CARL VON OSSIETZKY universität OLDENBURG
FAKULTÄT V
MATHEMATIK UND NATURWISSENSCHAFTEN

Application of Vegetable Oil-Based Fluids as Transformer Oil

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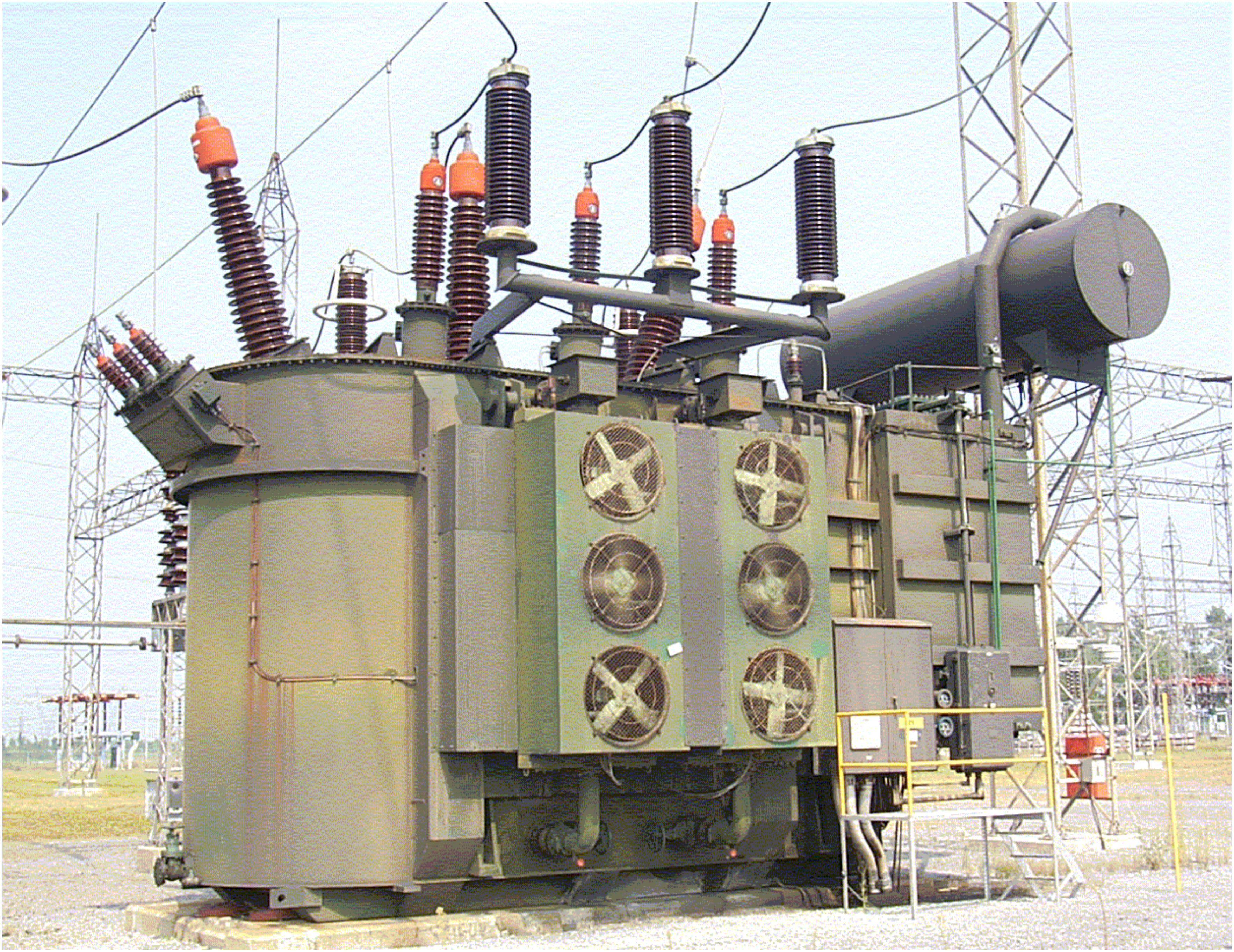
Oleochemicals under Changing Global Conditiones,
Hamburg, 25-27 February 2007



Hermetic sealed transformer

Vegetable-oil based fluids can replace non-renewable petroleum for a more environmental-friendly installation

NAME	TYPE	MANUFACTURER
BIOTEMP®	Comprised mostly of mono-unsaturated high oleic acid triglyceride vegetable oils. The oleic acid group is defined as having one carbon double bond, part of the eighteen carbon atoms in the hydrocarbon chain of a carboxylic acid. Examples of high oleic oils are sunflower, safflower, and rapeseed (canola).	ABB Inc.
BIOTRANS®	A mixture of partially hydrogenated soybean oil high in oleic acid content, methyl esters produced from soybeans, palm or coconut oils used to thin the dielectric liquid	Cargill
Envirotemp® FR3	Edible-seed oil based dielectric liquid. It is a natural ester (triglyceride - fatty acid ester) containing a mixture of saturated and unsaturated fatty acids with 14 to 22 carbon length chains containing one to three double bonds. Suitable vegetable oils, which may be used independently or combined, include: soya, sunflower, and rapeseed (canola).	Cooper Power Systems
Coconut Oil	Coconut Oil	University of Moratuwa, Sri Lanka

Environmental Technology Verification Report

Cooper Power Systems

Envirotemp®FR3™
Vegetable Oil-Based Insulating Dielectric Fluid

By

California Environmental Protection Agency
Department of Toxic Substances Control
Office of Pollution Prevention and Technology Development
Sacramento, California 95812-0806

June 2002

Transformers of

10 KV and 10 MVA

Properties of Envirotemp FR3 before application

Property	Value	Test Method
Electrical		
Dielectric Strength	56 kV @ 25°C (0.080 in. gap) 47 kV @ 25°C	ASTM D1816 ASTM D877
Relative Permittivity[Dielectric Constant]	3.2 @ 25°C	ASTM D924
Dissipation Factor[Power Factor]	0.05% @ 25°C	ASTM D924
Volume Resistivity	30 X 1012 Ω-cm @ 25°C	ASTM D1169
Impulse Strength (Sphere to Sphere)	226 kV @ 0.15" gap	ASTM D3300
Gassing Tendency	-79 (µl/min.)	ASTM D2300
Physical and Chemical		
Specific Gravity	0.92 @ 25°C	ASTM D1298
Interfacial Tension	27 mN/m @ 25°C	ASTM D971
PH	5.8	EPA 9045C
Neutralization (Acid) Number	0.022 mg KOH/g	ASTM D974
Kinematic Viscosity	33 cSt @ 40°C 8 cSt @ 100°C	ASTM D445
Moisture Content	<100 mg/kg	ASTM 1533B
Percent Saturation of Moisture	<5	CPS Method
Air Solubility	16% @ 25°C @ 1 atm.	ASTM D2779
Appearance	Clear, Light Green	ASTM D1524
Color	L 0.5	ASTM D1500

Dielectric Fluids, June 2004, Cooper Power Systems, Pewaukee, WI, USA

Thermal		
Flash Point (Closed Cup)	316°C	ASTM D93
Flash Point (Open Cup)	330°C	ASTM D92
Fire Point (Open Cup)	360°C	ASTM D92
Pour Point	-21°C	ASTM D97
Thermal Conductivity	4.0 X 10-4 cal/(cm •sec •°C) @ 25° C	CPS Method
Specific Heat	0.45 (cal/gm/°C) @ 25°C	ASTM D2766 CPS Method
Coefficient of Expansion	7.4×10^{-4} cc/cc/°C @ 25°C	ASTM E1269
Heat Capacity	2.10 @ 50°C 2.39 @ 100°C	
Environmental Properties		
BOB/COD Ratio	45%	APHA SM5210B
Aquatic Biodegradation	100%	EPA OPPTS 835.3100
Acute Toxicity to Trout Fry	Zero Mortality to Test End Point	OECD G.L. 203

Dielectric Fluids, June 2004, Cooper Power Systems, Pewaukee, WI, USA

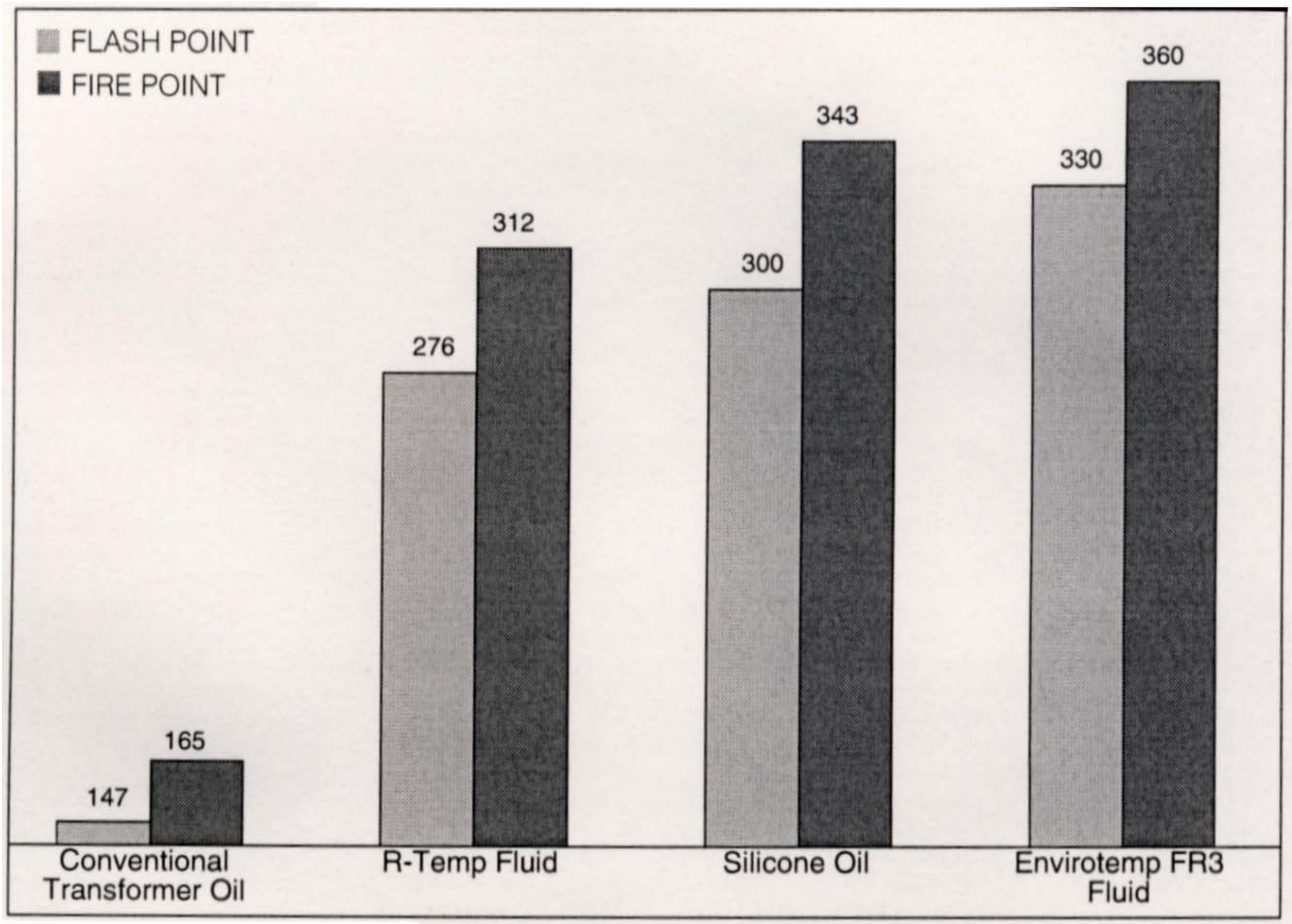
Comparison of Transformer Dielectric Fluids – Typical Values

New Isolating Fluids DIN 57370, Part 1
Breakdown Voltage U_D>50kV

http://www.cooperpower.com/library/pdf/98077.pdf

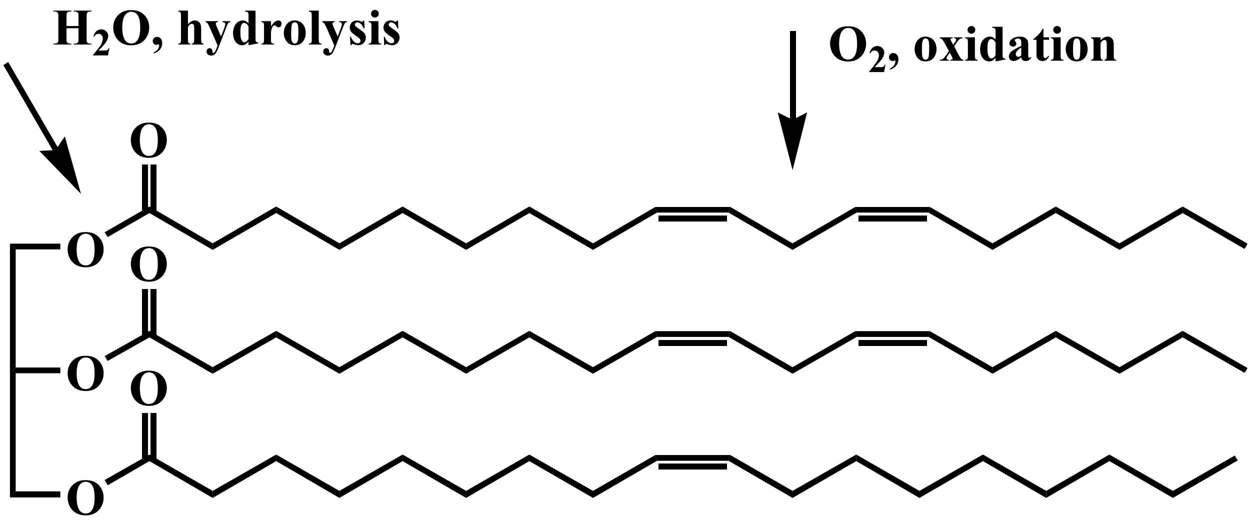
	Envirotemp FR3 Fluid	R-Temp Fluid	Mineral Oil	Silicone Oil
Electrical				
Dielectric Strength (kV) ASTM D877	56	52	45	40
Physical				
Viscosity (cSt) 40°C - ASTM D445	33	113	9.2	39
100°C - ASTM D445	8.0	12	2.3	17
Flash Point (°C) - ASTM D92	324	276	147	300
Fire Point (°C) - ASTM D92	360	312	165	343
Specific Heat (cal/gm-°C) ASTM D2766	0.50	0.45	0.39	0.36
Pour Point (°C) - ASTM D97	-21	-21	-50	-55
Specific Gravity - ASTM D1298	0.92	0.87	0.87	0.96
Environmental				
Biochemical Oxygen Demand (ppm) - 5-Day SM5210B	> 200	6.3	< 6	0
BOD/COD Ratio (%)	45	17	7	0
Biodegradation Rate (%) 21-day CEC-L-33	> 99.0	27.1	25.2	0.0

Flash point and fire point of insulating fluids (°C)



Dielectric Fluids, June 2004, Cooper Power Systems, Pewaukee, WI, USA

http://www.cooperpower.com/library/pdf/98077.pdf



Chemical structure of a native oil: soy bean oil

Aging of native oils

Oxidation

Many fatty acids of native oils contain two or more carbon-carbon double bonds, which undergo reactions with atmospheric oxygen. The oil is more susceptible to oxidation the more of these unsaturated fatty acids are available in the oil. Increase of oil temperature as well as traces of iron and copper in the oil accelerate the oxidation process.

Consequences of oxidation and hydrolysis

- Decomposition products
  (alcohols, aldehydes, ketones, acids)

- Increase of acid number

- Formation of polymerization products

- Increase of viscosity

Moisture, oxygen and environmental pollutants detrimentally affect the characteristics of dielectric fluids. Specifically, moisture reduces the dielectric strength of the fluid, while oxygen helps form sludge which is formed primarily due to the decomposition of the oil. Insulating fluids may comprise one or more additives to prevent these degradation reactions.

Additives

(used for mineral oil-based insulating fluids)

1. Oxidation inhibitors
Decrease of the formation of resins, acids and polymers. The inhibitor is slowly used up and has to be renewed. Example: butylated hydroxyl toluene (BHT) or anisole (BHA); 0.1-3.0%.

2. Metal deactivators:
Protection of the metal surface against corrosion. The catalytic activity of e.g. copper is reduced by benzotriazole derivatives (max. 1%)

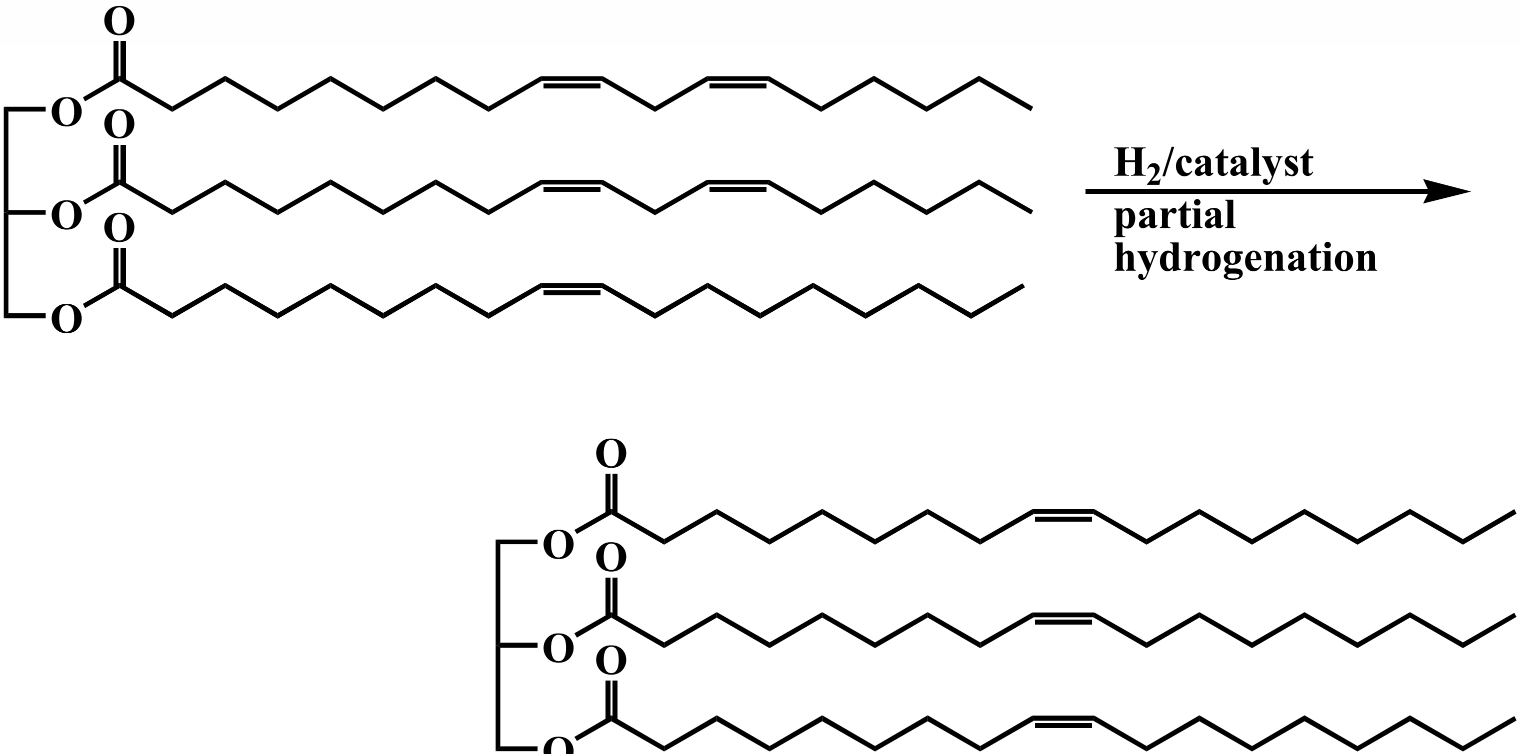
3. Pour point depressants:
Unfortunately, native oil-based fluids have higher pour points compared to mineral oil. Pour point depressants can be added when low pour points are needed.

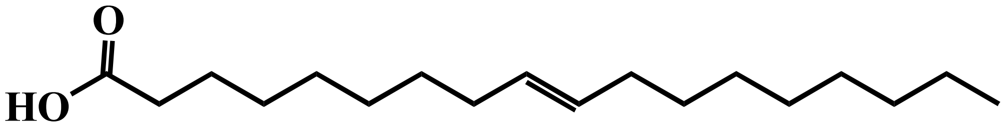
Soybean-based transformer oil and transmission line fluid.

Cannon, Glenn S.; Honary, Lou A. T. (Waverly Light and Power, USA). U.S. (1999), 9 pp. CODEN: USXXAM US 5958851 A 19990928 Patent written in English. Application: US 98-75963 19980511. CAN 131:230879 AN 1999:622258

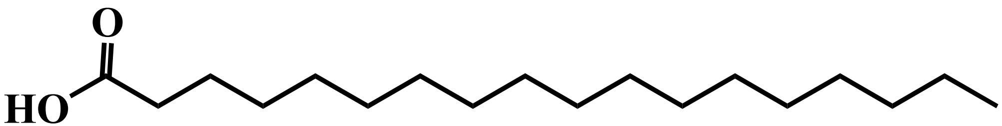
Abstract

A biodegradable soybean oil-based elec. insulating fluid is disclosed. The **base oil is hydrogenated to produce the max. possible stability of the soybean oil** and can be winterized to remove crystd. fats and improve the pour point of the base oil without the necessity of heating the oil. The base oil can also be combined with an additive package contg. materials specifically designed for improved pour point, improved cooling properties, and improved dielec. stability.

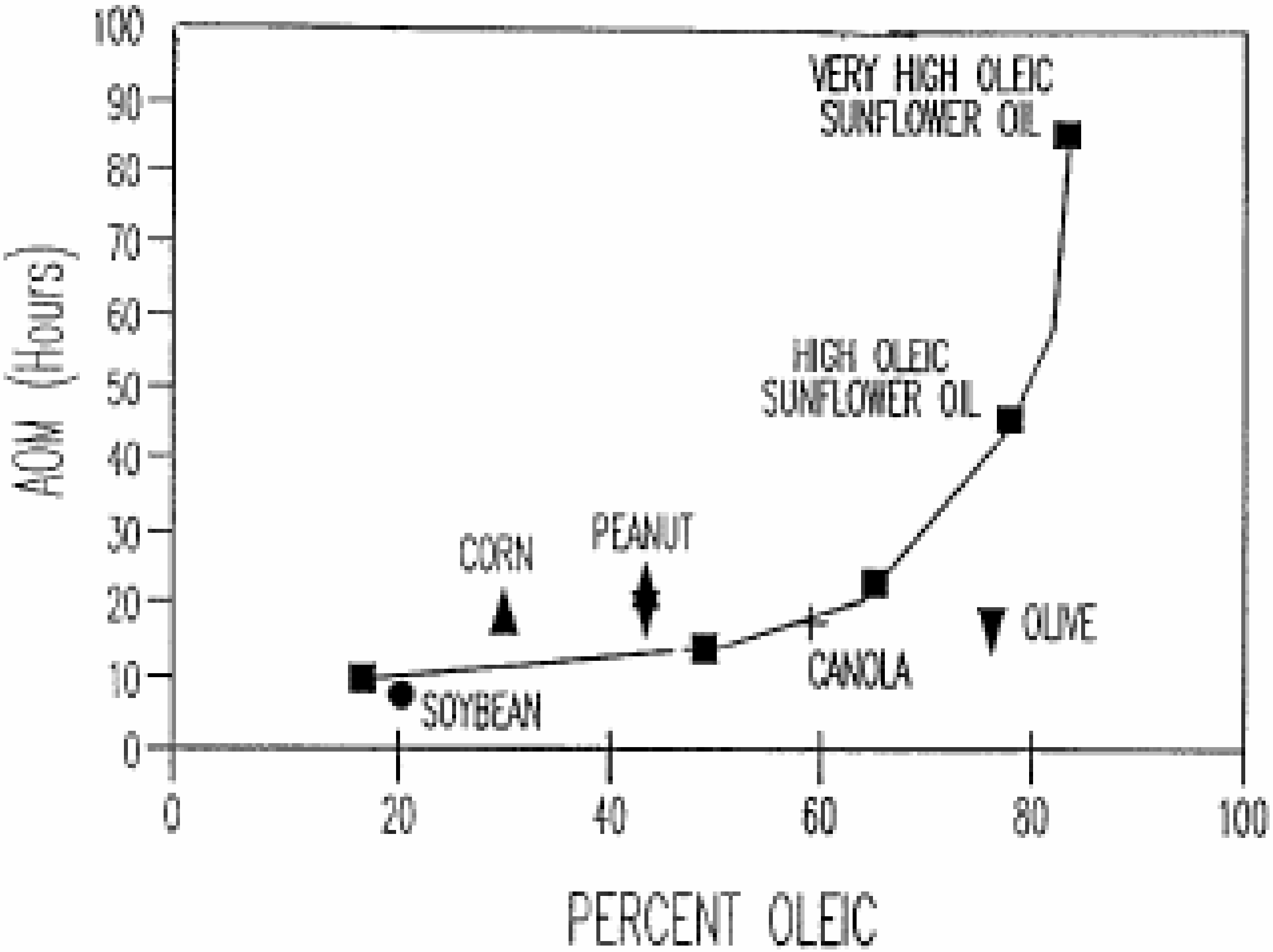




elaidic acid



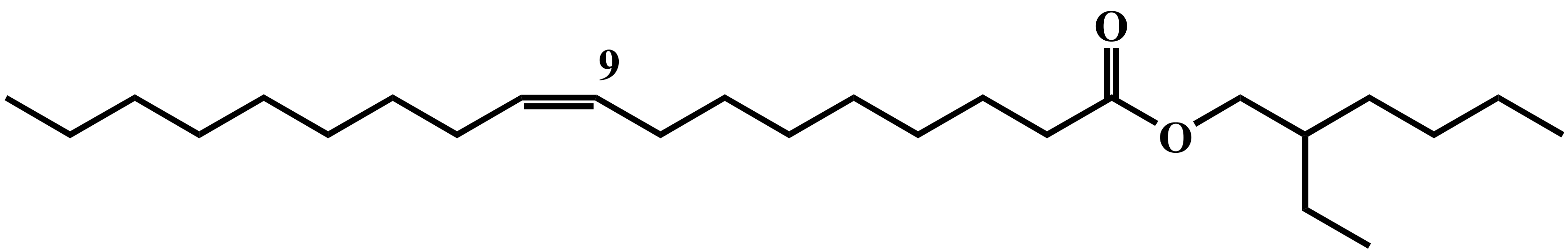
stearic acid



Oxidation stability of different native oils

Cannon, G. S.; Kotowsky, J. A. (Wavely Light and Power), U.S. 6340658, **2002**

Dielectric liquid compositions based on modified oleic rapeseed oil as insulating liquids and coolants, and electric devices containing them. Hoang, Le Chien; Bertrand, Yves. (Electricite de France Service National, Fr.). Fr. Demande (2004), 24 pp. CODEN: FRXXBL FR 2855527 A1 20041203 Patent written in French. Application: FR 2003-6595 20030530. CAN 141:419294 AN 2004:1035179



Oleic acid-2-ethylhexylester

RAPSOL T

Fatty acids

Palmitic acid	**Ø 4,8 %**
Stearic acid	**Ø 1,6 %**
Oleic acid	**Ø 60,0 %**
Linoleic acid	**Ø 21, 2 %**
Linolenic acid	**Ø 9,8 %**

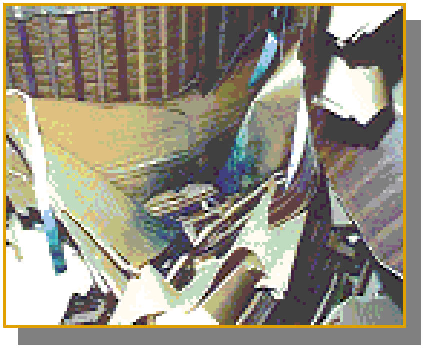
Characteristics

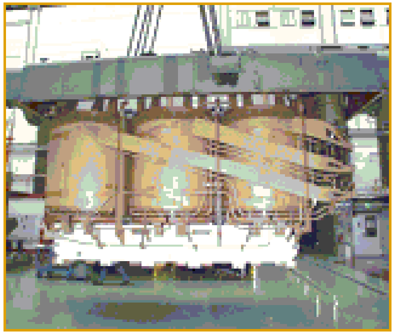
Cloudpoint [°C]	**0**
Flashpoint [°C] (Pensky Martens)	**> 220**
Total acid number [mg KOH/g]	**< 0,1**
Sulfur [mg/kg]	**< 1**

Additives: 0.1 % Antioxidant
0.02 % Metal deactivator

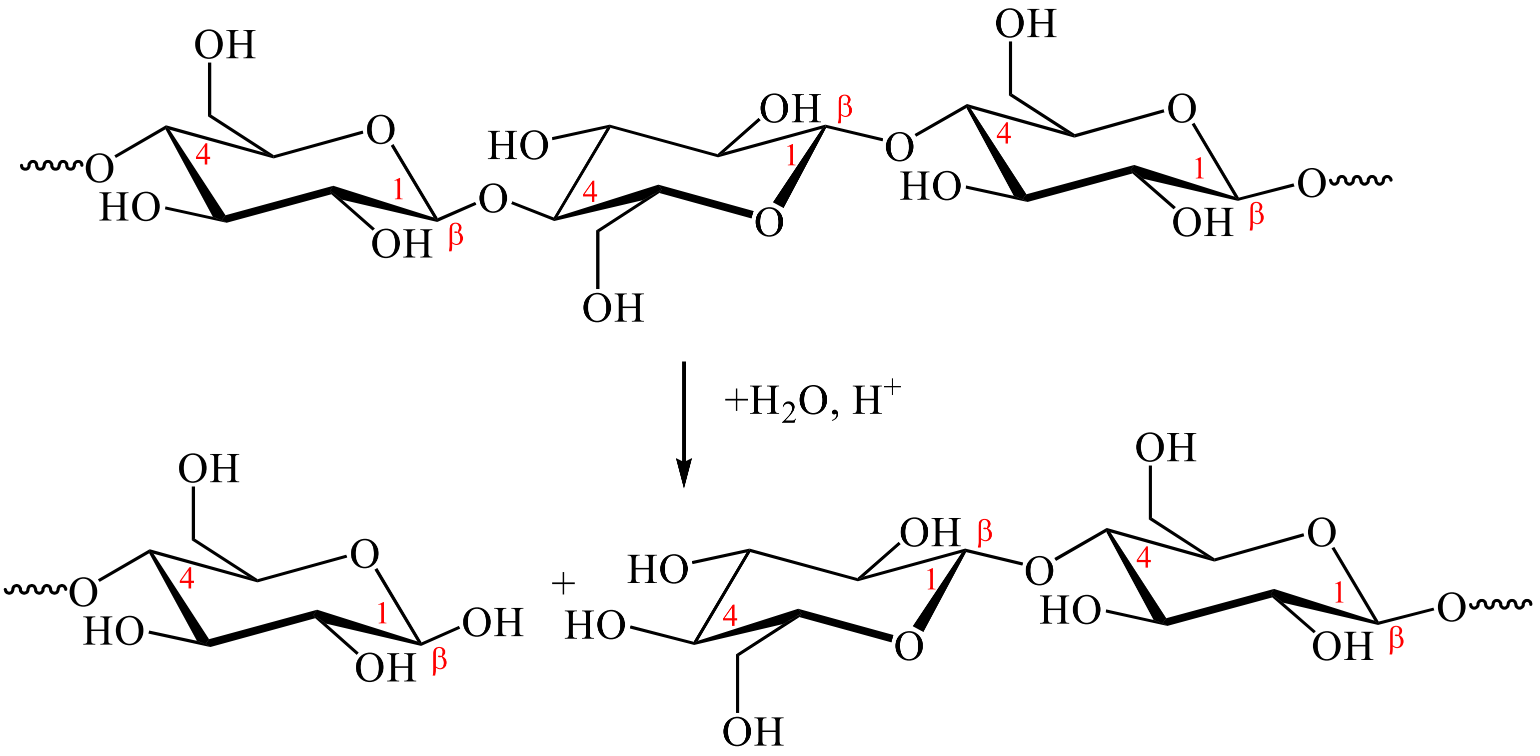
M. Hemmer, thesis, University of Karlsruhe, **2004**

The transformer consists mainly of the oil and bushings which contain the insulating paper. The degradation of the paper induced by water is a serious problem and can lead as a consequence to the transformer stopping.

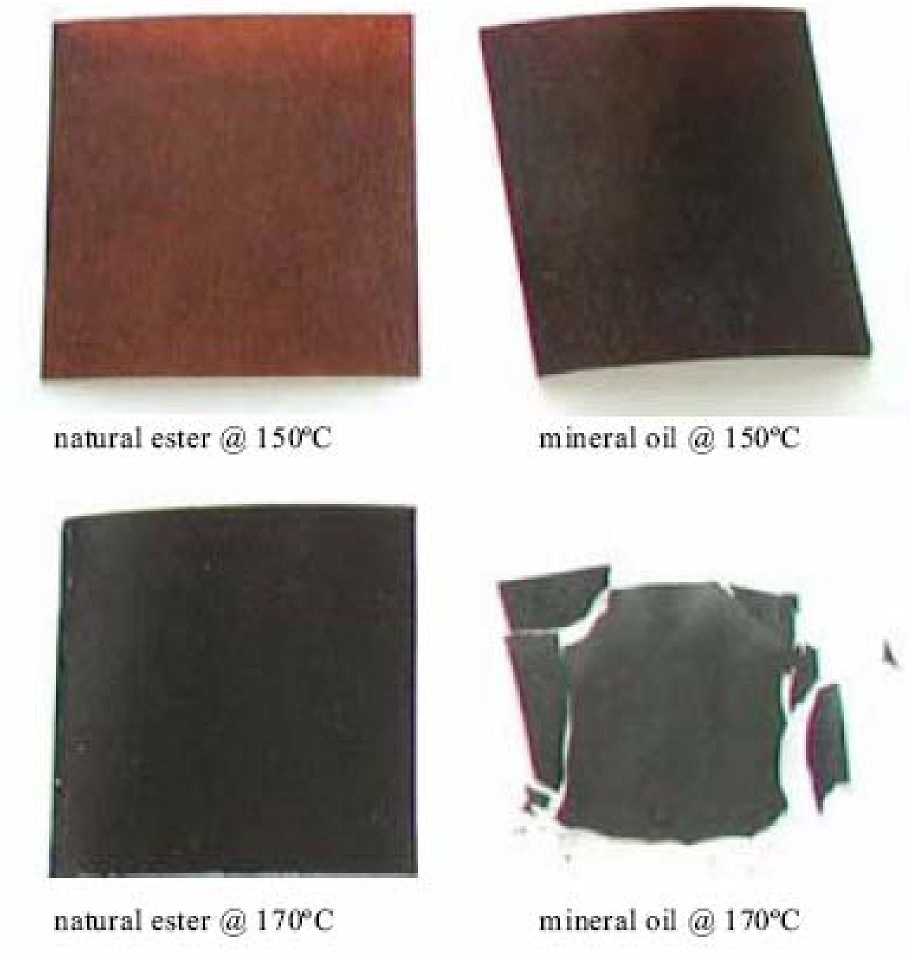




Degradation of cellulose in the presence of water

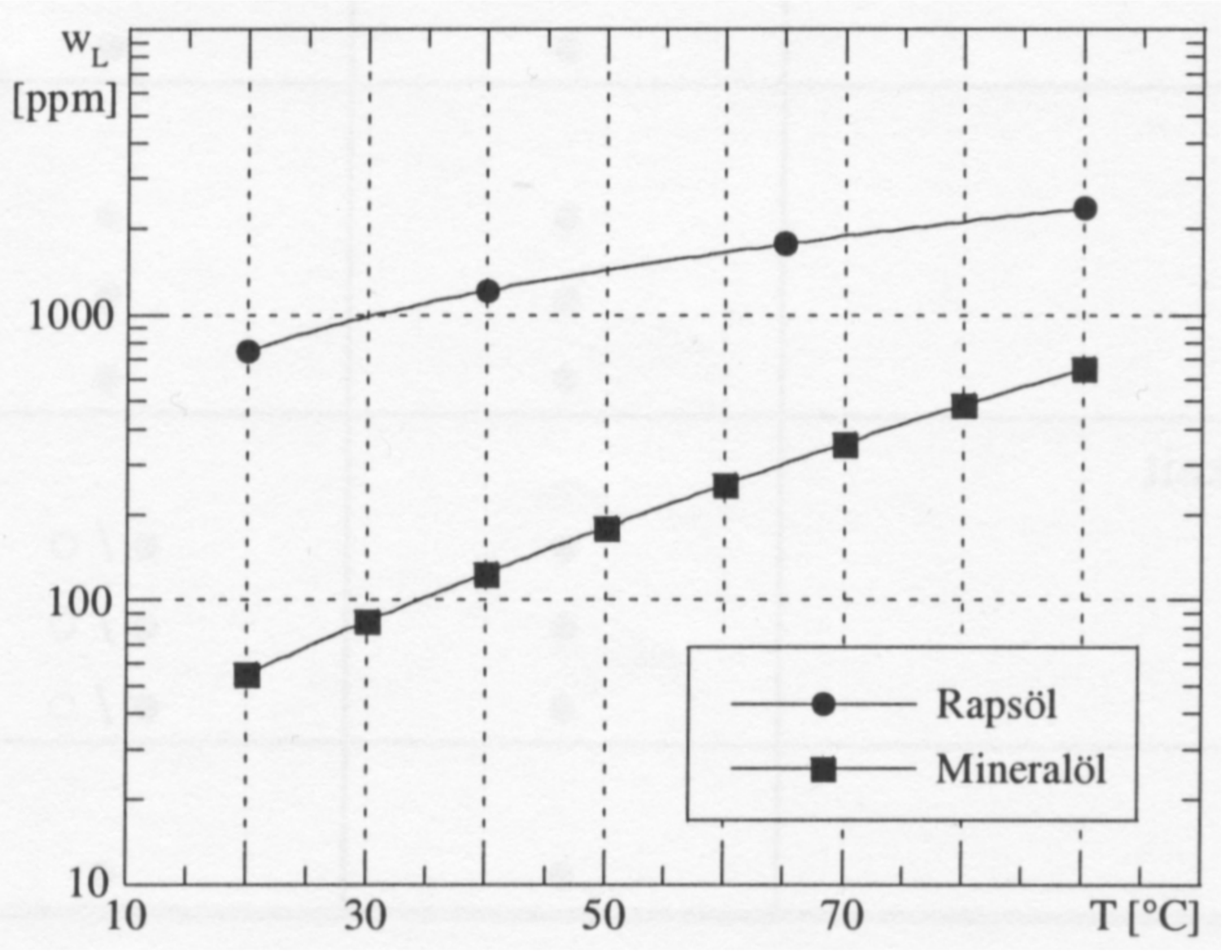


Thermally treated insulating paper after 4000h



C. P. McShane, K. J. Rapp, J. L. Corkran, G. A. Gauger, J. Luksich, *2001 IEEE/PES Transmission & Distribution Conference & Exposition, Oct. 28 - Nov. 02, 2001, Atlanta GA*

Water content as a function of oil temperature for rapeseed oil and mineral oil



M. Hemmer, thesis, University of Karlsruhe, **2004**

Advantages:

Renewable raw material, good biodegradability

High dielectric strength

High flash- and fire point

Low toxic risk

High water absorption

Disadvantages:

Moderate oxidative stability

High viscosity

High pour point, poor low temperature properties

Acknowledgement

We thank the EWE Foundation and the EWE for financial support of this work.