

Dielectric Fluids vs. Mineral Oils in Motor Cooling Applications

Part 1: Heat Transfer Comparison

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Introduction

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

Studies have identified direct contact, liquid phase cooling as the most efficient and least expensive means of cooling electronics assemblies (1, 2) Direct contact liquid cooling systems are the simplest and least expensive to build and operate. They're not pressurized and don't need specialized pumps.



Dielectric Fluids

Dielectric Fluids have been developed in the last 15 years, through advances in base oil and additive chemistry. Dielectric Fluids ("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 molecular molecular structure 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)

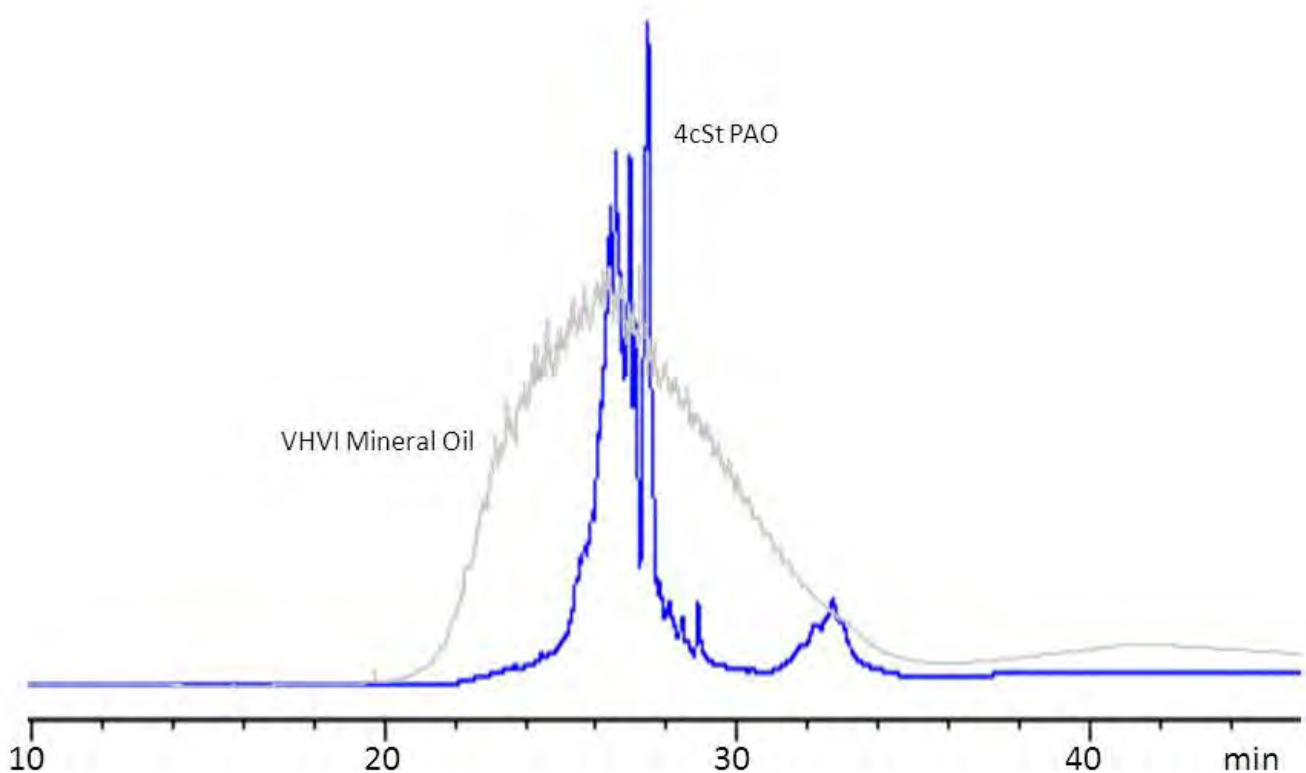


Fig. 1: Gas Chromatograph display that shows the wide variety of chemicals in a white oil, versus the narrow distribution of chemicals in a synthetic PAO oil.

Base oils used in blending DFs were created by a chemical reaction, and as a result, they contain very few impurities, compared with white oils or 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 any waxes. This makes them ideal in applications at very low temperatures.

Mineral and Transformer Oils

Mineral and Transformer Oils are made from refined petroleum. The term "mineral oil" can refer to base petroleum oils, without any additives, or a more highly refined transformer oil. Mineral oils are often referred to by other names, such as "pale oil" or "neutral 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.



Fig 2: Transformer Oil Used in Power Transformers

White Oils

"White Oil" is a special type of mineral oil that's undergone a refining process called "hydrotreating". Hydrotreatment removes many of the impurities found in refined products. White oils are often used in cosmetics and as medicine, but because of their clarity, wide availability and lower cost, have been tried as heat transfer fluids, also.

Like mineral oil, white oils do not contain any additives, and therefore have a lower resistance to oxidation. White oils generally have physical characteristics similar to those of mineral oils.



Figure 3, a commercially available white oil

Eight Important Characteristics to Consider

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

- Heat Transfer Effectiveness
- Electrical Insulating Properties
- Oxidation Stability
- Lubricity
- Material Compatibility
- Worker Health and Safety
- Biodegradation and Environmental Fate
- Cost

This series of reports will look at how Dielectrics compare with mineral oils in each of these important parameters. We'll start with Heat Transfer Effectiveness of the two oils

Heat Transfer Effectiveness

As form factors become smaller, heat density rises and the importance of excellent heat transfer effectiveness becomes more and more important.

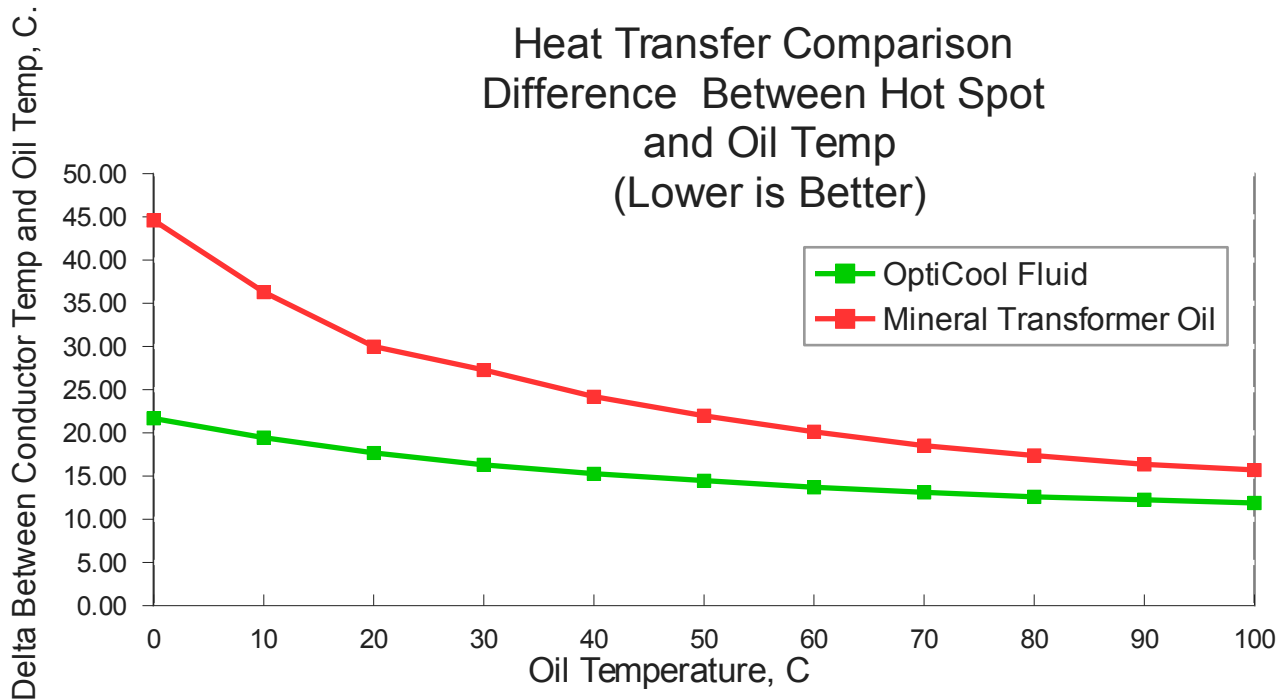
Heat transfer efficiency in a motor or electronic cooling application is a function of the characteristics of the cooling medium and the design of the cooling system. Many physical characteristics of the fluid are functions of temperature and fluid flow path. Whether the fluid flow is laminar or turbulent depends on viscosity (itself a function of temperature), the shape of fluid flow channels and the profile (the "smoothness") of the walls of the flow channels.

...A fluid's viscosity exerts the largest effect on its cooling performance. The lower, the better.

Prior studies (7,8,9) have investigated the relationship between different fluid characteristics and the effect that these characteristics have on cooling performance. A fluid's viscosity exerts the largest effect on its cooling performance. The lower, the better. Models have been developed that allow thermal engineers to change the application parameters and immediately see the predicted effect on cooling performance. They also allow a comparison of the relative performance of different

fluids in a given system. Iterative analysis allows design engineers to change the fluid path architecture and flow patterns so that heat transfer is optimized.

The graph below shows the difference in heat transfer capabilities of Dielectric Fluid (OptiCool Fluid®) and transformer oil in a closed system. In this system, the oil passes through ducting, over a 200 watt heat source component, 2x2 inches in size, removing the heat for later release to the atmosphere. Performance in this test is scalable in both directions. (Data developed in study shown in Reference 7)



This graph demonstrates heat transfer effectiveness by calculating the difference in temperature between a hot component and the bulk of the heat transfer fluid, after the entire system has come to a thermal equilibrium. A lower differential value indicates that as the fluid passes over the hot spot, it picks up enough energy that its temperature almost reaches that of the hot spot itself. A less efficient fluid will not pick up as much heat in the system, and the differential temperature will be greater. With a more efficient fluid, the entire system can be smaller and lighter.

...With a more efficient fluid, the entire system can be smaller and lighter...

Note that at all temperatures, the OptiCool Fluid maintains the lowest differential between the hot spot temperature and the fluid's temperature. The difference between the cooling performance of OptiCool Fluid and the other oils is more pronounced at lower temperatures. Note also the relatively stable viscosity of the Dielectric fluid as temperatures range from 0 to 100 degrees Celsius.

In this particular equipment design, when the oil temperature is 80 degrees C., the benefit of cooling with the Dielectric Fluid is approximately 8 degrees C. when compared with using a mineral oil. That is, the temperature of the hot component will be approximately 8 degrees lower when being cooled with Dielectric Fluid. Other equipment designs show similar results.

A newer cooling prediction model has been developed that allows engineers to change dimensions and heat input of the heated surface area, and compare the heat transfer coefficients of different fluids.

Figure Two compares the Heat Transfer Coefficients developed in these newer models. We can see the same pattern of heat transfer ranking between the different fluids, again driven by the viscosity. Between similar chemistries of heat transfer fluids in liquid phase contact cooling, the fluid with the lowest viscosity will be the most efficient.

Figure Two
Comparison of Heat Transfer Coefficients

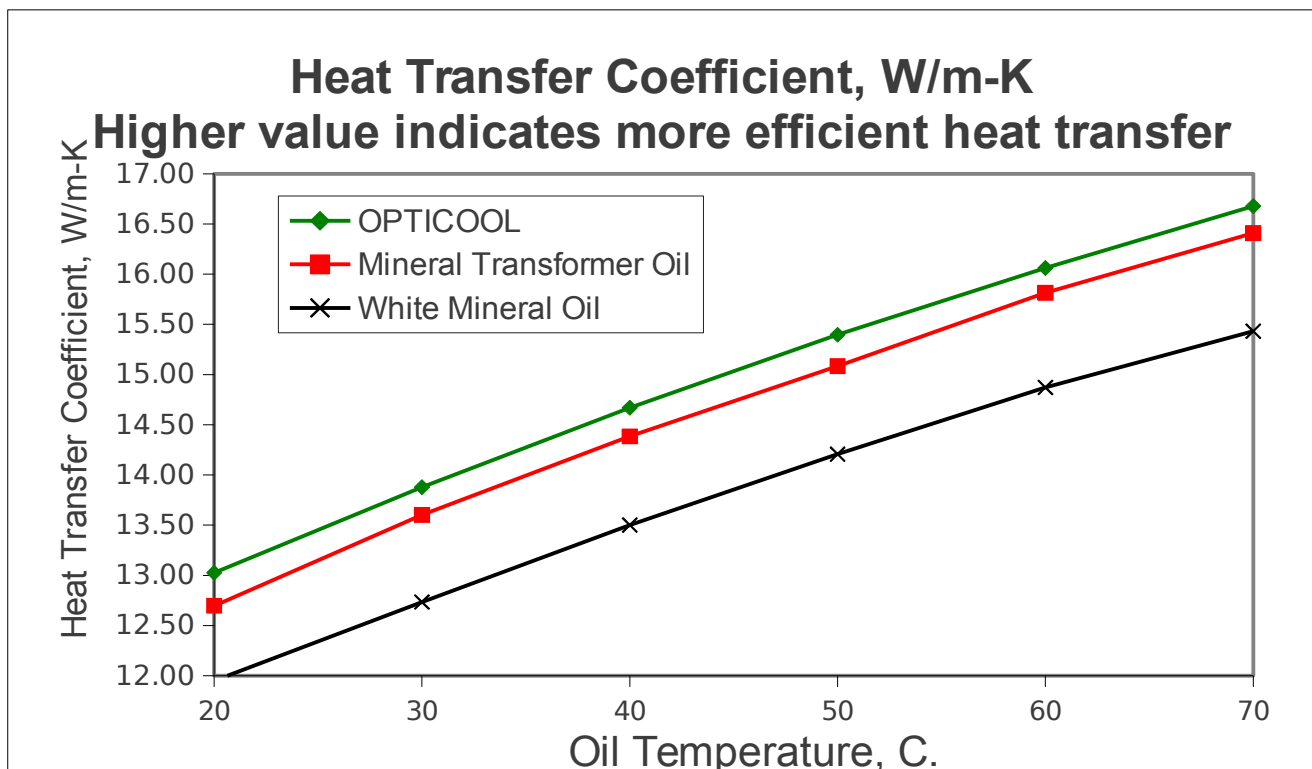
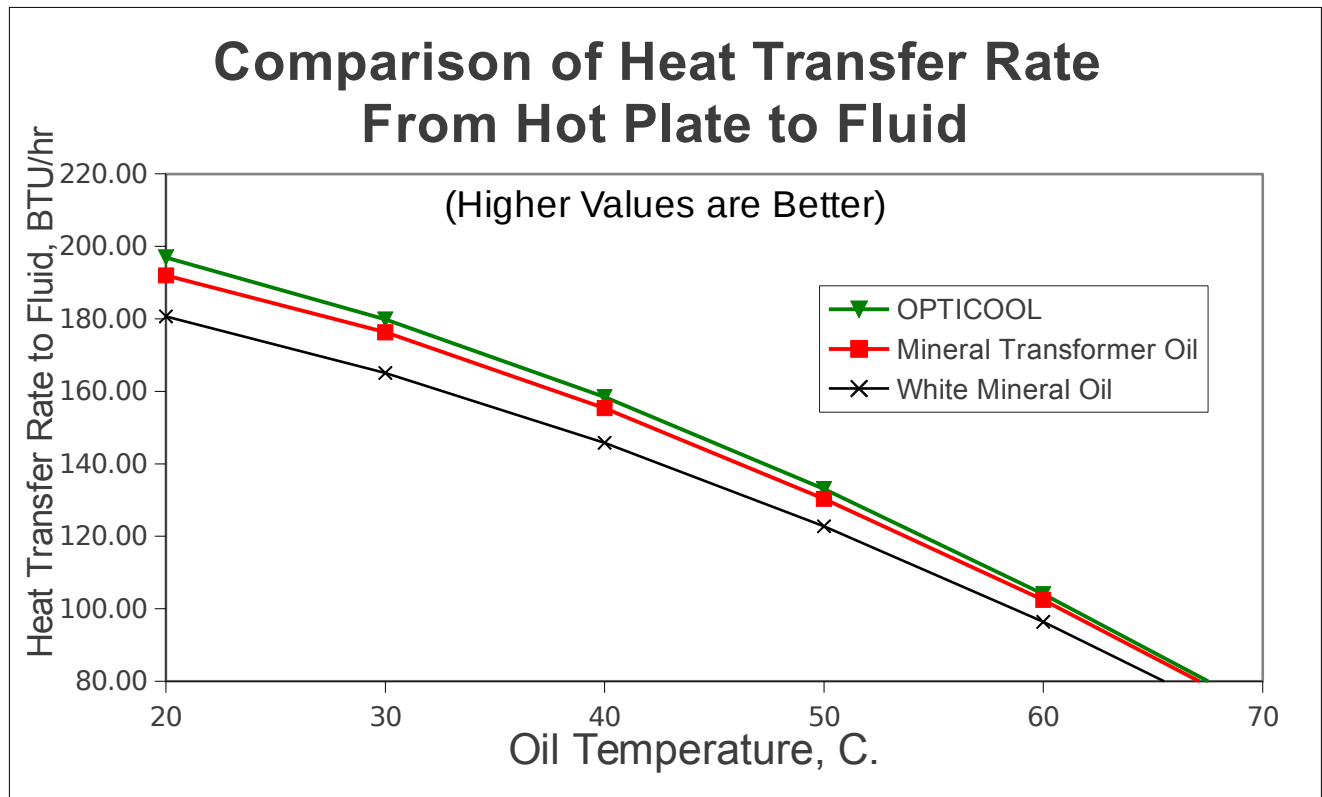


Figure Three shows Q , the rate of heat transfer from the plate to the liquid, given in BTU/hour, as the fluid temperature approaches the temperature of the plate. As before, differences are more pronounced with higher fluid viscosity at lower temperatures.

Figure Three



A more in-depth analysis of heat transfer characteristics of various fluids is given in the references (9).

Summary:

This study is a comparison of the characteristics of Dielectric Fluids and mineral oils on eight key parameters for electronic heat transfer. Part One introduced Dielectric Fluids and mineral oils, and described their chemical foundation and processing steps. A comparison of heat transfer effectiveness shows that the lower viscosity and better Heat Capacity of Dielectrics offer a

significant advantage in cooling performance when compared with mineral oils. Electronic circuits are cooled more efficiently with the Dielectric Fluids.

...Electronic circuits are cooled more efficiently with the Dielectric Fluids...

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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