reproductive toxicity.
Teratogenicity	No data available to indicate product or any components contained at greater than 0.1% may cause birth defects.

SECTION 12 – ECOLOGICAL INFORMATION

-- ENVIRONMENTAL TOXICITY --

Freshwater Fish Toxicity: The acute LC50 is 100 - 1000 mg/L based on similar products.

-- ENVIRONMENTAL FATE --

Persistence and Degradability: This product will biodegrade very rapidly based on OECD 301-type test data for similar products.

Chemical Oxygen Demand (COD) – 869,000 mg O_2/l – 0.88mg O_2/mg

Bioaccumulative Potential: 1 - 10% of the components potentially bioconcentrate, based on octanol/water coefficients.

Mobility in soil: Not determined.

Other Adverse Effects: None identified.

SECTION 13 – DISPOSAL INFORMATION

Do not empty into drains; dispose of this material and its container as non-hazardous waste.

This material, if discarded, is not a hazardous waste under RCRA Regulation 40 CFR 261. This material, if discarded, should be considered a European non-hazardous waste in accordance with Directive 91/689/EC.

European Waste Catalog Code (EWC-code): 13 01 12

SECTION 14 – TRANSPORTATION INFORMATION

UN Number	Not regulated.
UN Proper Shipping Name:	Not regulated.
Transport Hazard Class	Not regulated.
Package Group	Not regulated.
Marine Pollutant	No
Special Precautions	None.

SECTION 15 – REGULATORY INFORMATION

-- Global Chemical Inventories --

USA	All components of this material are on the US TSCA Inventory or are exempt.
EEC	All components are in compliance with the EC 7th Amendment Directive 92/32/EEC.
Canada	All components of this material are DSL listed or are exempt.
Japan	All components are in compliance with the Chemical Substances Control Law of Japan.
Australia	All components are in compliance with chemical notification requirements in Australia.
Korea	All components are in compliance in Korea.
Philippines	All components are in compliance with the Philippines Toxic Substances and Hazardous and Nuclear Wastes Control Act of 1990 (R.A. 6969).
China	All components of this product are listed on the Inventory of Existing Chemical Substances in China.

-- Other U.S. Federal Regulations --

EPA 550-B-01-003 This product does not contain greater than 1.0% of any chemical substances (0.1% for carcinogens) listed on the Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA) and Clean Air Act Section 112(r): EPCRA Section 302 Extremely Hazardous Substances, CERCLA Hazardous Substances, EPCRA Section 313 Toxic Chemicals, CAA 112(r) Regulated Chemicals For Accidental Release Prevention.

SARA 311 Classifications

Fire Hazard	No
Sudden Release of Pressure Hazard	No
Reactive Hazard	No
Immediate (Acute) Hazard	No

Delayed (Chronic) Hazard No

-- State Regulations --

Cal. Prop. 65 This product does not intentionally contain any chemicals known by the State of California to cause cancer and/or birth defects. Moreover, American Chemical Technologies does not routinely analyze its products for impurities which may be such chemicals.

-- Other / International --

Harmonized Tariff Schedule Number 3403.99.0000

SECTION 16 – OTHER INFORMATION

Label text:
Handling: Keep containers closed when not in use. Wash thoroughly after handling. Empty container contains product residue which may exhibit hazards of product.
First Aid:
Eye: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
Skin: After contact with skin, take off immediately all contaminated clothing , wash immediately with plenty of soap and water.
Inhalation: In case of accident by inhalation: remove casualty to fresh air and keep at rest.
Ingestion: If swallowed, do not induce vomiting: seek medical advice immediately.
Fire: In case of fire use dry chemical, carbon dioxide, foam, steam, or water fog. Water can be used to cool and protect exposed material.
Spill or Leak: To clean the floor and all objects contaminated by this material use an inert absorbent material.

Prepared By: Mark D. Latunski
Date Revised: 08 February 2013
Supersedes: 14 January 2012
Date Prepared: 19 January 2001

The information provided herein is believed to be accurate to the best of the company's knowledge as of the date of its issue. We do not warrant or guarantee the information provided and will not be held liable for any loss or damage from its use.

Date Translated: 08 February 2013

This SDS originated in English. Context errors associated with the translation to other languages are avoided to the best of our ability. If the translation is unclear, please reference the English version.

SAFETY DATA SHEET

AMERICAN CHEMICAL TECHNOLOGIES, INC.

This SDS conforms to the GHS, ISO 11014-1, and ANSI Z400.1
This SDS complies with 29 CFR 1910.1200
Prepared according to EU Directive 1907/2006/EC

SECTION 1 – CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name: EcoSafe® FR-100
Product Code: ESFR-100

Product Type: Polyether Polyol Lubricant
Recommended Use: Hydraulic fluid

Manufacturer/Supplier:
American Chemical Technologies, Inc.
485 E. Van Riper Road, Fowlerville, MI 48836
Office: 517-223-0300 Fax: 517-223-1703

Emergency Spill Information:
INFOTRAC 1-800-535-5053 (US & Canada)
INFOTRAC 1-352-323-3500 (International)
24 HOURS/DAY, 7 DAYS/WEEK

SECTION 2 – HAZARDS IDENTIFICATION

GHS Product Classification: None

Emergency Overview: This product has been evaluated and does not require any hazard warning on the label under OSHA criteria. The product does not require a hazard warning label in accordance with GHS criteria according to REGULATION (EC) No 1272/2008.

Risk Phrases: None

Safety Phrases: S3/14, S14, S26, S27/28, S29/35, S36/37, S36/39, S40, S43, S57, S62, S63

HMIS Code: (Health:1) (Flammability:1) (Physical Hazard:0) (Protection: B)

NFPA Code: (Health:1) (Flammability:1) (Reactivity:0)

WHMIS Code: None

SECTION 3 – COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS#	EC#	Range % by wt.
Polyether polyol	Proprietary	Not known	90% - 100%
Phenothiazine	92-84-2	202-196-5	0.1% - 0.9%

SECTION 4 – FIRST AID MEASURES

Eye: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

Skin: After contact with skin, take off immediately all contaminated clothing, wash immediately with plenty of soap and water.

Inhalation: In case of accident by inhalation: remove casualty to fresh air and keep at rest.

Ingestion: If swallowed, do not induce vomiting: seek medical advice immediately.

Symptoms/effects: Mild irritation may occur with overexposure.

Special treatment: Treat symptomatically.

SECTION 5 – FIRE FIGHTING MEASURES

Suitable Extinguishing Media: In case of fire use dry chemical, carbon dioxide, foam, steam, or water fog. Water can be used to cool and protect exposed material.

Unsuitable Extinguishing Media: Never use water.

Specific Hazards: Keep away from extreme heat and open flames.

Hazardous Combustion Products: Incomplete combustion results in oxides of carbon.

Fire Fighting Equipment: Fire fighters should wear an approved self-contained breathing apparatus.

SECTION 6 – ACCIDENTAL RELEASE MEASURES

Personal precautions: Wear suitable protective clothing and gloves.

Environmental precautions: Use appropriate containment to avoid environmental contamination. Do not empty into drains; dispose of this material and its container in a safe way.

Methods and materials for cleanup: To clean the floor and all objects contaminated by this material use an inert absorbent material.

SECTION 7 – HANDLING AND STORAGE

Handling: Keep containers closed when not in use. Wash thoroughly after handling. Empty container contains product residue which may exhibit hazards of product.

Storage: No special storage precautions required.

SECTION 8 – EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure limits:

Component	CAS#	Country	Long Term (8 Hours TWA)	Short Term (15 min)
Phenothiazine	92-84-2	USA	5 mg/m^3 (skin)	None

Engineering Controls: Use local exhaust ventilation to control mists or vapors.

Protective Equipment: Wear suitable protective clothing, gloves and eye/face protection.

SECTION 9 – CHEMICAL AND PHYSICAL PROPERTIES

Appearance	: Clear blue liquid	
Odor	: Mild	
Odor Threshold	: Not determined	
pH	: Not applicable	Method: ASTM D1293
Melting Point / Freezing Point	: Pour Point -35°C (-30°F)	
Initial Boiling Point	: Not determined	
Flash Point	: 307 °C (585°F)	Method: ASTM D92
Evaporation Rate	: Not determined	
Flammability	: Not flammable	
Upper/Lower Explosive Limits	: Not determined	
Vapor Pressure	: Not determined	Method: ASTM D5482
Vapor Density	: Not determined	
Specific Gravity	: 0.992 @ 25°C	Method: ASTM D1475
Solubility in Water	: <1g/100g @ 25 °C	
Partition Coefficient	: *n*-octanol/water	Method: ASTM E1147
Autoignition Temperature	: 382 °C (720 °F)	Method: ASTM E659
Decomposition Temperature	: 226 °C (439 °F)	Method: ASTM E2550
Viscosity	: 100.0 cSt @ 40°C	Method: ASTM D445

SECTION 10 – STABILITY AND REACTIVITY

Chemical Stability: Material is normally stable at moderately elevated temperatures and pressures.

Hazardous Reactions: None.

Conditions to Avoid: None identified

Materials to Avoid: Keep away from chlorine, fluorine, and other strong oxidizers.

Hazardous Decomposition Products: Material does not have explosive properties.

SECTION 11 – TOXICOLOGICAL INFORMATION

Eye Contact: Mildly irritating to eyes.

Skin Contact: Mildly irritating to skin.

Inhalation: Mildly irritating to respiratory system.

Ingestion: Slightly harmful if swallowed.

Primary Routes of Entry: None identified.

- ACUTE EXPOSURE --

Dermal Toxicity	The LD50 in rabbits is > 2000 mg/Kg. Based on data from components or similar materials.
Inhalation Toxicity	No data available to indicate product or components may be a toxic inhalation hazard.
Oral Toxicity	The LD50 in rats is between 2000 mg/kg and 5000 mg/kg. Based on data from components or similar materials. Swallowing material may cause irritation of the gastrointestinal lining, nausea, vomiting, diarrhea, and abdominal pain.
Dermal Sensitization	No data available to indicate product or components may be a skin sensitizer.
Inhalation Sensitization	No data available to indicate product or components may be respiratory sensitizers.

-- CHRONIC EXPOSURE --

Chronic Toxicity	No data available to indicate product or components present at greater than 1% are chronic health hazards.
Carcinogenicity	No data available to indicate any components present at greater than 0.1% may present a carcinogenic hazard.
Mutagenicity	No data available to indicate product or any components present at greater than 0.1% are mutagenic or genotoxic.
Reproductive Toxicity	No data available to indicate either product or components present at greater than 0.1% that may cause reproductive toxicity.
Teratogenicity	No data available to indicate product or any components contained at greater than 0.1% may cause birth defects.

SECTION 12 – ECOLOGICAL INFORMATION

-- ENVIRONMENTAL TOXICITY --

Freshwater Fish Toxicity: The acute LC50 is 100 - 1000 mg/L based on similar products.

-- ENVIRONMENTAL FATE --

Persistence and Degradability: This product will biodegrade very rapidly based on OECD 301-type test data for similar products.

Bioaccumulative Potential: 1 - 10% of the components potentially bioconcentrate, based on octanol/water coefficients.

Mobility in soil: Not determined.

Other Adverse Effects: None identified.

SECTION 13 – DISPOSAL INFORMATION

Do not empty into drains; dispose of this material and its container as non-hazardous waste.

This material, if discarded, is not a hazardous waste under RCRA Regulation 40 CFR 261. This material, if discarded, should be considered a European non-hazardous waste in accordance with Directive 91/689/EC.

European Waste Catalog Code (EWC-code): 13 01 12

SECTION 14 – TRANSPORTATION INFORMATION

UN Number	Not regulated.
UN Proper Shipping Name:	Not regulated.
Transport Hazard Class	Not regulated.
Package Group	Not regulated.
Marine Pollutant	No
Special Precautions	None

SECTION 15 – REGULATORY INFORMATION

-- Global Chemical Inventories --

USA	All components of this material are on the US TSCA Inventory or are exempt.
EEC	All components are in compliance with the EC Seventh amendment Directive 92 /32/EEC.
Japan	All components are in compliance with the Chemical Substances Control Law of Japan.
Australia	All components are in compliance with chemical notification requirements in Australia.
Canada	All components are in compliance with the Canadian Environmental Protection Act and are present on the Domestic Substances List.
Switzerland	All components are in compliance with the Environmentally Hazardous Substances Ordinance in Switzerland.
Korea	All components are in compliance in Korea.
Philippines	All components are in compliance with the Philippines Toxic Substances and Hazardous and Nuclear Wastes Control Act of 1990 (R.A. 6969).
China	All components of this product are listed on the Inventory of Existing Chemical Substances in China.

-- Other U.S. Federal Regulations --

EPA 550-B-01-003	This product does not contain greater than 1.0% of any chemical substances (0.1% for carcinogens) listed on the Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA) and Clean Air Act Section 112(r): EPCRA Section 302 Extremely Hazardous Substances, CERCLA Hazardous Substances, EPCRA Section 313 Toxic Chemicals, CAA 112(r) Regulated Chemicals For Accidental Release Prevention.

SARA 311 Classifications

Fire Hazard	No
Sudden Release of Pressure Hazard	No
Reactive Hazard	No
Immediate (Acute) Hazard	No
Delayed (Chronic) Hazard	No

-- State Regulations --

Cal. Prop. 65 This product does not intentionally contain any chemicals known by the State of California to cause cancer and/or birth defects. Moreover, American Chemical Technologies does not routinely analyze its products for impurities which may be such chemicals.

-- Other / International --

Harmonized Tariff Schedule Number 3403.99.0000

SECTION 16 – SPECIAL PRECAUTIONS

Label text:
Handling: Keep containers closed when not in use. Wash thoroughly after handling. Empty container contains product residue which may exhibit hazards of product.
First Aid:
Eye: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
Skin: After contact with skin, take off immediately all contaminated clothing , wash immediately with plenty of soap and water.
Inhalation: In case of accident by inhalation: remove casualty to fresh air and keep at rest.
Ingestion: If swallowed, do not induce vomiting: seek medical advice immediately.
Fire: In case of fire use dry chemical, carbon dioxide, foam, steam, or water fog. Water can be used to cool and protect exposed material.
Spill or Leak: To clean the floor and all objects contaminated by this material use an inert absorbent material.

Prepared By: Mark D. Latunski
Date Revised: 01 March 2013
Supersedes: 19 June 2012
Date Prepared: 19 January 2001

The information provided herein is believed to be accurate to the best of the company's knowledge as of the date of its issue. We do not warrant or guarantee the information provided and will not be held liable for any loss or damage from its use.

Date Translated: 01 March 2013

This SDS originated in English. Context errors associated with the translation to other languages are avoided to the best of our ability. If the translation is unclear, please reference the English version.

CIRQUE DU SOLEIL®

To: Jim Kovanda
From: Mark Castle

The original hydraulic oil used for the installation at the "KA" theater was determined in order to meet the necessary code requirements. The vegetable base fluid that was selected met these requirements and worked well for the first few years of operation.

Because a portion of our hydraulic system is outdoors, we began to determine a few problems with the oil in regards to the different range of outside air temperatures we are accustomed to in Las Vegas. One of these problems was a higher viscosity when the temperature got cold which resulted in occasional following errors when devices were used at high speed. We were able to counteract this problem by flushing and circulating the oil when the temperature dropped.

Several samples were sent out for analysis over the first year and determined nothing abnormal in the oil condition. Over time we began to have an increase in filter warnings throughout or system and increased pressure differential readings in our main filter cooling skid.

This condition prompted us to start changing filters more frequently than normal. Inspection of the pulled filter elements began to show signs of oil breakdown and residual varnish coating inside the filter housings. We also began to experience failures in the system pump compensators. The inspection of a failed compensator determined scoring of the spools and breakdown of the O-ring seals.

The result of third party testing determined that there was a rapid decrease in the acceptable condition of the oil. The rate and constant increase degradation in a short period of time prompted us to look for alternatives to a vegetable base hydraulic fluid.

The selected alternative chosen was Eco Safe FR 46 by American Chemical Technologies, Inc. This oil is a synthetic base fluid derived from propylene glycol which met all code and system requirements. The new oil has a greater resistance to temperature change and longer shelf life.

When the oil conversion process was completed, there were many filter changes due clumping of gum like deposits captured by the filters. The cause was of this was due to the new oil's cleansing of the residual varnish coating the system from the vegetable base oil. Once the cleansing was completed, no further filter changing was required.

We are operating in year three of the new oil in our system. In that time we have had few single component filters changes and no system pump compensator problems.

We are very satisfied with the performance of the Eco Safe FR oil along with the customer service provided from American Chemical Technologies, Inc. To ensure the longevity of our system we will continue using Eco Safe FR and never return to vegetable base hydraulic oil.

Mark Castle
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From: "Dhaemers, John F" <John.Dhaemers@arcelormittal.com>

Date: September 24, 2010 3:50:23 PM CDT

To: "Ross Kovanda" <rkovanda@americanchemtech.com>

Subject: EcoSafe vs. Polyol Ester

Ross, I'd like to share my experience with hydraulic fluids over the past 20 years in a brief synopsis:

My facility has a 4800 PSI Automatic Hydraulic Gauge Control System on the 4Hi Finishing Mill. I am running Rexroth Pumps AVSO 250 Axial Piston Pumps.

We used Cosmolubric from initial installation and had nothing but problems with the pumps and Moog Servo valves so we switched to Quintolubric because we suspected the fluid was a main source of the catastrophic pump failures and Servo valve failures. We did not have any better experience. We lost over 40 pumps between 1991 when the system was initially installed & 1997 because the fluid would inevitably degrade & destroy the pumps. The acid in the fluid would leach the bronze out of the shoes that ride on the swash plate in the pumps & they would self-destruct (sometimes so badly that the pump case was not even salvageable). Our hydraulic system & reservoirs are climate controlled with all the bells & whistles (i.e. desiccant filters, 3 micron duplex filter units, side-stream filters, heaters, coolers, case drain control & monitors, etc.). We had Quintolubric fluid in a bulk tank reservoir for 6 months that was just held in reserve that went bad and had to be disposed of besides having to constantly change fluid in the operating reservoir where the TAN number seemed to jump exponentially. Polyol ester has such an affinity for water (it is aqueous) that no matter what is done to prevent degradation: it can't be stopped in my experience. Here is a reliable axiom: with Polyol ester fluid: TAN goes up & Pumps go down!

In 1997 we switched from Quintolubric to EcoSafe, a polyether polyol fluid. We did not lose any more pumps for 10 years. One of the pumps we started with at the time of the changeover was removed from service three times after 10 or 12 thousand hours of service for an inspection, reassembled & put back in service twice. We have cycled a couple of pumps out for rebuild in the last couple of years but we just don't have any problems anymore compared to what we had when we ran the Cosmolubric & Quintolubric. I have been in this business for 38 years. I have never seen such a dramatic change in the operating characteristics of a hydraulic system as I have in this case. We also use EcoSafe in a 3400-PSI DeMag Plate Leveler Hydraulic System and have achieved similar results with the axial piston Parker Hydraulic pumps in it. I also have experience with a Slab Grinder Hydraulic System & a Walking Beam Heavy Plate Transfer Hydraulic System that both run Glycol in addition to Mill Roll Balance System that runs at 2500 PSI with a water hydraulic system that has a soluble oil additive for lubrication & weight loaded accumulator. If you want to talk to me, I can be reached at 219-787-3559. Good luck with commissioning your new system! You will really need it if you put Polyol-ester in it!

John Dhaemers, Project Engineer & Mechanical Planner, Burns Harbor 160" Plate Mill, AMUSA.