

3M™ Thermal Management Fluids



# Cool Under Fire

Dielectric heat transfer fluid solutions  
for military and aerospace applications

**3M**

## Mission-Critical Performance

The widespread adoption by both military and civilian procurement agencies of COTS (Commercial Off-The-Shelf) electronics has created a unique set of thermal management challenges for designers of advanced systems. Liquid cooling technologies are often required to meet these challenges.

Whether the application is indirect or direct contact, single phase or evaporative, 3M fluids are ideally suited for use as cooling media in demanding applications. 3M fluids are nonflammable, evaporate cleanly in case of spills and maintain low viscosity and high heat transfer efficiency over a wide operating temperature range.

As the complexity and sophistication of electronic systems for defense and aerospace applications continues to grow, so do the challenges of managing heat generated by these systems.

From the dense circuitry of today's advanced avionics and electronic countermeasures devices to the tightly-packed power electronics of commercial fly-by-wire systems, more and more heat is being confined to ever-smaller spaces. Removing this waste heat is critical, to help ensure battlefield survivability and to maintain reliable performance in extreme environments – from gritty desert heat to the icy vacuum of outer space.

3M™ Novec™ Engineered Fluids and 3M™ Fluorinert Electronic Liquids are unique dielectric materials used to solve a wide range of thermal management challenges. For example, 3M fluids can help reduce component bulk and weight; simplify design; and ensure system reliability, by eliminating the need for fans and cold plates in many applications.

These clean, colorless, high dielectric strength, chemically inert fluids also offer a number of important advantages over other dielectric coolants such as PAO (polyaliphatic olefins) and silicate esters, including:

- More efficient heat transfer properties (see table on page 3)
- Low toxicity, non-irritating
- Non-flammable and non-combustible
- Stable at temperatures up to 300°C
- Maintain low viscosities at temperatures down to -80°C
- Low latent heat of vaporization. This is an important consideration, because in the event of a leak, oil-type coolants trap dirt, and are difficult to clean up. 3M fluids evaporate quickly and completely, leaving no residue. Due to the fact they are inert, 3M heat transfer fluids will not interfere with the operation of other devices, should a leak or spill occur.
- Inert to common and even dissimilar metals.
- Compatible with all hard polymers and a variety of common elastomers
- Will not hydrolyze or degrade over time to form deposits that can occlude fluid passages

3M offers a broad range of thermal management fluids and technical support. Our experts are available to help you choose the right thermal management fluid to improve reliability, address environmental concerns, and lower your overall operating costs. Customers have used our products in many applications, including transformer, radar and computer cooling.



## 3M™ Thermal Management Fluids Properties

### 3M™ Novec™ Engineered Fluids

	Unit	Novec 7000	Novec 7100	Novec 7200	Novec 7300	Novec 7500	Novec 7600
Boiling Point	°C	34	61	76	98	128	131
Pour Point	°C	-122	-135	-138	-38	-100	-98
Molecular Weight	g/mol	200	250	264	350	414	346
Critical Temperature	°C	165	195	210	243	261	260
Critical Pressure	MPa	2.48	2.23	2.01	1.88	1.55	1.67
Vapor Pressure	kPa	65	27	16	5.9	2.1	0.96
Heat of Vaporization	kJ/kg	142	112	119	102	89	116
Liquid Density	kg/m <sup>3</sup>	1400	1510	1420	1660	1614	1540
Coefficient of Expansion	K <sup>-1</sup>	0.0022	0.0018	0.0016	0.0013	0.0013	0.0011
Kinematic Viscosity	cSt	0.32	0.38	0.41	0.71	0.77	1.1
Absolute Viscosity	cP	0.45	0.58	0.58	1.18	1.24	1.65
Specific Heat	J/kg-K	1300	1183	1220	1140	1128	1319
Thermal Conductivity	W/m-K	0.075	0.069	0.068	0.063	0.065	0.071
Surface Tension	mN/m	12.4	13.6	13.6	15.0	16.2	17.7
Solubility of Water in Fluid	ppm by weight	~60	95	92	67	45	410
Solubility of Fluid in Water	ppm by weight	<50	12	<20	<1	<3	<10
Dielectric Strength, 0.1" gap	kV	~40	~40	~40	~40	~40	~40
Dielectric Constant @ 1kHz	–	7.4	7.4	7.3	6.1	5.8	6.4
Volume Resistivity	Ohm-cm	10 <sup>8</sup>	10 <sup>8</sup>	10 <sup>8</sup>	10 <sup>11</sup>	10 <sup>8</sup>	10 <sup>10</sup>
Global Warming Potential	GWP	420	297	59	210	100	700

For test methods and variability, contact 3M Technical Service

### 3M™ Fluorinert™ Electronic Liquids

	Unit	FC-3284	FC-72	FC-84	FC-770	FC-3283	FC-40	FC-43
Boiling Point	°C	50	56	80	95	128	155	174
Pour Point	°C	-73	-90	-95	-127	-50	-57	-50
Molecular Weight	g/mol	299	338	388	399	521	650	670
Critical Temperature	°C	161	176	202	238	235	270	294
Critical Pressure	MPa	1.94	1.83	1.75	2.47	1.22	1.18	1.13
Vapor Pressure	kPa	35	30	11	6.6	1.4	0.43	0.19
Heat of Vaporization	kJ/kg	105	88	90	86	78	68	70
Liquid Density	kg/m <sup>3</sup>	1710	1680	1730	1793	1820	1850	1860
Coefficient of Expansion	K <sup>-1</sup>	0.0016	0.0016	0.0015	0.0015	0.0014	0.0012	0.0012
Kinematic Viscosity	cSt	0.42	0.38	0.53	0.79	0.75	1.8	2.5
Absolute Viscosity	cP	0.71	0.64	0.91	1.4	1.4	3.4	4.7
Specific Heat	J/kg-K	1100	1100	1100	1038	1100	1100	1100
Thermal Conductivity	W/m-K	0.062	0.057	0.060	0.063	0.066	0.065	0.065
Surface Tension	mN/m	13	10	12	15	15	16	16
Solubility of Water in Fluid	ppm by weight	14	10	11	14	7	<7	7
Solubility of Fluid in Water	ppm by weight	<5	<5	<5	<5	<5	<5	<5
Dielectric Strength, 0.1" gap	kV	>40	>40	>40	>40	>40	>40	>40
Dielectric Constant @ 1kHz	–	1.9	1.8	1.8	1.9	1.9	1.9	1.9
Volume Resistivity	Ohm-cm	10 <sup>15</sup>	10 <sup>15</sup>	10 <sup>15</sup>	10 <sup>15</sup>	10 <sup>15</sup>	10 <sup>15</sup>	10 <sup>15</sup>

For test methods and variability, contact 3M Technical Service

For discussion on GWP, refer to additional content in this brochure.

### 3M™ Novec™ 649 Engineered Fluid

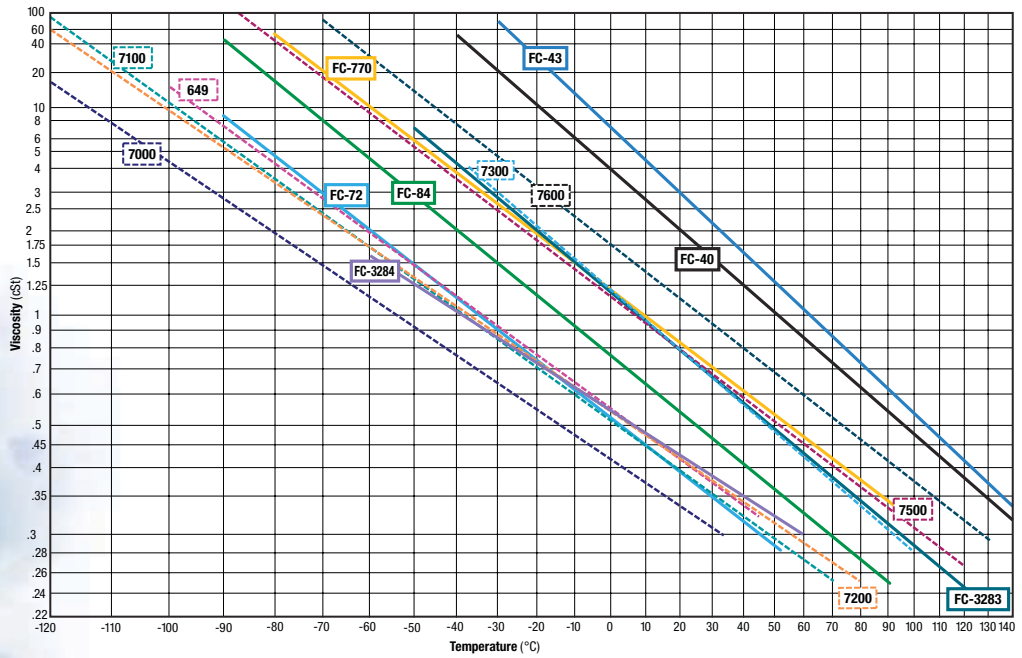
	Unit	Novec 649
Boiling Point	°C	49
Pour Point	°C	-108
Molecular Weight	g/mol	316
Critical Temperature	°C	169
Critical Pressure	MPa	1.88
Vapor Pressure	kPa	40
Heat of Vaporization	kJ/kg	88
Liquid Density	kg/m <sup>3</sup>	1600
Coefficient of Expansion	K <sup>-1</sup>	0.0018
Kinematic Viscosity	cSt	0.40
Absolute Viscosity	cP	0.64
Specific Heat	J/kg-K	1103
Thermal Conductivity	W/m-K	0.059
Surface Tension	mN/m	10.8
Solubility of Water in Fluid	ppm by wt	20
Dielectric Strength, 0.1" gap	kV	>40
Dielectric Constant @ 1kHz	–	1.8
Volume Resistivity	Ohm-cm	10 <sup>12</sup>
Global Warming Potential	GWP	1

Novec 649 fluid is an advanced heat transfer fluid with the lowest Global Warming Potential (GWP) in the Novec family. It belongs to a new class of fluoroketone fluids which are being explored for their use in thermal management applications such as direct and indirect heat transfer systems and Organic Rankine Cycle (ORC) systems.

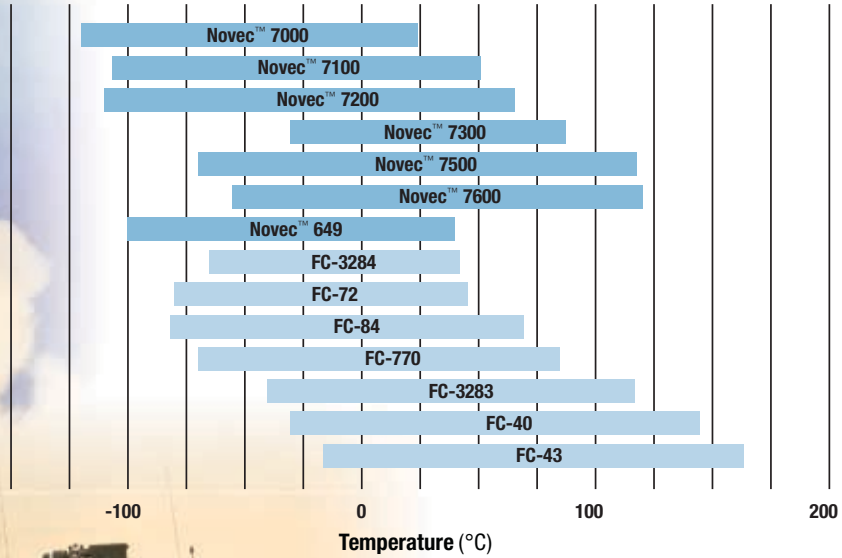
3M heat transfer fluids, sold under the 3M™ Novec™ Engineered Fluids and 3M™ Fluorinert™ Electronic Liquids brands, are available in a wide range of boiling points (34°C up to 175°C) and freezing points (-38°C down to -138°C), to meet your specific requirements.

# 3M™ Thermal Management Fluids Kinematic Viscosity

Viscosity vs. Temperature



Recommended Operating Temperature Range\*



\* For pumped single phase systems.



## 3M™ Novec™ Engineered Fluids

3M™ Novec™ Engineered Fluids are a family of low-Global Warming materials designed to deliver on the Novec promise of safe, sustainable chemistry.

### Performance

Novec Engineered Fluids have excellent properties for heat transfer applications:

- Excellent dielectric properties
- Wide range of boiling points
- Good materials compatibility

These fluids require little maintenance and offer dependable performance. They have high resistivity and will not damage electronic equipment or integrated circuits in the event of a leak or other failure.

### Environmental profile

Novec Engineered Fluids also offer favorable environmental and worker safety properties:

- Low toxicity
- Nonflammability
- Low Global Warming Potential (GWP)
- Zero Ozone Depletion Potential (ODP)

The chemical inertness and non-corrosivity of Novec Engineered Fluids offer workers more safety in handling, while the favorable environmental properties provide a reduced footprint for both today's and tomorrow's world.

### The next generation of heat transfer fluids

In heat transfer applications, Novec Engineered Fluids offer the best of both worlds. These fluids balance high performance with favorable environmental and worker safety properties to deliver the safe, reliable thermal management you need.

The favorable environmental, health and safety properties of Novec fluids also make them a long-term, sustainable solution. Novec fluids have been recognized by a number of industry and regulatory bodies around the world, including 3M™ Novec™ Engineered Fluids 7100 and 7200 being approved for "use without restriction" under the U.S. EPA's Significant New Alternatives Policy (SNAP).



Direct contact cooling with 3M™ Novec™ Engineered Fluids helped enable development of dense electronics, such as supercomputers, traction inverters and spray cooled modules.

Safe  
Reliable  
Sustainable  
Chemistries



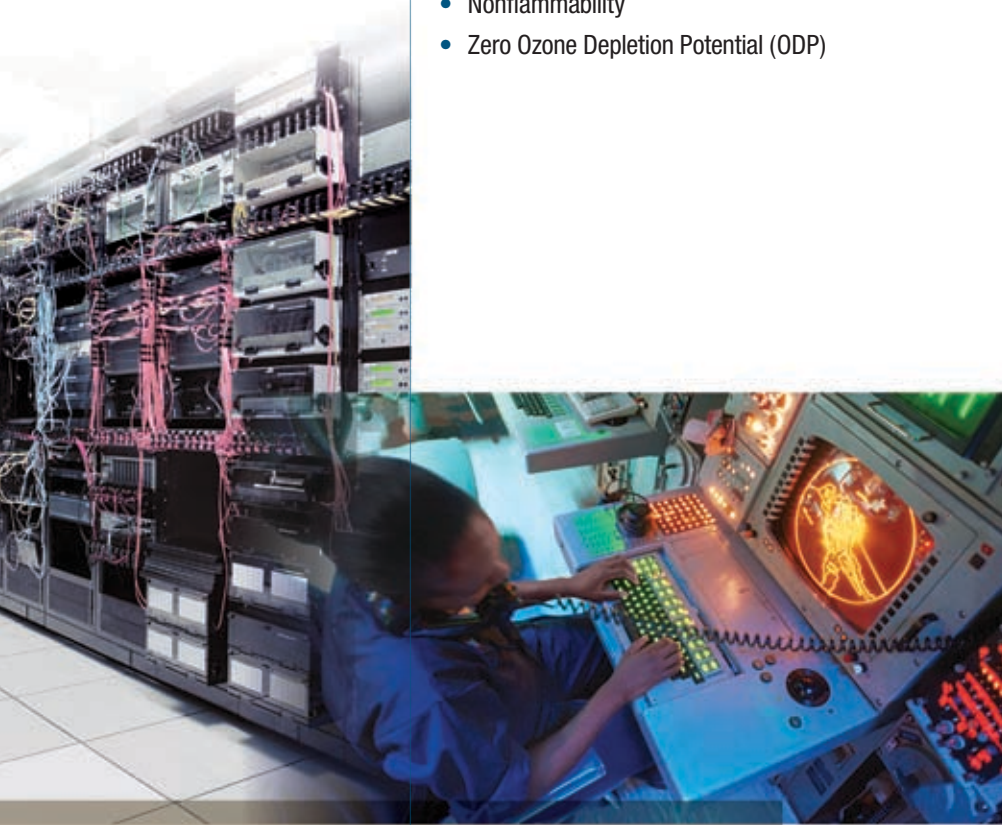
## 3M™ Fluorinert™ Electronic Liquids

3M™ Fluorinert™ Electronic Liquids are part of a family of fully-fluorinated compounds known as perfluorocarbons, or PFCs. Fluorinert liquids are premier heat transfer fluids, and have long been used as heat transfer media for extreme cooling applications in the military.

Proven in over 50 years of service in demanding military and aerospace applications, Fluorinert liquids offer:

- Excellent dielectric properties
- Wide range of boiling points
- Good materials compatibility
- Low toxicity
- Nonflammability
- Zero Ozone Depletion Potential (ODP)

While they are non-ozone depleting, high-performance Fluorinert liquids do have high global warming potentials (GWP) and long atmospheric lifetimes. Due to the atmospheric properties of PFCs, these materials are used in applications that, due to very unique performance requirements, cannot use a Novec fluid. When PFCs are necessary, users must take care to carefully manage and minimize emissions.



# More Options

## Material Compatibility

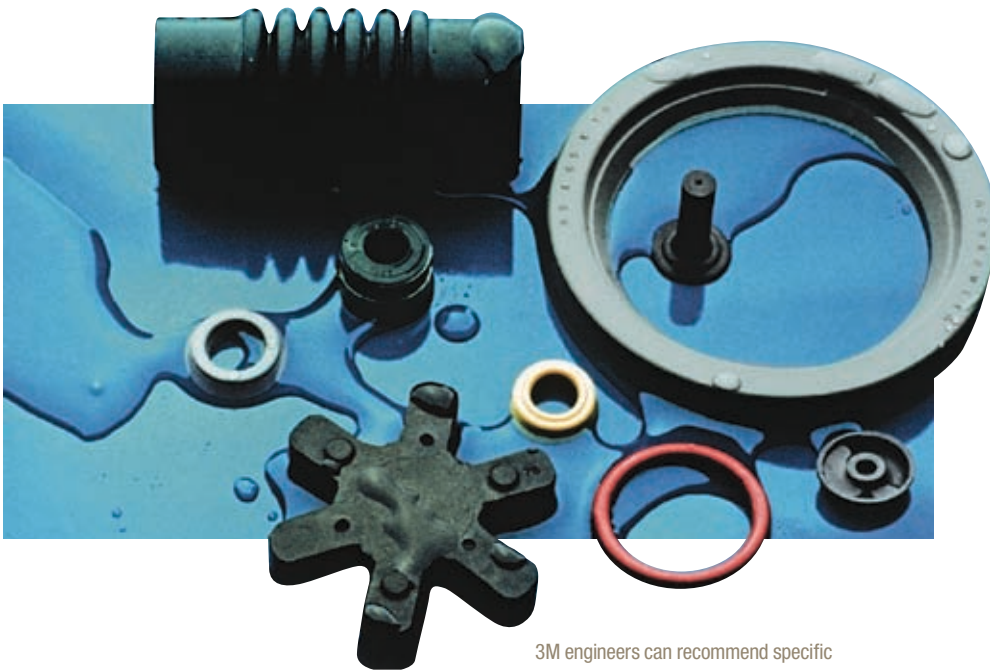
3M™ Novec™ Engineered Fluids and 3M™ Fluorinert™ Electronic Liquids are compatible with a wide variety of materials used in heat transfer equipment. As with any design, selection of these materials is very important. A 3M specialist in this area can help you make the proper choice.

### Polymers

Most of the materials commonly considered “hard” plastics will perform well with both Novec fluids and Fluorinert liquids.

### Elastomers

Elastomers should be limited to those that are not heavily plasticized. 3M engineers can assist you with recommendations and testing on specific compounds.



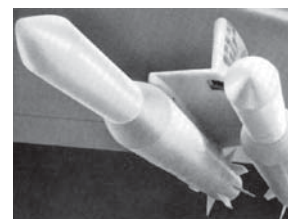
3M engineers can recommend specific compounds for evaluation or help you with material selection.

# More Answers



### A proud history of innovation

3M's involvement with military and aerospace electronics cooling goes back over 50 years, to 3M's pioneering development of dielectric fluorochemical heat transfer fluids in the late 1940s. The unique properties of these materials helped usher in a new era of electronics miniaturization, and enabled the development of sophisticated radars, guidance systems, transmitters and other devices for use in demanding aerospace environments.



Because of their ability to maintain solid state electronics at a constant temperature, and to remain stable over a wide operating temperature range, 3M™ Fluorinert™ Liquids were used to cool the inertial guidance system of Skybolt missiles in the early 1960s. Because of their outstanding performance and reliability, many of these early systems cooled by Fluorinert liquids are still in active service.

## The Hidden Benefit: 3M Experience

The use of fluorochemicals in heat transfer systems is a science that 3M has studied like no other company. Bringing this extensive knowledge to bear on your heat transfer equipment is a major part of our Thermal Management program... and a major benefit of purchasing 3M™ Novec™ Engineered Fluids or 3M™ Fluorinert™ Electronic Liquids.

Here are just some of the services that 3M can provide to help you utilize these innovative fluids in your heat transfer equipment:

### Heat Transfer Seminar/ Design Assistance

Given free of charge at qualifying customer sites, this seminar teaches appropriate design procedures by discussing material compatibility, sources of leakage, pumping, component selection, environmental issues and more. The content of these seminars can be tailored to the specific interests of the audience. 3M has conducted seminars at numerous customer locations.

### Compatibility Testing

3M engineers can evaluate parts with advanced testing methods to help you determine if a component or material is suitable in your design.

### On-Site Consultations

Working side-by-side with equipment designers and end users, 3M engineers frequently help customers tighten-up equipment and optimize system performance.

### Analytical Services

3M has state-of-the-art analytical resources which are used to help answer customer questions.

### The 3M™ Novec™ Brand Family

The Novec brand is the hallmark for a variety of patented 3M products. Although each has its own unique formula and performance properties, all Novec products are designed in common to address the need for safe, effective, sustainable solutions in industry-specific applications. These include precision and electronics cleaning, heat transfer, fire protection, lubricant deposition and several specialty chemical applications.

3M™ Novec™ Engineered Fluids ■ 3M™ Novec™ Aerosol Cleaners ■ 3M™ Novec™ 1230 Fire Protection Fluid ■ 3M™ Novec™ Electronic Coatings ■ 3M™ Novec™ Electronic Surfactants

**Important Notice:** Before using this product, you must evaluate it and determine if it is suitable for your intended application. You assume all risks and liability associated with such use.

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### Electronics Markets Materials Division

3M Electronics  
3M Center, Building 224-3N-11  
St. Paul, MN 55144-1000  
www.3M.com/electronics  
1-800-810-8513

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