



## Introduction to Fluids Employed in SprayCool Products

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### **ABSTRACT**

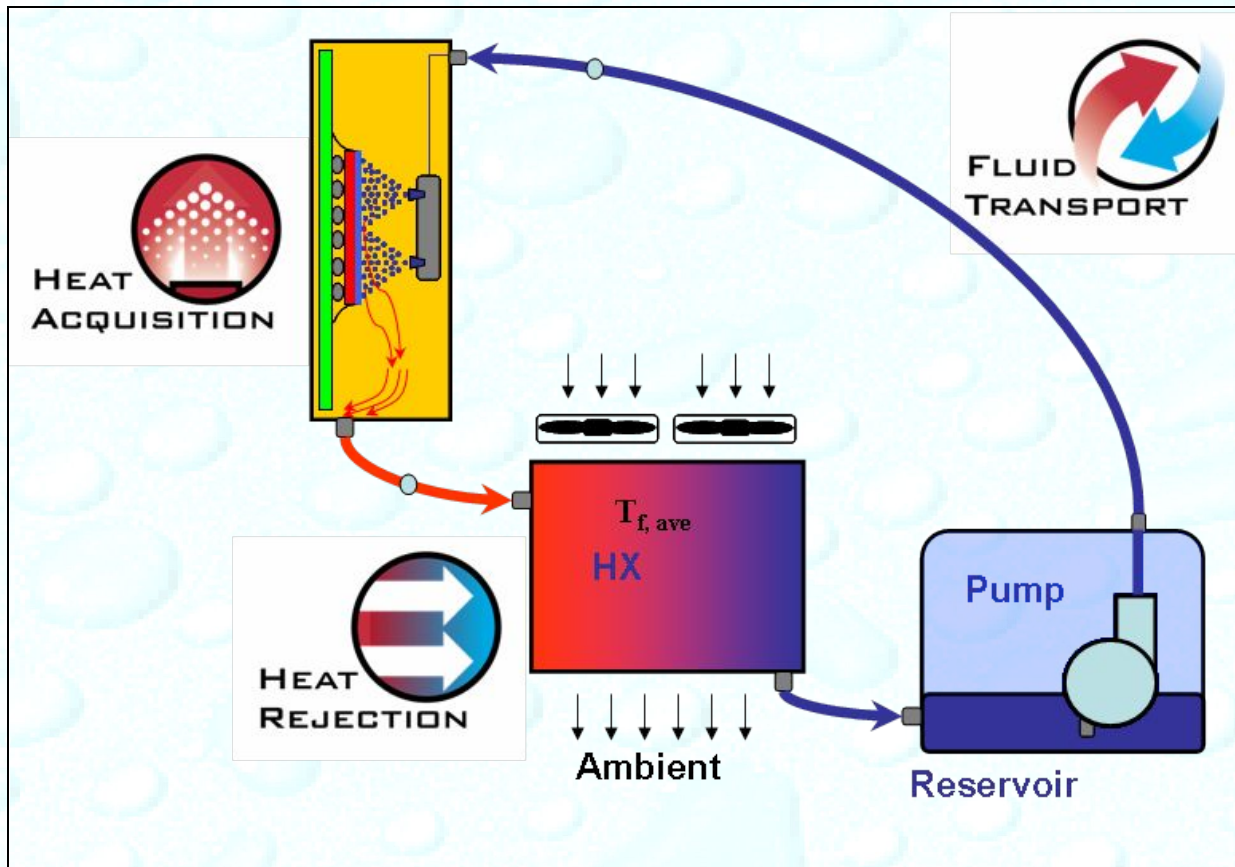
Liquid cooling has been around for many years both in industry and military alike. Rising heat density in electronics at a rate consistent with Moore's Law creates even more interest in liquid cooling today. While liquid cooling offers many advantages thermally, there is a general unfamiliarity with the fundamentals of fluid properties, safety and material handling. This paper will introduce heat transfer fluids used by SprayCool for electronics cooling applications. Sources for fluid information provided by the OEM are also provided.

*Keywords: SprayCool, electronics cooling, Fluorinert, heat transfer fluids*

### **BACKGROUND**

SprayCool products utilize evaporative or direct spray, in which liquid droplets are sprayed directly onto the hot electronic components and then evaporate to remove excess heat. Depending on the system configuration, either liquid or a liquid-vapor mixture is transported to a heat exchanger where remaining vapor is condensed and waste heat is rejected. Thus, the fluid is continuously recycled for reuse within a closed cycle system as shown in Figure 1. The heat exchanger can be mounted with the electronics or remotely located to reject to any medium such as ambient air, PAO, EGW, PGW, fuel, ram air, etc. SprayCool uses Fluorinert® by 3M as the primary working fluid. Fluorinert is an electrically insulating, inert perfluorocarbon fluid which is used in many heat transfer applications. Other fluids such as 3M's Novec brand fluids are being evaluated by SprayCool, but are not in use at the present time. Water mixtures can also be used for indirect spray applications such as sealed transit cases or power electronics.

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**Figure 1 SprayCool System Diagram**

SprayCool enclosures enable the dielectric liquid/vapor environment to remain very close to the saturation temperature of the fluid, resulting in an “isothermal” environment for the electronics. This isothermal environment effectively reduces hot spots and thermal cycling, as well as providing increased cooling efficiency.

The result of reduced thermal mechanical stresses and lower operating temperatures, compared to other cooling methodologies, is increased reliability and higher achievable power density. SprayCool therefore plays a pivotal role in the design of high reliability, high performance embedded electronic systems. In many applications of SprayCool products, significant Space Weight, and Power (SWaP) improvements have been demonstrated using dielectric fluids. Platform level tradeoffs will not be discussed in this paper, but can be found on the SprayCool website ([www.spraycool.com/whitepapers....](http://www.spraycool.com/whitepapers....)).

## **FLUORINERT BRAND FLUIDS**

Fluid selection is critical in direct spray enclosures for multiple reasons: Boiling point, thermal properties, material compatibility, inertness, handling, safety and of course dielectric properties. Perfluorocarbon fluids have been used for over 50 years in electronics applications and are commonly employed in electronics cooling today. A [Thermal Management overview](#) is available on the 3M website with general information about all fluids available directly from the OEM.

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3M's Fluorinert brand fluids offer several options for boiling points that coincide with ideal component temperatures, such as FC-72, and FC-84. Another brand with similar properties is Performance Fluid (PF) -5060 and PF-5070, also from 3M. Currently, all SprayCool products use 3M dielectric heat transfer fluids. 3M provides information on Fluorinert Brand fluids at the following website: [3M Fluorinert Product Page](#). 3M has also published a document including frequently asked questions on topics ranging from compatibility to reclamation more specifically addressing [Heat Transfer Applications](#).

## Fluid Properties

The fluid properties of most interest to heat transfer applications are specific heat, latent heat of vaporization, dielectric strength and boiling point. Fortunately, there are OEM data readily available on these properties. Table 1 provides links to OEM fluid properties on respective products.

Fluid	Boiling Point	Product Information
FC-72	56°C	<a href="#">Data Sheet</a>
FC-84	80°C	<a href="#">Data Sheet</a>
PF-5060	56°C	<a href="#">Data Sheet</a>
PF-5070	80°C	<a href="#">Data Sheet</a>

**Table 1** Datasheet links on 3M fluids

Most SprayCool enclosures utilize the higher boil point fluids such as FC-84 and PF-5070. The ambient conditions of the application determine the fluid selection more than single factor. As the ambient temperatures rise beyond the boiling point of the fluid, the internal pressure of the SprayCool system increases. SprayCool enclosures are not intended to be high pressure vessels, so a higher boiling fluid would be selected to reduce pressure. Similar evaluation is necessary for low temperature operation.

In general, for storage or operational ambient temperatures below -25°C or above 40°C the fluid of choice is FC-84. For more benign environs, FC-72 has slightly better thermal properties and is therefore the preferred fluid.

## Safety and Handling

The best source for safety and handling information is the manufacture, 3M. The documents referenced in Table 1 provide a general overview of the handling and precautions of perfluorocarbons. Table 2 includes links to the Material Safety Data Sheet (MSDS) for each fluid containing more detailed information. In general, the perfluorocarbon fluids are very stable and safe to use in most environments.

Fluid	Boiling Point	Product Information
FC-72	56°C	<a href="#">MSDS</a>
FC-84	80°C	<a href="#">MSDS</a>
PF-5060	56°C	<a href="#">MSDS</a>
PF-5070	80°C	<a href="#">MSDS</a>

**Table 2** MSDS links on 3M fluids

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With the ability to be highly oxygenated and harmless to the human body, Fluorinert has been used as a blood plasma substitute. Comparing the MSDS of household shampoo it is obvious that Fluorinert is even less harmful to the human body than shampoo because it doesn't irritate the eyes and can be swallowed as shown in Table 3.

<b>Product</b>	<b>FC-84</b>	<b>Shampoo</b>
Emergency Overview	N/A	N/A
Potential Health Effects	None	None
Eye Contact	No irritation	<b>Mild irritation</b>
Skin Contact	No irritation	No irritation
Inhalation	No effects	No effects
Ingestion	No effects	No effects
First Aid Procedures		
Eye Contact	Flush with water	Flush with water
Skin Contact	Wash with Water	Wash with Water
Inhalation	Get to fresh air	Get to fresh air
If Swallowed	No action required	<b>Call Doctor or Poison Control</b>
Flammable Properties	N/A	
Extinguishing media	<b>Will not burn</b>	Water
Protection of Fire Fighters	<b>Wear Bunker gear</b>	None
Unusual Fire and Explosive Hazards	<b>None/Decomposition</b>	None
Accidental Release Measures	Ventilate, contain, dispose	Contain, dispose
Handling	No Smoking, Use ventilation	<b>Avoid contact with eyes</b>
Storage	Store away from heat	Store away from heat
Engineering Controls	Provide local exhaust	Provide local exhaust
PPE		
Eye/Face Protection	Safety glasses	Industrially - goggles
Skin Protection	Wear Gloves	Industrially - gloves
Respiratory Protection	For Normal use: None	None
Stability	Stable	Stable
Hazardous Decomposition	<b>PFIB, HF Extreme Heat &gt;200C</b>	<b>Carbon Monoxide, Carbon Dioxide</b>
Disposal Considerations	Reclaim or incinerate	Reclaim or dispose
RCRA	Not regulated	Not regulated
Fire Hazard	None	None
Pressure Hazard	None	None
Reactivity Hazard	None	None
Immediate Hazard	None	None
Delayed Hazard	None	None
NFPA	<b>Health 3, 0 on others</b>	Not Stated
HMIS	0 on all	0 on all

**Table 3** Comparison of Fluorinert and shampoo

The creation of harmful decomposition byproducts from thermal breakdown of Fluorinert is a common concern. While many tests have been conducted by various independent labs such as NASA, the only formal statement on thermal breakdown is from 3M. From the PF-5060 and PF-5070 MSDSs listed in Table 2, the following statement is provided in section 10 of each respective document:

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*“NOTE: 200°C is the recommended temperature limit for a system's entire fluid charge during continuous operation. In certain systems/applications designed to operate below 200°C, small portions of the fluid charge may exceed this temperature for brief periods, for example, during failure of immersed electronics. In such applications, thermal decomposition is often insignificant or its effects easily mitigated with in situ fluid treatment.*

*In air filtration or "scrubber" applications, airstreams containing fluid vapors may be deliberately heated above 200°C. In such applications, the fluid residence time is short and oxygen gas (known to suppress the formation of PFIB) is present. Under these conditions, significant thermal decomposition is not observed and the safety of perfluorocarbon fluids is well established.”*

To date, no use cases expose an entire SprayCool system to 200°C continuously; furthermore, in the 20 year history of SprayCool, no decomposition byproduct has been generated by SprayCool customers. Thermal decomposition materials are almost impossible to create because the SprayCool enclosure depends on small amounts of air (oxygen) to prevent cavitation in the pumping system. In spite of this unlikely event, SprayCool's lab and field fluid handling tool has filters designed to capture decomposition byproducts such as PFIBs.

## **Distribution**

Global procurement, service and support of all heat transfer fluids is provided by 3M at any of their distribution sites worldwide. All of the contact information is available on the product pages, datasheets and FAQs documents presented in the text, Table 1 and Table 2. SprayCool can also provide small quantities of fluid when necessary in the United States.

## **Summary**

Ever increasing demand for performance in embedded electronics drives many to consider liquid cooling. Understanding of the fluids used for such applications is critical for consumers to make educated product decisions. 3M has been a global leader in heat transfer fluids such as Fluorinert for decades. Product information is readily available on fluid properties, safety and handling as well as distribution channels.