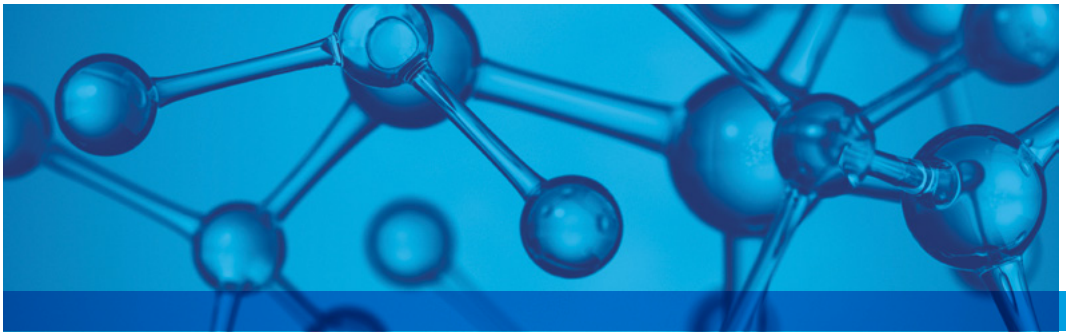

SOLVAY
asking more from chemistry®

Frequently Asked Questions

Galden® PFPE

1. What is Galden® PFPE?

Galden® fluids are low molecular weight PerFluoroPolyEther (PFPE) having the following general structure:

$$CF_3 - (OCF\underset{\underset{CF_3}{|}}{CF_2})_n - (OCF_2)_m - OCF_3$$

Galden® PFPE is a line of dielectric fluids with boiling points ranging from 55 °C to 270 °C and a typical operating range from –100 °C to 270 °C.

Galden® PFPE fluids are high performance, inert fluids characterized by:

- High thermal stability (up to +290 °C)
- The highest boiling point among fluorinated fluids (up to +270 °C)
- Very good dielectric strength and volume resistivity properties
- Excellent chemical inertness
- Good compatibility with metals, plastics, and elastomers
- No flash or fire point, no autoignition point
- Safe. Galden® PFPE fluids are NSF approved

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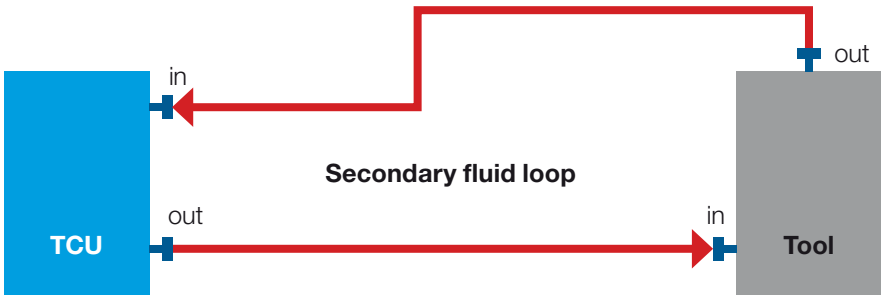
2. What are the Typical Industrial Applications for Galden® PFPE?

Their excellent dielectric properties, high chemical stability combined with their capacity to operate at very low as well as elevated temperatures and in aggressive conditions make them useful in many industrial applications.

Typical industries served by Galden® PFPE fluids are semiconductor manufacturing, electronic testing and cooling, cleaning, carriers for fluorinated lubricants, solar, CPI, batteries, pharmaceutical and food.

- Heat Transfer (HT grades)
- Electronic Testing (D grades)
- Vapour Phase Soldering/Heating (LS–HS grades)
- Solvents (SV grades)

Heat Transfer



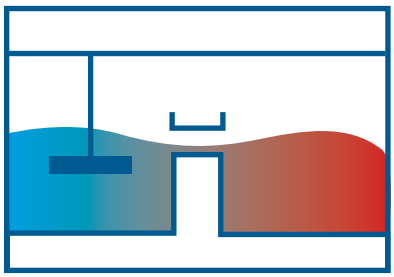
The products offered for use in heat transfer applications are called Galden® HT. This is a line of dielectric fluids with boiling points ranging from 55 °C to 270 °C. Galden® PFPE excellent dielectric properties, high chemical stability combined with their capacity to operate at very low as well as elevated temperatures make them the best heat transfer fluids for the aggressive conditions found in many semiconductor processes, electronic, and solar industries.

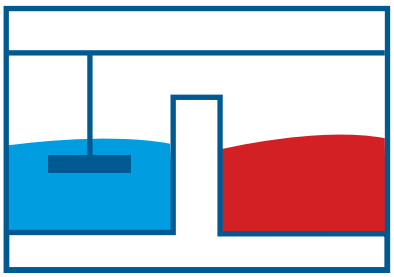
Electronic Reliability Testing

Non-reactivity, excellent dielectric properties, low toxicity, non-flammability, and non-solvent features make Galden® D electronic fluids suitable for electronic reliability testing including thermal shock and hermetic seal testing.

Thermal shock testing

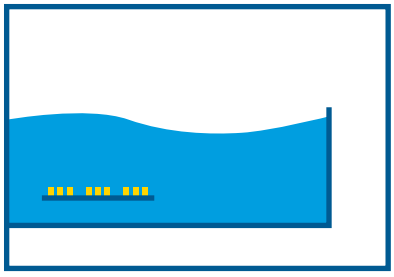
Thermal shock testing is performed to check the resistance of electronic devices to extreme changes of temperature; often used for automotive and in the military applications. Here are some of the standards often referenced: MIL STD 883 method 1011 or MIL STD 202 method 107. The test is carried out by alternately dipping the devices in liquids maintained at two different temperatures; many applications test devices at 65 °C and 150 °C or higher. Galden® D fluids can be used both for single and dual fluids systems.

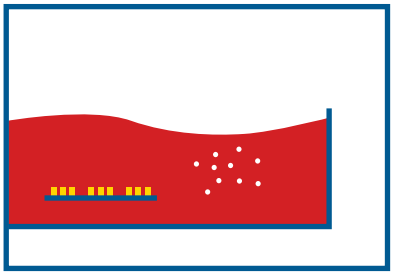




Hermetic seal test

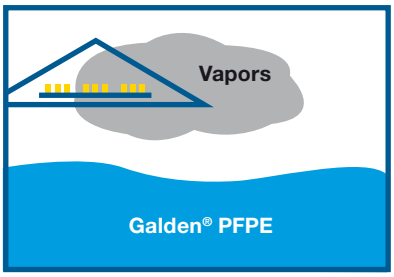
Electronic devices must be completely sealed to avoid moisture to penetrate and damage the electrical response of the silicon chip. Here are some of the standards often referenced: MIL STD 883, MIL STD 750 and MIL STD 202. Galden® D fluids being extremely inert and residue-free are currently used as detector and indicator fluids in leak test procedure.





Vapor Phase Soldering

VPS' principle is to use the latent heat of condensation of Galden® PFPE vapors in order to melt solder paste and hence to obtain reliable metal joints. The narrow molecular weight distribution, as well as the very strong carbonfluorine bond containing no bromines, and the flexible ether link provide the properties which make Galden® LS/HS ideal for use in VPS.



Solvent

Galden® SV fluids are low molecular weight perfluoropolyether fluids that have no flash point and are inert, non-toxic, odorless and colorless. They are used for cleaning operations where solvents are:

- Applied to hot components
- Heated prior to application
- Pressure sprayed onto components

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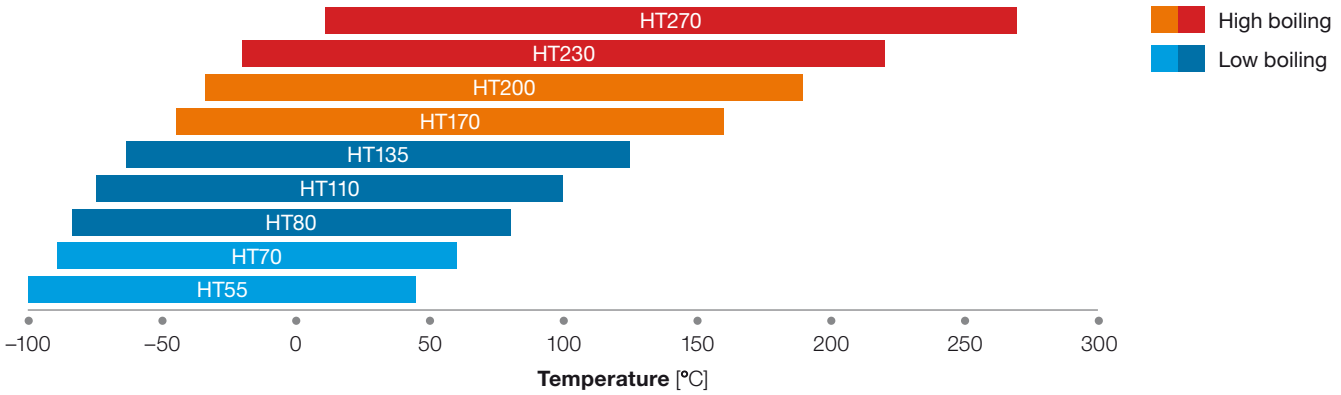
3. What is the Typical Temperature Range for Use of Galden® PFPE?

Galden® PFPE is a line of dielectric fluids with boiling points ranging from 55 °C to 270 °C.

For heat transfer application the working temperature ranges are reported in the graph below and the temperature limits are setted as follows:

- The lower temperature limit is set when the fluid viscosity reaches the value of 20 cP (11 – 12cSt). This is typically the operating range of many commercially available fluid pumps.
- The upper limit is set at 10 °C below the boiling point of the fluid itself.

Operating temperature range



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4. What is the Pour Point of Galden® PFPE?

The pour point is the lowest temperature at which a fluid will flow. This property is crucial for fluids that must flow at low temperatures. A commonly used rule of thumb when selecting fluids is to ensure that the pour point is at least 10 °C lower than the lowest anticipated ambient temperature. Galden® HT line of fluids offers a wide range of very low temperatures pour points from –115 °C to –66 °C.

Grade	Pour Point [°C]
Galden® HT55	< –125
Galden® HT70	< –110
Galden® HT80	–110
Galden® HT110	–100
Galden® HT135	–100
Galden® HT170	–97
Galden® HT200	–85
Galden® HT230	–77
Galden® HT270	–66

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5. What is the Density of Galden® PFPE?

The density of a material is defined as its mass per unit volume. Density at 25 °C for Galden® PFPE grades is the following:

Grade	Density [g/cm³]
Galden® HT55	1.65
Galden® HT70	1.68
Galden® HT80	1.69
Galden® HT110	1.71
Galden® HT135	1.72
Galden® HT170	1.77
Galden® HT200	1.79
Galden® HT230	1.82
Galden® HT270	1.85

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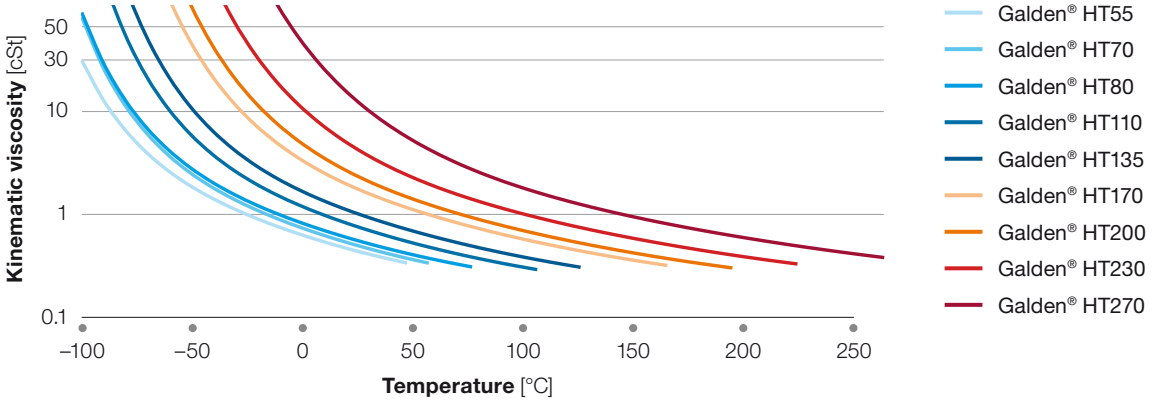
6. What is the Viscosity Range of Galden® PFPE?

Viscosity is an internal property of a fluid that offers resistance to flow. The viscosity of a liquid usually depends on its temperature. Viscosity generally decreases as the temperature increases and generally increases as the temperature decreases. For many heat transfer applications the lower temperature limit (pumpability limit) is set when the fluid viscosity reaches the value of 20 cP (11 – 12 cst).

Kinematic viscosity vs. temperature



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7. Is Galden® PFPE Flammable?

No, Galden® PFPE are not flammable. They don't have flash, fire or autoignition point.

Galden® PFPE fluids are Factory Mutual Underwriters approved.
Galden® PFPE fluids are complaint to FM 6930 Approval Standard Fluids.

FM APPROVED

Certificate of Compliance

INDUSTRIAL FLUIDS

This certificate is issued for the following materials:

GALDEN® HT-55, HT-70, HT-90, HT-110, HT-135, HT-170, HT-200, HT-230, HT-270, E-65, DET, D02, D02-TS, D03, D05, D-20, D-40, HS-240, HS-260, LS-155, LS-165, LS-200, LS-210, LS-215, LS-230, PFS-1, PFS-2, SV-55, SV-70, SV-80, SV-90, SV-110, SV-135,

H-GALDEN® ZT-85, ZT-100, ZT-130, ZT-150, ZT-180, ZV-60, ZV-75, ZV-85, ZV-100, AND

FOMBLIN® Y04, Y06, Y25, Y45, YR, YPL1500, YR1500, YR1800, YLVAC 06/6, YLVAC 14/5, YLVAC 16/6, YLVAC 25/6, YHVAC 18/8, YHVAC 25/9, YHVAC 40/11, YHVAC 140/13, LC-08, LC-55, LC-80, LC-200, LC-250, YLOX-100, YLOX-120

Manufactured by: Solvay Solexis S.p.A.
Viale Lombardia 20
20021 Bollate (MI)
Italy

FM Approvals confirms that the items have been found to comply with the following standard:

FM Approvals Standard 6930

Project Identifier: 3026109 Date of Approval: November 3, 2006

FM Approvals

Richard P. Ferron, P.E.
Group Manager – FM Approvals

11/3/06
Date

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8. Is Galden® PFPE Hazardous?

No, Galden® PFPE are very safe fluids:

- No flash or fire point
- No explosion hazard
- No toxicity
- No autoignition point
- Thermal, oxidative & chemical stability
- Shelf life over 20 years

Galden® PFPE are stable in thermal conditions above 300 °C. In the presence of oxygen the continuous use temperature of these fluids is somewhat lowered to 290 °C. Up to these temperatures, the decomposition of the fluids is negligible. Galden® PFPE can be stored and handled without specific precautions, do not react with chemicals and refrigerants and does not get oxidized.

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9. What is the Degradation Temperature of Galden® PFPE?

Galden® PFPE are stable in thermal conditions above 300 °C. In the presence of oxygen the continuous use temperature of these fluids is somewhat lowered to 290 °C. Up to these temperatures, the decomposition of the fluids is negligible.

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10. Do Galden® PFPE Cause Corrosion?

No. Galden® PFPE do not corrode metals because they interrupt the electrical circuit that is the base for the corrosion process: the conducting environment for ionic movement is disabled by the high volume resistivity of Galden® PFPE fluids that does not vary over time (the volume resistivity of DI water is at least 10^7 Ω·cm, and this value tends to reduce over time – DI water extracts metal ions).

Property	Galden® PFPE	DI-Water
Volume Resistivity (Ω·cm)	$> 10^{15}$	$< 10^7$

Corrosion in Galden® PFPE heat transfer systems can generally be linked to either a separate water phase or thermal decomposition of the fluid. In order to have a separate water phase the amount of water in the system must be beyond the saturation level of the fluid. The saturation level of water in a Galden® PFPE fluid is usually less than 20 ppm by weight. Water present in the fluid at or below this level has never been linked to corrosion. Water present above this level means a separate water phase. If such water is entrained into contact with metal parts, corrosion can be rapid. Water can enter heat transfer systems in a few different ways: components can be hydrotested and never dried before installation.

Thermal decomposition of the fluid: fluoride ion can be generated any time the fluid is brought above its decomposition temperature and this can lead to corrosion. Thermal degradation for Galden® PFPE start at about 290–300 °C. HF can be generated only when the fluid is brought above its decomposition temperature and these conditions are far from the working temperature range. Experience indicates that corrosion resulting from decomposition is very rare and is only observed in systems which have undergone a failure. Examples include: a burned out heater, high voltage discharge in dielectric systems or a burned out electrical component in a direct contact electrical application.

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11. What are the Electric Properties of Galden® PFPE?

Galden® PFPE fluids are excellent dielectrics. This is the main reason they are used in many applications.

Property	Unit	Value
Dielectric strenght	kV at 2.54 mm gap	40
Volume resistivity	Ohm·cm	$1.5 \cdot 10^{15}$

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12. What is the Solubility of Water in Galden® PFPE

The saturation level of water in a Galden® PFPE fluid is usually less than 10 ppm by weight.

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13. Is Galden® PFPE Compatible with Various Materials?

Galden® PFPE fluids are increasingly used as heat transfer fluids, especially in the tools used in semiconductor manufacturing. They are fluorinated fluids and their excellent dielectric properties, high chemical and thermal stability combined with their capacity to operate at very low as well elevated temperatures make them the best heat transfer fluids for the aggressive conditions used in semiconductor manufacturing.

The compatibility of a fluid with various materials is strongly dependent on the fluid properties.

Galden® PFPE Fluid Properties

- **Surface tension**
  Surface tension is a measure of the fluid to wet other materials – the lower the surface tension, higher is the wetting power. Galden® PFPE fluids have low surface tension and are capable of wetting almost all the conventional sealing and gasket materials. This allows the fluids to creep out of very small leak paths. The best sealing materials should have low surface energies in order to minimize wetting.
- **Chemical and physical compatibility**
  In spite of the excellent compatibility, due to the low surface tension, these fluids could penetrate the elastomers and plastics and cause swelling and/or extraction of plasticizers and fillers. Swelling could have a positive effect on sealing, but the sealing could fail if the joint is opened for maintenance or other purposes. It is recommended that a new seal or gasket material is used if excessive swelling is noticed. The extraction of plasticizers would reduce the elasticity of the seals, gaskets, hoses and tubes. The material could turn rigid and become brittle. This problem could become severe if there is temperature cycling.
- **Dielectric properties and static electricity build-up**
  Galden® PFPE fluids are excellent dielectric fluids and possess high electrical resistivity. This property that makes these fluids very attractive for their use in semiconductor manufacturing tools that use Rf energy, has one negative effect – potential to build-up of static electricity when these fluids flow on non-conductive materials such as plastics and elastomers. The build-up static electricity, when reaching high values, will discharge into the surroundings with arcing. This could cause pinholes in hoses and tubes causing the fluid to leak. The build-up and discharge of static electricity depend on many factors such as nature of the material, flow velocity, surrounding humidity etc. and is very difficult to reproduce in the laboratory. One of the properties that determines the dissipation of the built of electrostatic charges is the conductivity of the fluid as well as that of the tube or the hose in which the fluid flows. One would expect a quicker dissipation with the increased conductivity. Conductive hoses and tubes with good grounding have been and are being used in the industry with good success. The conductivity of the fluid could be increased by suitable additives as done with gasoline. However, additives may affect the dielectric properties of the fluid and may be absorbed by filters in the system.

Materials of Construction

The commonly encountered materials of construction can be classified into elastomers, plastics and metals. Before selecting these materials, it is important to verify if they are recommended for the temperature range of interest. The compatibility of these materials with the fluids depends on the base material and the formulations used in making the seals, gaskets and hoses as well as the operating temperatures and temperature cycling.

The compatibility of the pure materials could be different from that of the seals and gaskets that are formulated with these materials. Different formulated products based on the same base material could have different compatibility. Hence it is very difficult to make general statements about the compatibility. Often compatibility tests have to be performed with the formulated seals and gaskets.

- **Fluorinated elastomers and plastics**
  Fluorinated elastomers include Tecnoflon® FKM/FFKM produced by Solvay Specialty Polymers, Viton® produced by DuPont and Fluorosilicones. Fluorinated plastics include Algoflon® PTFE, Hyflon® MFA®, and Hyflon® PFA produced by Solvay Specialty Polymers and Teflon® produced by DuPont. Typically fluorinated products have low surface energies and hence are difficult to wet. They make good seals against Galden® PFPE. However, compatibility of the seals and gaskets made out of these materials with Galden® PFPE a under operating conditions should be confirmed before using them. For example Kalrez® is an expensive, specialty fluorinated material, but its physical compatibility with Galden® PFPE fluids is very poor.

- **Non-fluorinated elastomers and plastics**
  Among the non-fluorinated materials, silicones have the lowest surface energy and hence make leakproof seals and gaskets for the Galden® PFPE. As in the case of fluorinated materials, the compatibility under operating conditions should be confirmed. Hoses and tubes made of other materials such as NBR, BR, EPDM, PB etc. have been successfully used; it is important to confirm that leaching of plasticizers will not be an issue with these hose materials.
- **Conductive plastics**
  The build-up and discharge of static electricity is an important phenomenon that should be controlled in order to avoid pinholes and subsequent fluid losses. Where metal tubes cannot be used, conductive hoses with suitable grounding have been successfully used to eliminate problems related to static electricity build-up. When using these conductive materials, in addition to swelling and changes in the mechanical properties of the materials, leaching of the conductive filler should also be considered. Generally, using carbon fillers increases the conductivity of plastics. Some hoses have a thin layer of carbon deposited on the plastic. The latter have not been found to be very useful due to the breaking down of the carbon layer caused by fluid attrition with time. The carbon so liberated could deposit on undesired parts of the tool.
- **Metals**
  Galden® HT, if properly used, i.e. far from thermal degradation temperature and in waterfree system, are fully compatible with metals commonly encountered in TCUs or chillers; they do not corrode and do not react with construction materials. Compatibility tests with different metals and at different temperatures have been carried out and no evidence of corrosion or reaction were detected. With reference to AlMgSi alloy and Stainless Steel 1.4404, based on our experience and knowledge we do not expect any adverse reaction.

Compatibility Tests

Test conditions: Compatibility tests have been carried out using pure Galden® PFPE at 200 °C for 500 hrs.

- Appearance and weight changes of metal specimen were determined.
- Acidity and viscosity of the fluid were checked as well.

Galden® PFPE metal compatibility chart:

Metal	Result
Stainless Steel 1.4301	Compatible
Stainless Steel 1.4404	Compatible
Iron	Compatible
Nickel	Compatible
Copper	Compatible
Brass	Compatible
AlMgSiCu (*)	Compatible

(*) test carried out at 90 °C per customer's request

- **Valves and fittings**
  Once again, the unique properties of these fluids and the unusual conditions under which they operate, make it necessary to pay particular attention to the selection of valves and fittings. Valves with static seals have shown to be very effective in reducing fluid losses due to leakage. Swagelok, a leading manufacturer of valves and fittings has carried out several tests with Galden® PFPE fluids. These tests included higher system pressures, temperature cycling and leak rate measurements. The major reason for fluid leakage is the dynamic seal in a plug valve. This problem could be overcome by the use of ball valves with static flange seals. Silicone seals have shown good performance over a wide range of temperatures.
- **Conclusions**
  Fluid leakage due to poor material compatibility and poor choice of seals and gaskets could amount to thousands of dollars as well as to undesired loading of environment. Solvay Specialty Polymers has carried out compatibility tests in their laboratories and also work closely with manufacturers of OEM tools, thermal control units (chillers and heat exchangers) and system components such as pipes, seals & gaskets and valves & fittings.

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14. What Types of Materials IS NOT an Issue?

As a general rule the following tab can be followed:

Metals	Plastics	Elastomers
AISI 316	PE low density	Butyl rubber
Copper	Polypropylene	NBR
Brass	Polycarbonate	EPDM
Iron	ABS copolymer	Natural rubber
Nickel	Polyphenyloxide	Silicone rubber
Aluminum	PET	FKM
Stainless steel	PTFE	Fluorosilicone
	PMMA	

The compatibility of the pure materials (i.e. elastomers) could be different from that of the seals and gaskets that are formulated with these materials. Different formulated products based on the same base material could have different compatibility. Hence it is very difficult to make general statements about the compatibility. Often compatibility tests have to be performed with the formulated seals and gaskets.

Galden® PFPE Fluid Compatibility with Plastics

The following plastics (not formulated) were unchanged after immersion in Galden® PFPE for 1,000 hrs at 70 °C:

Acetal copolymer (POM)	Polyethylene terephtalate (PET)
Acrylonitrile-butadiene-styrene copolymer (ABS)	Polypropylene (PP)
Phenylene-oxide based resins (PPO)	Polystyrene (PS)
Polyamide 6,6 (Nylon 6,6)	Polystyrene impact resistant (HIPS)
Polybutylene terephtalate (PBT)	Polyvinyl chloride (PVC)
Polycarbonate (PC)	Polyvinyliden sulfide (PVDS)
Polyethylene high density (HDPE)	Styreneacrylonitrile copolymer (SAN)
Polyethylene low density (LDPE)	

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15. How Do I Select a Fluid for a HT Application?

We suggest selecting a HT fluid according two main parameters:

Viscosity at the lowest operating temperature

- Typical value < 20 cp or < 10 – 12 cSt for fluorinated fluids for pump-ability

Vapor pressure at the highest operating temperature

- Suggested boiling point of fluid at least 10 °C higher than the highest operating temperature in order to:
  - Avoid excessive pressure in the HT circuit
  - Reduce fluid losses
  - Reduce cavitation

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16. Can I Lower My TCO and Reduce GHG Emissions?

Yes, by using Galden® HT High Boiling Grades.

Galden® HT High Boiling is a line of dielectric fluids with boiling points ranging from 170 °C to 270 °C. These high performance fluids are a family of heat transfer fluids engineered for high temperature applications. Thanks to their high boiling point, they offer a significantly lower evaporation rate than that of low boiling point fluids. Galden® HB fluids can also be used at moderate temperatures to replace fluids with higher evaporation rates, thereby reducing evaporation losses and emissions.

Working closely with equipment designers and end-users, Specialty Polymers' engineers can help you selecting the best grade fitting with your requirements

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17. How Do I Size a Heater for Use with Galden® PFPE Fluids?

For Galden® PFPE grades, a general recommendation is not to install a heater watt density higher than 5 W/cm^2, in order to avoid instability in heater surface temperature for low flow units (i.e. fluid reservoir in the TCU). Having the heater section where fluid flow is present near the outlet of the pump, it will allow higher watt density heaters to be used. The critical breakdown is ~ 14 W/cm^2. The decision to go beyond this level should be made by the customer.

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18. What is the Difference Between Galden® HT and Galden® LS/HS?

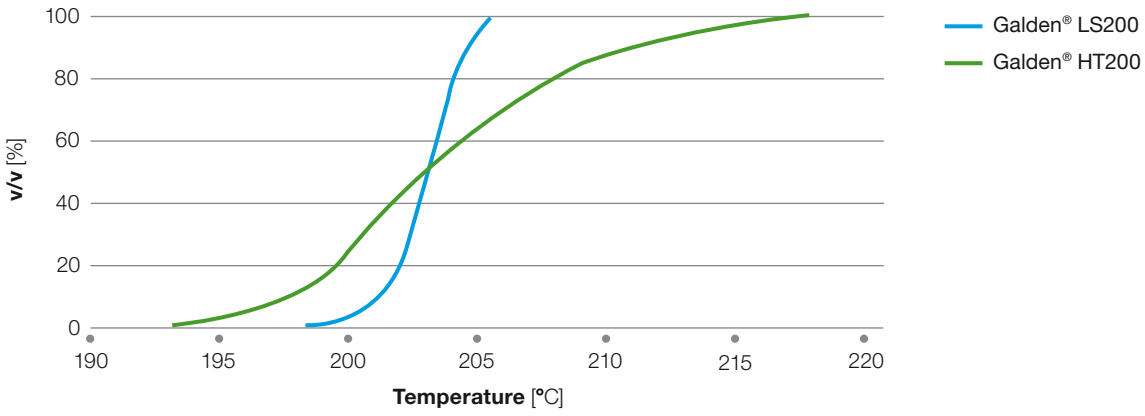
Galden® LS/HS fluids are specifically designed for vapor phase soldering process. A strict control of the molecular weight distribution and of the vapors temperature is performed by measuring respectively:

- Distillation range (ASTM D1078)
- Boiling temperature (TRV ASTM D1120)

The above characteristics are always included in the material specifications:

Property	LS200	LS215	LS230	HS240	HS260
Distillation range [°C]	196–212	211–223	222 — 235	237–250	256–273
Boiling temperature TRV [°C]	194–200	212–218	227–233	237–243	260–266

The sharp molecular weight distribution eliminates the preferential evaporation of low boiling components during VPS process. This phenomenon leads to higher losses of the fluids as well as a shift towards higher vapor temperature with time ► undesired boiling point drift.



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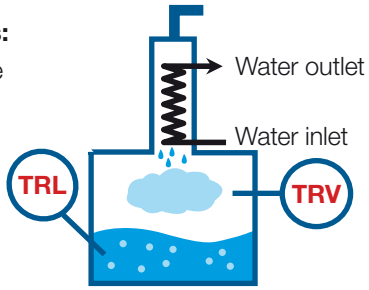
19. What is the Difference Between Boiling Point, TRL and TRV?

The boiling point of an element or a substance is the temperature at which the vapor pressure of the liquid equals the environmental pressure surrounding the liquid. Boiling temperature for each fluid is determined according test method ASTM D1120. TRL means Temperature Reflux Liquid and it is a value worth for HT Fluids. TRV means Temperature Reflux Vapor and it is a value worth for HS and LS Fluids.

Galden® HT fluids:

TRL = **T**emperature
Reflux
Liquid



Galden® LS/HS fluids:

TRV = **T**emperature
Reflux
Vapor

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20. How Can I Detect Fluid Leaks?

Even at room temperature Galden® PFPE fluids have a vapor pressure value higher than 0 Torr, so they release vapors even if at negligible rate, depending by grade. In order to detect fluid leaks a halogen leak detector can be used; these are available through most commercial refrigeration supply centers.

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21. Are Galden® PFPE Fluids Food Grade Approved?

Galden® PFPE fluids are NSF approved all with the related intended use described below.

H1	General–incidental contact
HT1	Heat transfer fluids–Incidental contact
HTX1	Ingredients for use in HT1 heat transfer fluids
HX1	Ingredients HX1 for use in H1 lubricants (incidental contact)

The fluids approved are the following:

Galden® HT55	Galden® HT170
Galden® HT70	Galden® HT200
Galden® HT110	Galden® HT230
Galden® HT135	Galden® HT270

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22. Do Galden® PFPE Fluids Satisfy MIL Requirements?

Yes. Galden® PFPE fluids satisfy MIL requirements. Hermetic seal testing is performed to check hermetic devices.

Leak test procedure is performed according to:

- MIL STD 883, method 1014
- MIL STD 750, method 1071
- MIL STD 202, method 112

MIL Standards suggests for a testing fluid the following properties:

Appearance	Clear and colorless
Density at 25 °C	> 1.6 gm/cm^3
Dielectric strength at 2.54 mm	> 30 kV
Viscosity profile	According the equipment manufacturer
Residue	< 50 ppm
Composition	NO chlorine and NO hydrogen

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23. Are Galden® Fluids BAM Approved?

According BAM (Bundesanstalt für Materialforschung und -prüfung) there are no objection with regard to technical safety to use:

Galden® HT230
in piping, valves and fittings or other components for oxygen service at the following conditions:

Maximum Temperature	Maximum Oxygen Pressure
up to 60 °C	up to 100 bar

Galden® HT270
filling liquid for gaseous oxygen service at the following conditions:

Maximum Temperature	Maximum Oxygen Pressure
230 °C	3 bar

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24. Are Galden® PFPE Fluids REACH Registered?

Polymers, among them Galden® PFPE, are exempted from registration and evaluation (art.2.9, EC 1907/2006).

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25. What is the shelf life for Galden® PFPE?

The real shelf life of Galden® PFPE as far as the chemical stability is concerned is over 20 years based on our experience. Within this time frame the above products, if stored under normal condition in original sealed containers, maintain their chemical-physical properties unchanged.

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