SUBMERGEDEEP®

A MULTIFUNCTIONAL HEAT TRANSFER AND HYDRAULIC FLUID FOR MARINE ELECTRIC VEHICLES

Dr. David Sundin, Engineered Fluids, Inc.

ABSTRACT

ROVs for deep sea applications are required to operate in the harshest conditions on earth in terms of pressure, temperature, and environment. ROVs rely entirely on batteries, electric motors, and hydraulic actuation for their powertrain and manual actuators. In addition to pressure compensation, these components require water intrusion protection, thermal management, and highly reliable hydraulic power transfer fluids.

The use of traditional hydraulic fluids in these applications has unfortunately resulted in significant exposure-related health issues for operation and maintenance personnel, as well as the introduction of hazardous oil pollution to sensitive marine environments. This article examines the use of an entirely new type of synthetic multifunctional fluid to meet the requirements of ROVs pressure compensation / electrical insulation / thermal management / hydraulic fluids that provide higher operational performance, while eliminating the health and environmental issues posed by traditional formulations.

BACKGROUND

In the last two decades, there have been rapid developments in electric battery and motor technology, leading to the adoption of electric drivetrains in ROVs and marine vehicles in general. Requirements for lubricants and coolants are being reevaluated with an eye towards consolidation of the number of different types of fluids used.

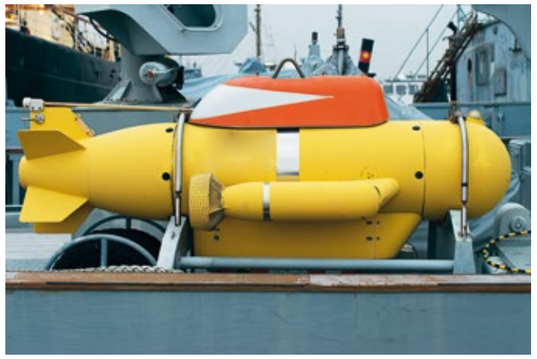
Research into battery and electronics cooling has shown that Single-phase Liquid Immersion Cooling (SLIC) technology is an efficient and safe thermal management approach for a wide variety of electrical devices. SLIC technology refers to moving heat from hot electronics or motors with an electrically insulating fluid, then cooling the fluid somewhere else.

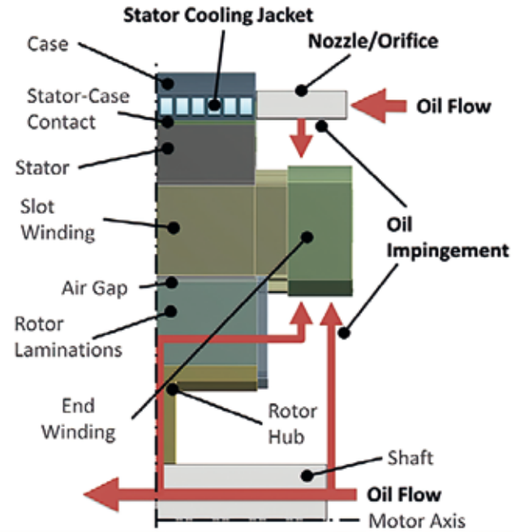
Hot electrically live components are fully immersed in a dielectric liquid coolant. The components are cooled through low pressure circulation of dielectric coolant through and around electronics or motors, then dumping waste heat using liquid-to-liquid or liquid-to-air heat exchangers. Using an electrically insulating fluid eliminates the need for any insulation between the electrically-live motor and electronics and the fluid itself. As liquids are about 2,000 times more efficient at moving heat than air, power-dense systems can be easily cooled with SLIC technology.

PROLIFERATION OF FLUID TYPES

ROVs and other Marine Electric Vehicles (MEVs) use battery coolants, motor coolants, charging cable coolants, hydraulic fluids, pressure compensation fluids and lubricants in various applications on each vehicle. One of the problems that this has brought about is the proliferation of different types of fluids in today's vehicles. Reduction in the number and weight of different fluids is especially important in the case of marine applications. Some of the applications for different functional fluids in ROVs are:

BATTERY COOLING – as batteries are charged and discharged, they generate heat. The faster that this charge/discharge cycling occurs, the more heat is generated. However, electric batteries operate efficiently in a narrow temperature band. To maximise battery performance and life, it's important to keep the temperature within this band. Cooling batteries by immersing them in an electrically insulating fluid has been proven to be one of the most efficient means of keeping batteries in the desired temperature range.





MOTOR COOLING – high torque DC motors are used in EV powertrains. Traditionally, these motors have been lubricated with recirculating motor oils, hydraulic fluid, or Automatic Transmission Fluid. Environmental regulations are expected to increase demand for highly biodegradable, non-toxic alternatives.

ELECTRONICS COOLING – Electronics assemblies on board MEVs are now smaller but have increased power capacity. Today's Marine EVs have several assemblies of power-dense electronics components that require advanced thermal management.

HYDRAULIC POWER TRANSFER – One of the largest volume applications for a functional fluid in marine vehicles is for hydraulic fluid. ROVs use hydraulic pumps and cylinders to engage directional changes and movement of external arms, grippers, and sensors. Functional requirements of hydraulic fluids are not expected to change, but regulatory demands are moving the industry towards the use of highly biodegradable, non-toxic base oils.

PRESSURE COMPENSATION – ROVs and other deep-sea equipment need a way to compensate for the tremendous hydraulic pressure that can be encountered in subsea applications. This can be done by strengthening the external housing or by flooding the EV with a noncompressible fluid to compensate for the external pressure.

HYDRAULIC FLUID APPLICATION

As hydraulic fluids have represented the largest volume of any single type of functional fluid on MEVs to date, there have been efforts to use them to perform the job of other functional fluids. Obviously, for lubrication of hydraulic pumps and cylinders, hydraulic fluids perform well. They have shortcomings, however, when used in battery, electronics, and motor cooling, or as a pressure compensation fluid. Hydraulic fluids' low dielectric strength limits their application as electronics coolants. The zinc and phosphorous-containing additives that hydraulic fluids typically use are not only toxic but can cause a variety of health problems with workers. "Touching some hydraulic fluids may cause weakness in the hands or burns to the skin depending on the chemical make-up of the fluid."

Electrically, hydraulic fluids have poor resistivity and low dielectric strength, preventing their use as nonconductive fluids for cooling electronics, batteries, or charging systems. The petroleum base oils used typically contain sulfur, which attacks electrical circuit boards and are too highly compressible to be used in pressure-compensation applications.

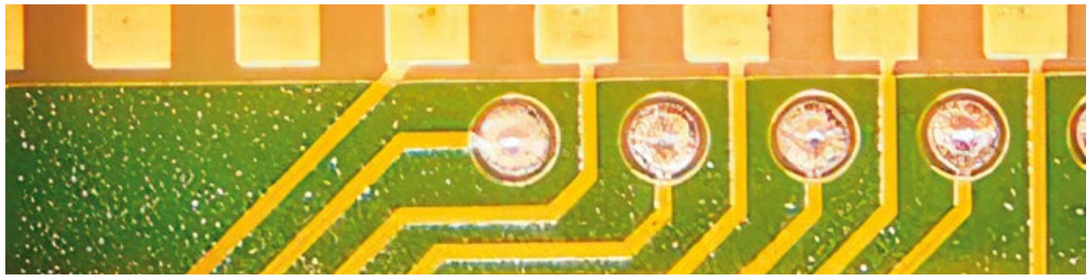
MODERN CHEMISTRIES YIELD NEW MULTIFUNCTIONAL FLUIDS

Recently, the use of more modern raw materials with newly discovered chemical reaction pathways led to the development of fluids with multipurpose functionality. In 2020, researchers succeeded in the development of noncompressible, electrically insulating hydrocarbon molecule with enhanced lubricity characteristics. This molecular structure can be used to make fluids that have characteristics that, until now, were considered antagonistic to one another; impossible to exist within a single chemical.

In 2022, SubmergeDeep* was introduced by Engineered Fluids, Inc., as an example of a Multifunctional Fluid specifically made for Marine Electric Vehicles. SubmergeDeep, a non-toxic, biodegradable dielectric heat transfer fluid acts as a coolant, an electrical insulator, a pressure-compensation fluid, and as a hydraulic fluid.

The comparison shows that SubmergeDeep has advantages over a typical hydraulic fluid in many applications:

- A lower viscosity, combined with higher thermal conductivity means that SubmergeDeep is more efficient with respect to heat transfer. This means that lower fluid volumes and fluid flowrates are required to maintain the motors at their optimum operating temperature.
- High flash and fire points of SubmergeDeep add a significant margin of safety against fire and explosion.
- Higher dielectric strength allows SubmergeDeep coolants to be used in SLIC applications where electrically live components are submerged directly into the coolant fluid.
- Absence of zinc and phosphorous-based additives means that SubmergeDeep does not cause skin allergies and health problems often associated with these chemicals in hydraulic fluids.
- Lower pour point allows SubmergeDeep to remain fluid at lower temperatures.
- A higher biodegradation rate is better for our environment in case of a spill.



CONCLUSION

Electric powertrain improvements have led to the development of electrified ROVs and MEVs in the last decade, which have different requirements for functional fluids than vehicles powered by combustion engines. One of these requirements is cooling a variety of electrical components (motors, batteries, charging systems, electronics, etc.). The most efficient way to cool live electrical components is with SLIC Technology, where the hot component is immersed in the flow of a dielectric fluid.

Hydraulic fluid has been used for many of the functional fluid applications on ROVs and MEVs, but their poor electrical properties have limited their application in cooling electrical parts. In addition, hydraulic fluids have problems meeting modern HES (Health, Environmental and Safety) requirements. Electrical insulating oils, on the other hand, have traditionally not had the lubricity and antiwear properties required to be used in hydraulic systems. In addition, their material compatibility profile made them unsuitable for use with many hydraulic pumps.

A new class of Multifunctional Fluids has been developed, which can be used as both a dielectric coolant as well as a hydraulic fluid. These hydrocarbon liquids have an excellent HESprofile. They also have sufficient anti-wear functionality to protect hydraulic systems while retaining excellent electrical characteristics. SubmergeDeep, a product line of Multifunctional Fluids is now being used commercially in MEVs in place of hydraulic fluids. SubmergeDeep is the first product that can be used in both hydraulic and thermal management systems, as well as acting as a deep-sea pressure compensation fluid.