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BecFluid 9902 - a new ester based insulating liquid

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Introduction:

Electrical transformers are enabling cost efficient transportation and distribution of electrical energy over long distances. The inherent electrical energy losses throughout transformation process lead to heating up the iron core and the copper windings. To manage this thermal energy and to improve overall electric properties most of the transformers are still filled with mineral oil. During a long period there were a lot of substantial improvements made, but the chemical basis could not be changed. Aside the insulating and heat managing base properties of mineral oil are still the same, and can be described in the following sentences:

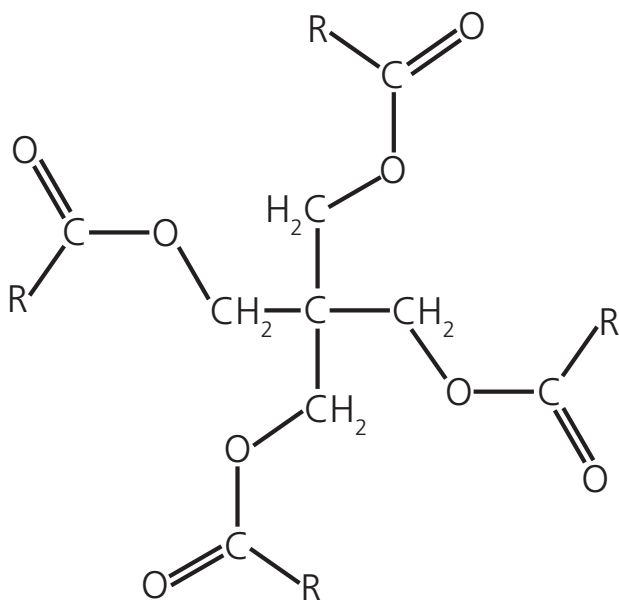
Mineral oil is toxic to living organisms and nearly not biodegradable in the environment. These facts cause a lot of additional costs in case of unexpected escape of the mineral oil into the environment and immense collateral damage to organisms.

In case of fire caused through an internal electrical failure by a shortcut or external fire the mineral oil burns heavily what makes fire fighting very difficult and dangerous and the following damages are immense.

Between these dramatic behaviour in case of faults there are other disadvantages known like corrosive sulphur, sludge formation and water insolubility.

In regard to these facts there are environmental regulations not only in protected regions which indicates to take a look at alternative insulating and cooling liquids.

BecFluid 9902 – a “new” cooling and insulating fluid



The first substitution used for mineral oil appeared in the 1930s with the introduction of chlorinated aromatic hydrocarbons such as polychlorinated biphenyls (PCB, Ascarel). These liquids were banned because in the case of fire there can highly poisoning dioxins and furans occur and escape to environmental, first most severe registered accident in Seveso, Italy. As an alternative to the PCBs there were developed silicones in the 1970s, followed in the 1980s by synthetic fluids such as polyalphaolefins (PAO) and polyolesters (POE)

offering a very high flash and fire points with less risks of environmental pollution.

The BecFluid 9902 is a polyolester based on pentaerythritol formulated for use in distribution, power and traction transformers and for hybrid technology. Its unique environmental, fire safety, chemical and electrical properties are advantageous versus conventional mineral oils. These excellent properties are well known since 30 years.

Performance

a) Fire Safety

The flashpoint is defined as the temperature where you can ignite the equilibrium vapour over a chemical substance from outside by e.g. open fire, electric arc, etc. At the fire point the vapour pressure of a substance and the generated initial energy is on a level where it is high enough for continuous burning.

In comparison to mineral oil BecFluid 9902 has a very high flash and fire point

	Unit	BecFluid® 9902	Mineral oil
Flash point	°C	274	160
Fire point	°C	303	170
Specific heat	J / kg · K	1816	1860
Heat of combustion	kJ / g	36,8	46,0

and is defined as a K-class fluid for use in transformers. Clearly the high fire point of the synthetic ester is the main reason for its resistance to ignition. Further results of ignition tests of mineral oil and synthetic esters have shown that the ester fluids have slower heating rate, another important factor. The low heating rate of BecFluid 9902 is due to the high specific heat and thermal conductivity of the fluid. During the exposition to the torch mineral oil is blackening after a short time. This indicates thermal decomposition with hard to define cleavage products. Synthetic Ester is after much longer exposure only slightly darkened showing that only minimal decomposition had occurred.

One of the most important aspects of the fire behaviour of a material is its tendency to produce smoke and toxic fumes, both of which can seriously hinder the escape of personnel to safety from a fire. In this respect transformer fluids based on PCB's displayed the worst possible characteristics. They are producing dense black smoke containing large amounts of corrosive and acidic hydrogen chloride (HCl) gas together with smaller quantities of highly toxic dioxins and furans. Fire tests with synthetic esters have shown that BecFluid 9902 would not contribute fumes any more hazardous than those already present in a fire, and that smoke emission would be minimal, much lower than that from mineral oil and askarels. The gases produced through a fire with synthetic ester liquids are comparable to wood fumes. Since BecFluid does not contain chlorine it cannot evolve dangerous hydrogen chloride gas or dioxins.

Synthetic Esters like BecFluid 9902 has been tested and approved by insurers and fire authorities for use in transformers located inside buildings and other critical areas without the need for special fire precautions.

b) Environmental & Health

In times of increased pressure on the environment it is in our responsibility to choose the most environmentally friendly materials available. BecFluid 9902 is a far better option than both mineral oil and silicone oil with regard to environmental protection.

BecFluid 9902 can be classified as readily biodegradable after OECD 301 test method. It satisfies the dual criteria of 60 % biodegradation occurring within 10 days of exceeding 10 % degradation, and at least 60 % degradation occurring by

day 28 of the test. In fact in the tests 99 % degradation had occurred after day 28.

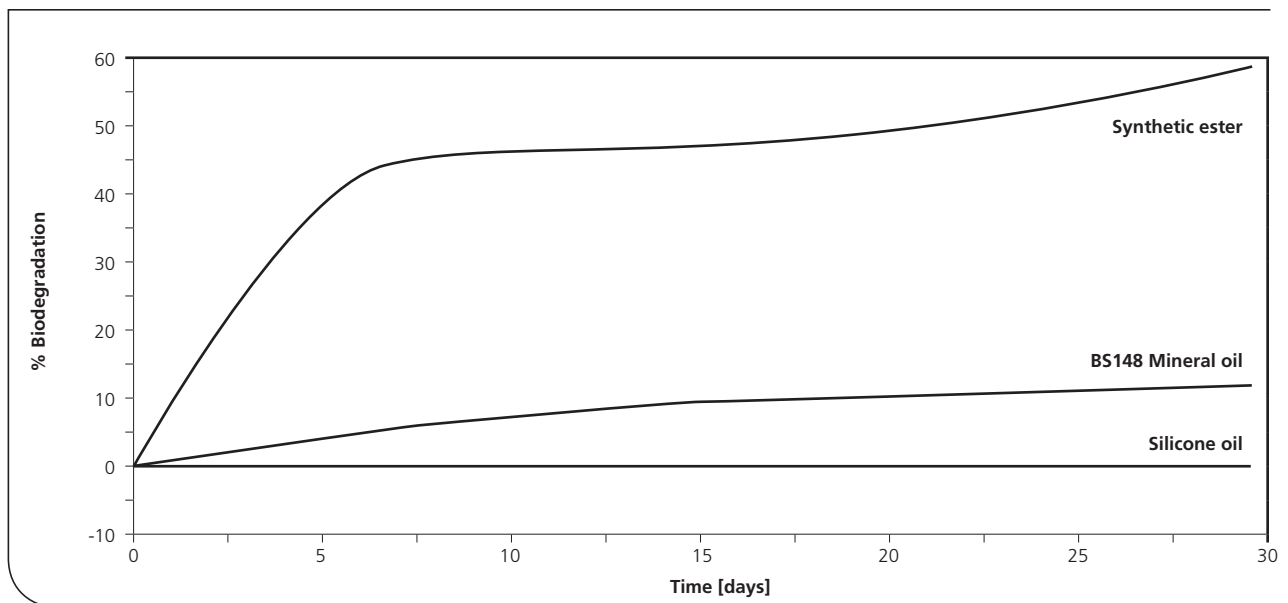
Not only is it important for a transformer fluid to be biodegradable, but it should not represent a hazard to the ecosystem in the short time it remains in the environment. In acute fish toxicity studies synthetic esters showed no mortality or other toxic effects to Rainbow trout and water fleas. In these tests were values measured, which would represent extremely high concentrations of fluid in watercourses and there is no acute risk to aquatic communities by BecFluid 9902 in the unlikely event of a spillage. Furthermore, a sustained gradual release of fluid from a leaking transformer is unlikely to result in concentrations of BecFluid in the water sufficient to create any problems to the aquatic life.

Biological sewage treatment plants use 'activated' or microbially active sludge to break down organic matter within sewage. Contaminating chemicals can destroy these microorganisms and a total cessation of the sewage treatment process may result. This is a very costly and time consuming problem for the sewage treatment industry and water companies act very stringently to avoid such contamination problems by imposing regulations, issuing prosecutions and ultimately fining guilty parties who are proved to be at fault. Mineral oils can reduce the degradation activity in biological treatment plants by destroying the microorganisms or by forming an oil film over them, thus preventing oxygen exchange and hence stopping the sewage breakdown process.

The activity of microbes in activated sludge is measured by their rate of respiration. Hence the behaviour of any potential microbe destroying contaminants can be measured by how the process of respiration is inhibited. In tests carried out by BASF in Germany, synthetic ester showed no effect on the respiratory inhibition of activated sludge up to concentrations of approximately 2000mg/l.

Such high concentrations of BecFluid 9902 are highly unlikely to occur in water or sewage systems and it can be concluded that synthetic esters does not represent a risk to biological treatment plants.

OECD 301D test on synthetic ester, Mineral oil and Silicone oil



Concern about the contamination of potable and ground-water supplies by industrial chemicals led to the setting up in 1976 of a specialist committee to advise the German Federal Ministry of the Interior on the handling, transport, storage and packaging of water endangering materials. The committee's task was to define the term 'water endangering materials' and to develop a procedure for the classification of such materials.

On the basis of the results of biological and ecotoxicological tests the commission maintains a register of validated water endangering materials.

BecFluid 9902 offers you a transformer fluid, which is biodegradable, non-toxic to aquatic life, will not affect the degradation activity of activated sludge in biological sewage treatment plants and has been evaluated as non-water hazardous by the German Federal Department of the Environment, Umweltbundesamt.

Where transformers are located in close proximity to rivers, canals, lakes, aquatic leisure facilities, sewage treatment works or any other sensitive environment, minimise the risk to that environment by choosing BecFluid 9902.

c) Moisture Tolerance

The presence of moisture in a transformer deteriorates transformer insulation by decreasing both the electrical and mechanical strength.

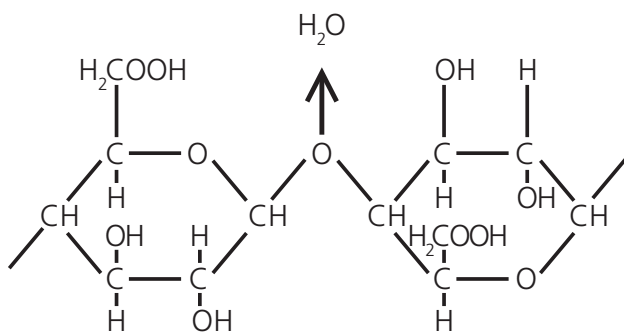
Mineral oils are non-polar substances leading to very low abilities in water uptake. BecFluid 9902 as a synthetic ester has a much higher ability to absorb water in a chemical way without compromising its dielectric properties.

In general, by doubling the water content the mechanical life of the insulation of mineral oil filled transformer is reduced by half. The rate of thermal deterioration of the insulating paper is proportional to its water content. Because of that

ester filled transformers can significantly reduce deterioration of the insulation of transformers.

Moisture inside transformers could appear from the ambient air, what could be controlled by using hermetically sealed transformers. Most of the distribution and power transformers are free breathing for cost reasons.

Water in paper may be found in four states: It may be adsorbed to surfaces, as vapour, as free water in capillaries, and as imbibed free water. Water is catalysing the ageing of cellulose and is an end product of the degradation of the cellulose:



The paper can contain much more moisture than mineral oil. The moisture content follows equilibrium curves shown in many technical publications, and depending on temperatures and local parameters.

Finally the water content is most evident for the electrical behaviour and the ageing of the insulation.

BecFluid 9902 will still be within specification up to a water content of 400 ppm in running transformers. In contrary, mineral oil will be out of specification above just 30 ppm water content. Small amounts of water in mineral oil cause a rapid deterioration in breakdown voltage. In contrary BecFluid 9902 maintains a high breakdown voltage even when moisture levels exceed 500 ppm.

Should the moisture content rise above the maximum in-service limit of BecFluid 9902, the same methods and equipment that are used for removing moisture from mineral oil can also be used e.g. molecular sieves, filtration units, etc.

Summary

Back to the main topic, the increasing costs for electrical energy can be reduced by using BecFluid 9902 as a new ester based insulating liquid in transformers.

- The working temperature can be raised because of the high fire point.
- The electrical losses through the transportation process can be decreased.
- There is no need for special fire precautions.
- Losses of transformers and damages through fire could be minimised.
- There are no restrictions because of environmental concerns.
- The storage and use of the ester liquid is much less dangerous and complicated.
- The life-time of transformers can be increased through significant reduced aging of the insulation.
- The electrical failures because of moisture content probably occur.
- The maintenance and monitoring costs can be reduced.
- BecFluid 9902 is fully miscible with mineral oil and can be used for retrofilling.

The good experience with synthetic ester since nearly 30 years and the superb properties should conclude to use BecFluid 9902.