Dielectric Fluids vs Mineral Oils in Electrical Cooling Applications

Part 2: Electrical and Fire Safety

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Introduction

Advanced heat transfer fluids, called Dielectric Fluids are helping today's thermal engineers lower temperatures, lower failure rates and longer service life. Dielectric Fluids are replacing standard mineral oils in both stationary and mobile cooling applications because of their exceptional stability, cleanliness and heat transfer characteristics.

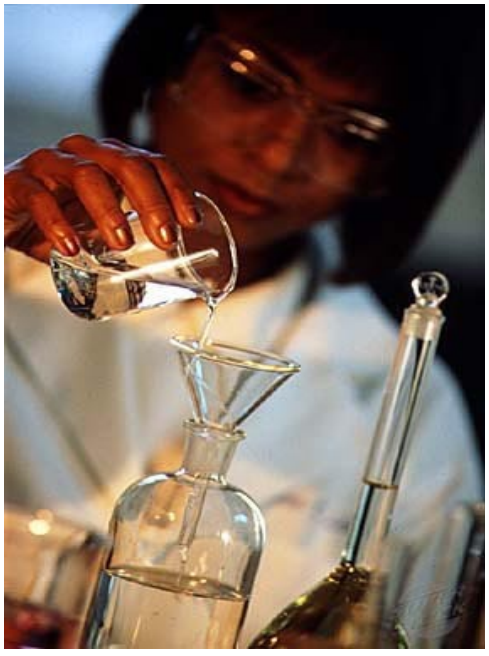
Direct contact, liquid phase cooling is a highly efficient and inexpensive way to cool electrical equipment.

We have over 100 years' experience in immersion cooling of electrical equipement. History has proven that direct contact, liquid phase cooling is a highly efficient and inxpensive means of cooling electrical equipment (1, 2) Direct contact liquid cooling systems are the simplest and least expensive to build and operate.

Dielectric Fluids

Dielectric Fluids have been developed in the last 15 years, through advances in base oil and additive chemistry. Dielectric Fluids, or DFs, are made from one or more low viscosity, high purity synthetic oils developed for automotive and aerospace applications. (3)

There are several types of synthetic oils used to blend DFs. These include isoparaffin, Poly Alpha Olefin (PAO) and synthetic esters and VHVI oils.



These base oils have a paraffinic molecular molecular structure that is very similar to that of a mineral oil, so they behave in similar ways.

Because these base oils are synthetic, they have a more narrow range of molecular species in each one, so they are almost homogeneous in their molecular makeup. This means that they exhibit better stability and material compatibility.

Figure One shows the difference between the number of different chemicals in mineral oil and a synthetic PAO base oil. The synthetic PAO shows sharp spikes, meaning very few different chemicals, while the mineral oil shows a wide variety of different molecular weights and chemical compounds. (4)

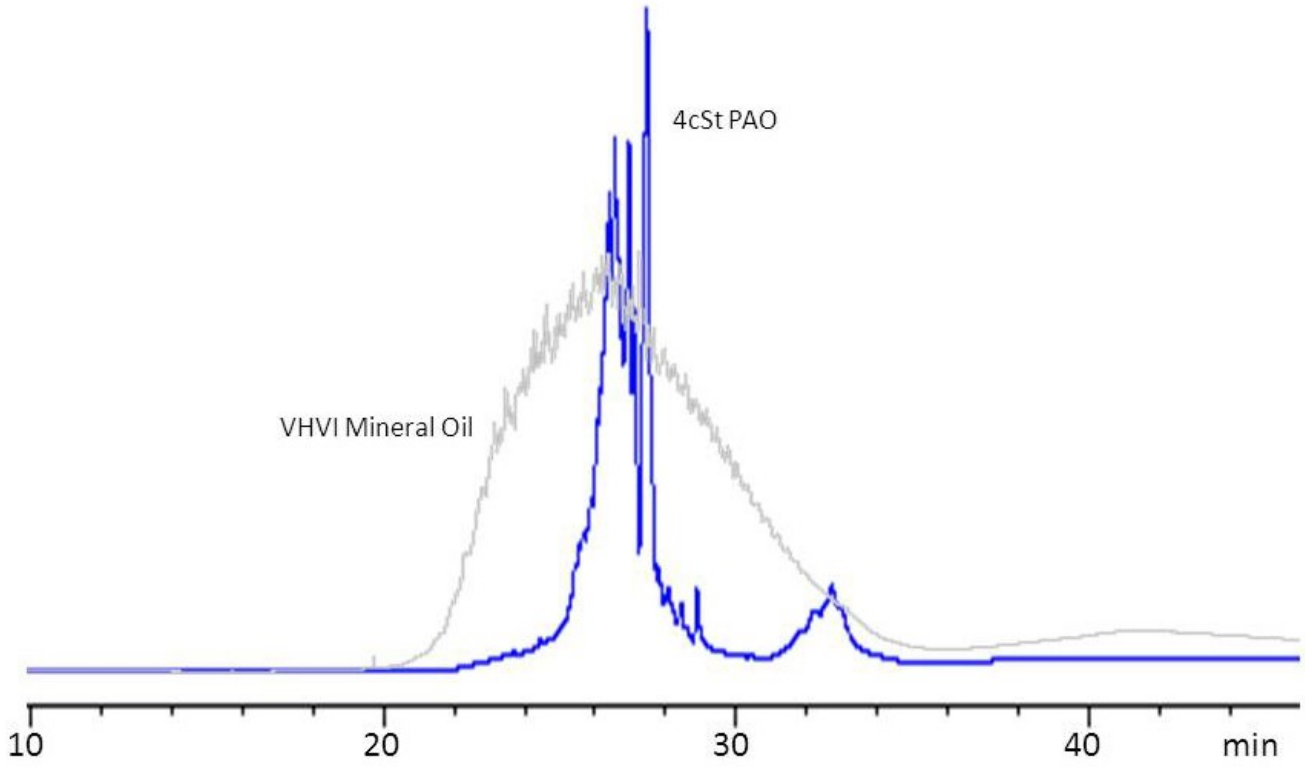


Fig. 1: Gas Chromatograph display that shows the wide variety of chemical species in a white oil, versus the narrow distribution in a synthetic PAO oil.

Base oils used in blending Dielectric Fluids were created by a chemical reaction, and as a result, they are far cleaner than mineral oils. This helps with issues such as oxidation resistance and material compatibility. Synthetic oils also have very low pour points because they don't contain waxes. This makes them ideal in applications at very low temperatures.

Dielectrics Are Not Just Synthetic Base Oils

While synthetic base oils, such as PAOs are chemically cleaner than petroleum, they are incomplete by themselves. Synthetic base oils have the same problems as petroleum oils in that they have not been processed, cleaned, dried, and are not fortified with any additives. These additives perform important functions of ensuring long term stability and resistance to oxidation.

Mineral Oils, Transformer Oils and White Oils

These are names for different types of petroleum. The term “mineral oil” can refer to base petroleum oils, without any additives, or to transformer oil, or a pharmaceutical white oil.

Mineral oils have been used as electrical cooling oils for many years, in distribution and power transformers.(5) Chemically, mineral oils are a mixture of many different types oils and contain impurities, such as metals, soaps and salts that pass through the refining process.

Commodity white oils and mineral oils do not contain any additives, and therefore have a lower resistance to oxidation and poorer compatibility with plastics and . White oils generally have physical characteristics similar to those of mineral oils.

Transformer oils are guaranteed to meet industry specifications, while “Base 80” and other mineral oils and white oils have no testing for electrical characteristics and are not guaranteed to meet important fire and electrical safety standards.

> *“Mineral oils and white oils are typically not tested and guaranteed to meet important fire and electrical safety characteristics.*

Eight Important Characteristics to Consider

There are eight important characteristics to consider when evaluating a heat transfer fluid in electrical cooling applications. They are:

- Heat Transfer Effectiveness
- Electrical Safety
- Flammability and Fire Safety
- Oxidation Stability
- Material Compatibility
- Worker Health and Safety
- Biodegradation and Environmental Fate
- Cost

This series of reports examines how Dielectrics compare with mineral oils in each of these important parameters. The first installment looked at heat transfer characteristics and thermodynamic analysis. This Second Installment will examine the electrical and fire safety of these new fluids.

Flammability and Fire Safety

As large tanks of dielectric fluid represent a significant source of fuel, the flammability characteristics of the fluids must be evaluated. As the voltages encountered in electronics cooling applications are usually low, the chance of an electrical arc being present as an ignition source are very small. Mineral transformer oil has been used in indoor distribution transformers located indoors for over 70 years (5) For these reasons, the flammability characteristics of standard mineral transformer oil (fire point > 145 C) is considered to be an acceptable minimum yardstick for heat transfer fluid in electronics cooling application.

With this in mind, a comparison of fire points for the different fluids under consideration is shown in Table 1.

Table 1: Flammability Characteristics

	Dielectric	White Oil	PAO	PETROLEUM BASE OIL
Fire Point, ASTM D92, degrees C.	160-200	130-150	140	140-180

* Values shown are typical for the type used.

Moisture Content and High Temperature Vacuum Processing

To a large part, the electrical characteristics of a dielectric fluid depends on its cleanliness. Removal of all polar material – water, particulate matter and polar contaminants improves the fluid's dielectric strength. The cleaner and more pure the coolant, the better the electrical characteristics will be.

Dielectric in Vacuum Degassifier

The best way to improve the electrical characteristics is to remove dissolved gases and moisture from the oil. This is done is by processing the oil at high temperature and high vacuum, then filtering the fluids to remove any small particulate contamination.

Table One shows moisture content for the fluids under study. Moisture Content is not typically specified or tested with these other oils. Only a finished dielectric fluid has been high vacuum processed to remove moisture dissolved gases and tested to meet industry standards.

Table One – Moisture Content of Dielectric Cooling Fluids
Specifications and Typical Values

Characteristic:	Dielectric Fluid	White Oil	PAO	Petroleum Base Oil
Moisture Content, Typical Production Values,	9 ppm	NOT TYPICALLY MEASURED		
Moisture Content, Industry Specification Values	35 ppm Maximum	NO SPECIFICATIONS		

Table Two - Moisture Content of Dielectric Cooling Fluids
as Tested[15]

Test Method	Dielectric Fluid	White Oil [12]	PAO [13]	Petroleum Base Oil [14]
Moisture Content, ASTM D1533(b)	12	40	29	31

Electrical Safety – Dielectric Breakdown Strength:

The Dielectric Breakdown Strength is critical to the efficiency of immersion cooling. This is the voltage that will cause a dielectric failure, leading to spark and the risk of fire.

Illustration 1: Dielectric Strength Testing of Coolant

The insulating character of a dielectric fluid allows direct immersion and intimate contact with hot components. Because of this electrical insulating ability, there is no need for heat pipes, indirect cooling, thermal pastes or any of the other inefficient workarounds that are used with conductive liquids, such as water or glycols. Each of these introduces inefficiency into the cooling design.

Table Two - Dielectric Strength of Dielectric Cooling Fluids

A) SALES SPECIFICATIONS

Characteristic:	Dielectric Fluid	White Oil	PAO	Petroleum Base Oil
Dielectric Strength, with hemispheric (VDE) electrodes ASTM D1816, (2mm gap)	56 kV minimum	NOT MEASURED		
Dielectric Strength Using Flat Disk Electrodes, 1 mm gap ASTM D877	30 kV minimum	NOT MEASURED		
Dielectric Strength, Industry Specification Values	56 kV minimum	NO SPECIFICATIONS		

B) DIELECTRIC STRENGTH AS TESTED [15]

Test Method	Dielectric Fluid	White Oil [12]	PAO[c] [13]	Petroleum Base Oil [14]
Dielectric Strength, with hemispheric (VDE) electrodes ASTM D1816, (2mm gap)	65	16	38	25

Summary:

This series compares the characteristics of Dielectric Fluids and mineral oils on eight key parameters for electronic heat transfer. Part One described how the lower viscosity and better Heat Capacity of Dielectrics offer a significant advantage in cooling performance when compared with mineral oils.

Part Two compares the difference in electrical and flammability characteristics of Dielectrics with those of mineral oils. One of the key differences is that Dielectrics have been processed to remove impurities, contain additives and have been tested and certified to meet international safety standards.

OptiCool Fluid ®

OptiCool Fluid® is an Dielectric Fluid manufactured by DSI Ventures, Inc. OptiCool has been used for over 15 years to cool electrical circuitry in motors, transformers, RF and microwave transmission devices and computer systems.

OptiCool Fluid is a colorless, odorless, food grade synthetic oil. It's biodegradable and non-toxic. OptiCool Fluid has extremely high heat transfer coefficients, making it ideal for removing heat from circuitry with high heat flux densities.

Contact DSI to find out more about OptiCool Fluid and its cooling applications.

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