3M Science. Applied to Life.™

3M Immersion Cooling

The next generation of data centers is here.

The rise of the data economy is fundamentally changing the way we live and our always-on, highly-integrated world is pushing businesses to operate at an ever-increasing pace. Almost every aspect of our daily lives — smart devices, homes, cities and autonomous vehicles — relies on what is happening inside data centers.

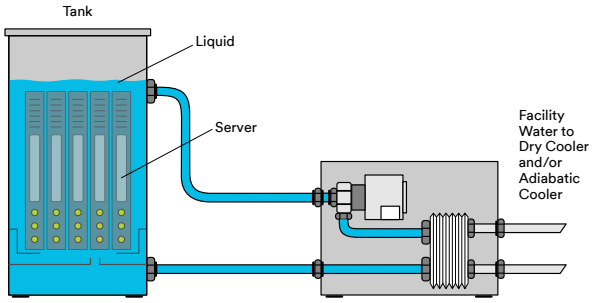
However, these centers come at a tremendous cost in energy consumption, water use, footprint and more. It's clear — we need faster, smarter, more energy-efficient and more sustainable data centers.

By transitioning data centers from traditional cooling methods to immersion cooling with 3M fluids, businesses can better prepare for the unprecedented performance requirements of the future while managing costs and the impact on our natural resources.

Enter what would otherwise be impossible — a new era of data centers.

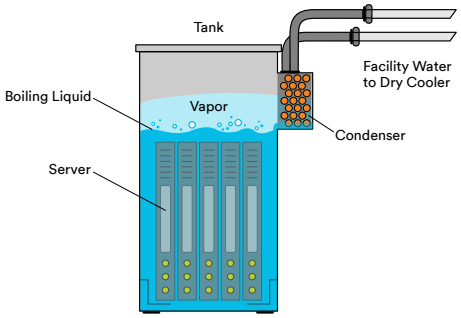
Liquid cooling techniques enabled by 3M fluids

3M fluids can be used for single-phase and two-phase immersion cooling applications, as well as single-phase and two-phase direct-to-chip applications.



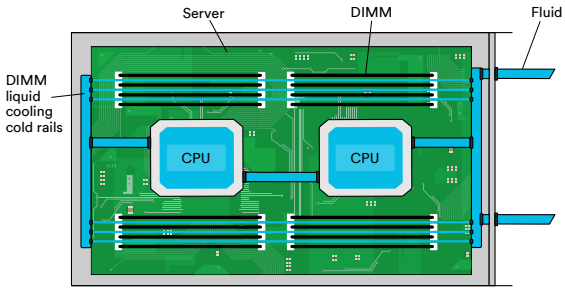
Single-phase immersion cooling

In single-phase immersion cooling, fluid remains in its liquid phase. Electronic components are directly immersed in dielectric liquid in a sealed but readily-accessible enclosure where heat from electronic components is transferred to the fluid. Pumps are often used to flow the heated fluid to a heat exchanger, where it is cooled and cycled back into the enclosure.



Two-phase immersion cooling

In two-phase immersion cooling, fluid is boiled and condensed, exponentially increasing heat transfer efficiency. Electronic components are directly immersed in dielectric liquid in a sealed but readily-accessible enclosure where heat from electronic components causes the fluid to boil, producing vapor that rises from the liquid. The vapor condenses on a heat exchanger (condenser) within the tank, transferring heat to facility water that flows outside of the data center.



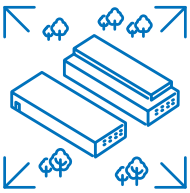
Direct-to-chip cooling

Direct-to-chip cooling rejects heat by pumping fluid through cold plates attached to electronic components. The fluid never makes direct contact with electronics. While non-dielectric fluids (e.g., water glycol) are often used in direct-to-chip cooling, dielectric fluids can be used in direct-to-chip applications to mitigate risks associated with leaks, increasing hardware/IT equipment reliability. Direct-to-chip cooling can be implemented using single-phase and two-phase technologies.

Discover what 3M fluids can do for five different data center applications.

Immersion cooling with 3M™ Fluorinert™ Electronic Liquids and 3M™ Novec™ Engineered Fluids can help improve efficiency while reducing costs and dependency on natural resources center — from design and construction to maintenance and operations. A next-generation data center is right around the corner — let 3M science help get you there.

Hyperscale

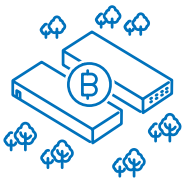


Supercomputing

Enterprise HPC

Edge/5G

Cryptocurrency



Geographically and environmentally agnostic

Build more consistent cooling infrastructure globally, regardless of location decisions and environmental variations. Denser form factors also better enable space- and weight-sensitive applications.

Reduce capital and operational expenses

Reduce capital expenditure by minimizing or eliminating air-cooling infrastructure (e.g., chillers, CRACs, CRAHs, PDUs, RPPs, telecom/networking, facility footprint). With increased cooling efficiency, electricity costs dedicated to ancillary cooling needs can be reduced.

Greater performance and cooling efficiency

Elevate computing performance thanks to increased cooling efficiency and support new or more compute-intensive workloads that traditional cooling solutions struggle to cool in an efficient and cost-effective way.

Increase hardware reliability

Mitigate common hardware failures by minimizing moving parts (e.g., fans) that are necessary for traditional cooling methods.

Roadmap to future power density needs

Deploy high-density units with small form factors engineered to support current and future workloads.

Simpler data center designs to scale more efficiently

Enjoy smaller and simpler data center topologies (e.g., mechanical, electrical, networking). Simplify data center design by eliminating the need for complex airflow management.

Reduce Power Usage Effectiveness (PUE) and water usage

With PUEs as low as 1.03, build more power-efficient and sustainable data centers. Also, reduce or eliminate water waste with either single-phase or two-phase immersion cooling through the use of dry coolers.

Lower latency

Help reduce delays by running latency-sensitive workloads in denser, space-optimized units closer to the user.

Extend life of assets

Sealed but readily accessible units protect IT hardware from environmental contaminants such as dust and moisture. A reduction in moving parts also helps improve reliability and extends the life of units.

Discover the right 3M fluid for your liquid cooling needs

Both 3M™ Novec™ Engineered Fluids and 3M™ Fluorinert™ Electronic Liquids offer top-tier thermal management performance backed by 3M's research and expert guidance for single-phase and two-phase liquid cooling applications.

3M™ Fluorinert™ Electronic Liquids

3M Fluorinert Electronic Liquids have set the industry standard for direct-contact electronics cooling for over 60 years. These extremely inert, fully-fluorinated liquids have exceptionally high dielectric strength and excellent material compatibility. 3M Fluorinert Electronic Liquids are clear, odorless, non-flammable, non-oil-based, low in toxicity, non-corrosive, offer a wide temperature operating range and high thermal and chemical stability. 3M Fluorinert Electronic Liquids also have low dielectric constants making them ideal for single-phase and two-phase data center immersion cooling applications.

3M™ Novec™ Engineered Fluids

3M Novec Engineered Fluids are designed to balance performance with favorable environmental and worker safety properties. They are available for a wide variety of applications including heat transfer, cleaning, testing and lubricant deposition. These fluids are non-flammable, non-oil-based, low in toxicity, non-corrosive, have good material compatibility and thermal stability. 3M Novec Engineered Fluids also have a low global warming potential (GWP) and zero ozone depletion potential (ODP), giving data center owners an innovative, trusted and sustainable solution for their single-phase or two-phase data center liquid cooling (direct-to-chip and immersion cooling) applications. 3M currently recommends using hydrofluoroether-based (HFE) 3M Novec Engineered Fluids for data center liquid cooling applications.

As data center design evolves, our unique experience in immersion cooling can help you tackle your next data center project.

Get more information and answers to frequently asked questions by visiting our website **www.3M.com/ImmersionCooling.**

Safety Data Sheet: Consult Safety Data Sheet prior to use.

Regulatory: For regulatory information about this product, contact your 3M representative.

Technical Information: The technical information, recommendations and other statements contained in this document are based upon tests or experience that 3M believes are reliable, but the accuracy or completeness of such information is not guaranteed.

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Data Center Liquid Cooling Applications with 3M™ Novec™ Engineered Fluids

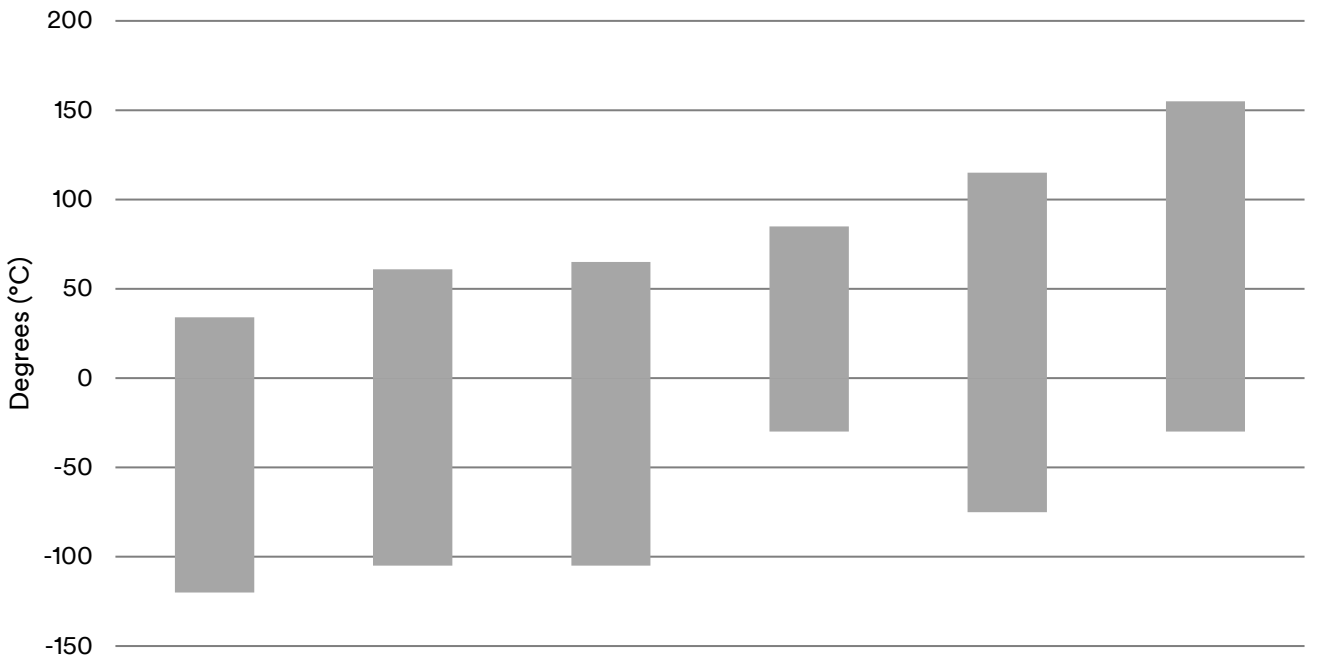
3M™ Novec™ Engineered Fluids are designed to balance performance with favorable environmental and worker safety properties. They are available for a wide variety of applications, including heat transfer, cleaning, testing, and lubricant deposition. These fluids are not classified as flammable and are non-oil-based, low in toxicity, non-corrosive and have good material compatibility and thermal stability. Novec fluids also have low global warming potential (GWP) and zero ozone depletion potential (ODP). For single-phase or two-phase data center liquid cooling (direct-to-chip and immersion cooling) applications, 3M recommends the use of the fluids listed below. It should be noted that these hydrofluoroether-based (HFE) Novec fluids have high dielectric constants that may lead to insertion losses in high-frequency applications due to exposed circuit traces. These fluids have been used successfully in cryptocurrency mining applications and may potentially be used in other data center applications if modifications are made to the IT hardware to enable operation in an HFE-based Novec fluid. Please consult 3M Technical Service for use of Novec fluids for immersion cooling.

Properties	Unit	3M™ Novec™ Engineered Fluids					
		Recommended products for two-phase liquid cooling applications			Recommended products for single-phase liquid cooling applications		
		7000	7100	7200	7300	7500	7700
Boiling Point	°C	34	61	76	98	128	167
Pour Point	°C	-122	-135	-138	-38	-100	-50
Molecular Weight	g/mol	200	250	264	350	414	528
Critical Temperature	°C	165	195	210	243	261	290
Critical Pressure	MPa	2.48	2.23	2.01	1.88	1.55	1.41
Vapor Pressure	kPa	65	27	16	5.9	2.1	<0.1
Heat of Vaporization	kJ/kg	142	112	119	102	89	83
Liquid Density	kg/m^3	1400	1510	1420	1660	1614	1797
Coefficient of Expansion	K^{-1}	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	2.52
Absolute Viscosity	cP	0.45	0.58	0.58	1.18	1.24	4.54
Specific Heat	J/kg-K	1300	1183	1220	1140	1128	1040
Surface Tension	mN/m	12.4	13.6	13.6	15.0	16.2	18.0
Solubility of Water in Fluid	ppm by weight	~60	95	92	67	45	14
Solubility of Fluid in Water	ppm or ppb by weight	<5 ppm	12 ppm	<5 ppm	<295 ppb	<4 ppb	<1 ppb
Dielectric Strength Range, 0.1" Gap	kV	>25	>25	>25	>25	>25	>25
Dielectric Constant @ 1 kHz	-	7.4	7.4	7.3	6.1	5.8	6.7
Volume Resistivity	Ohm-cm	10^8	10^8	10^8	10^{11}	10^8	10^{11}
Global Warming Potential[1]	GWP	530	297	57	310	100	436
Flash Point[2]	°C	None	None	None[3]	None	None	None

Not for specification purposes. All values @ 25°C unless otherwise specified.
[1]GWP-100 year ITH, CO_2 = 1.0, per IPCC 2013, with the exception of Novec 7100 fluid, which notes IPCC 2007.
[2]Per closed cup flash point test method.
[3]Does not display a closed cup flash point but does display upper and lower flammability limits. See SDS for details.

Data Center Liquid Cooling Applications using 3M™ Novec™ Engineered Fluids

Recommended Operating Temperature Range



	Two-Phase			Single-Phase		
	Novec 7000	Novec 7100	Novec 7200	Novec 7300	Novec 7500	Novec 7700
Maximum[1]	34	61	65	85	115	155
Minimum[2]	-120	-105	-105	-30	-75	-30

[1] Maximum operating temperature for two-phase liquid cooling fluids is the boiling point; typical values for single-phase liquid cooling fluids is 10°C below the boiling point.
[2] Typical values for single- and two-phase liquid cooling fluids are the measured or calculated temperature at 20-30 cSt viscosity.

To learn more about how 3M fluids can help enable your data center liquid cooling applications, visit 3M.com/immersioncooling.

To learn more about 3M™ Novec™ Engineered Fluids visit 3M.com/Novec.

Safety Data Sheet: Consult Safety Data Sheet before use.
Regulatory: For regulatory information about this product, contact your 3M representative.
Product Use: Many factors beyond 3M's control and uniquely within user's knowledge and control can affect the use and performance of a 3M product in a particular application. Given the variety of factors that can affect the use and performance of a 3M product, user is solely responsible for evaluating the 3M product and determining whether it is fit for a particular purpose and suitable for user's method of application.
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Data Center Immersion Cooling Applications with 3M™ Fluorinert™ Electronic Liquids

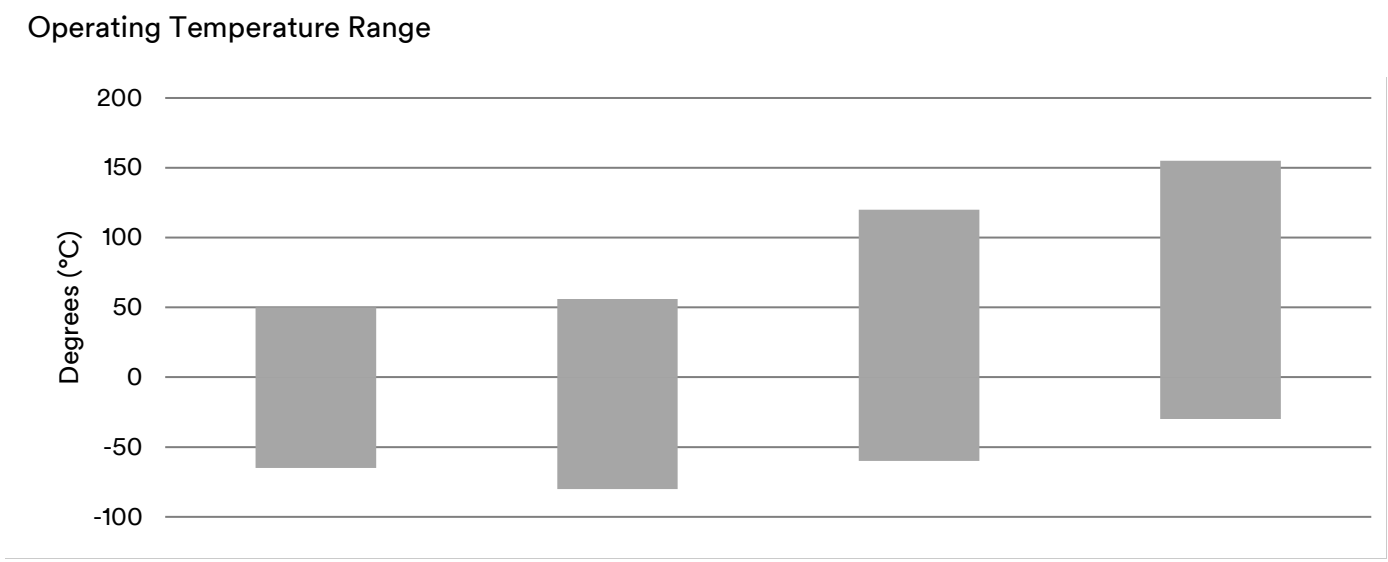
3M™ Fluorinert™ Electronic Liquids have set the industry standard for direct-contact electronics cooling for over 60 years. These extremely inert, fully-fluorinated liquids have exceptionally high dielectric strength and excellent material compatibility. Fluorinert liquids are clear, odorless, non-flammable, non-oil-based, low in toxicity, and non-corrosive and offer a wide temperature operating range and high thermal and chemical stability. Fluorinert liquids also have low dielectric constants making them ideal for single-phase and two-phase data center immersion cooling applications.

Properties	Unit	3M™ Fluorinert™ Electronic Liquids			
		Recommended products for two-phase immersion cooling applications		Recommended products for single-phase immersion cooling applications	
		FC-3284	FC-72	FC-3283	FC-40
Boiling Point	°C	50	56	128	165
Pour Point	°C	-73	-90	-65*	-57
Molecular Weight	g/mol	299	338	521	650
Critical Temperature	°C	161	176	235	270
Critical Pressure	MPa	1.94	1.83	1.22	1.18
Vapor Pressure	kPa	35	30	1.4	0.29
Heat of Vaporization	kJ/kg	105	88	78	68
Liquid Density	kg/m^3	1710	1680	1820	1855
Coefficient of Expansion	K^{-1}	0.0016	0.0016	0.0014	0.0012
Kinematic Viscosity	cSt	0.42	0.38	0.75	2.2
Absolute Viscosity	cP	0.71	0.64	1.4	4.1
Specific Heat	J/kg-K	1100	1100	1100	1100
Thermal Conductivity	W/m-K	0.062	0.057	0.066	0.065
Surface Tension	mN/m	13	10	15	16
Solubility of Water in Fluid	ppm by weight	14	10	7	<7
Dielectric Strength Range, 0.1" Gap	kV	>40	>40	>40	>40
Dielectric Constant @ 1 kHz	-	1.9	1.8	1.9	1.9
Volume Resistivity	Ohm-cm	10^{15}	10^{15}	10^{15}	10^{15}

Not for specification purposes. All values @ 25°C unless otherwise specified.
* Fluid is considered super cooled at this temperature. Talk to a Tech Service Engineer for more information.

Data Center Liquid Cooling Applications using 3M™ Fluorinert™ Electronic Liquids

Recommended Operating Temperature Range



	Two-Phase		Single-Phase	
	FC-3284	FC-72	FC-3283	FC-40
Maximum[1]	50	56	120	155
Minimum[2]	-65	-80	-60	-30

[1] Maximum operating temperature for two-phase liquid cooling fluids is typically the boiling point. Higher temperatures are possible in pressurized systems. Typical values for single-phase liquid cooling fluids is 10°C below the boiling point.
[2] Typical values for single- and two-phase immersion cooling fluids are the measured or calculated temperature at 20-30 cSt viscosity.

To learn more about how 3M fluids can help enable your data center liquid cooling applications, visit 3M.com/immersioncooling.

To learn more about 3M™ Fluorinert™ Electronic Liquids visit 3M.com/Fluorinert. You can also explore our other data center liquid cooling fluids, 3M™ Novec™ Engineered Fluids, at 3M.com/Novec.

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