

Galden[®] - PFPEs

Comparison with other Heat Transfer fluids



Progress beyond

2023



What are PFPEs



PerFluoroPolyEthers (PFPEs) are clear and colorless fluoropolymer, liquid in a wide range of temperatures and based on a proprietary and unique technology composed entirely of:

- **C**arbon
- **O**xygen
- **F**luorine

- Linear $\text{CF}_3\text{O}-[(\text{CF}_2\text{CF}_2\text{O})_m-(\text{CF}_2\text{O})_n]-\text{CF}_3$
- Branched $\text{CF}_3\text{O}-[(\text{CF}_2\text{CFO})_m-(\text{CF}_2\text{O})_n]-\text{CF}_3$
 CF_3

C-C and **C-O**

bonds shielded by a cloud of **F**

C-F

the strongest bond in organic chemistry

PFPEs Chemistry Effect



Features due to the presence of *Fluorine*

- Excellent thermal and oxidative stability
- Excellent chemical stability
- Dielectric properties
- Non flammable
- Low surface energy

Features due to the presence of *Oxygen*

- Imparts flexibility to the polymer chain
- Liquid in a very large temperature range
- Excellent flow behavior at low temperature
- Higher viscosity index (VI) for linear PFPE (higher O/C ratio)



Features and benefits



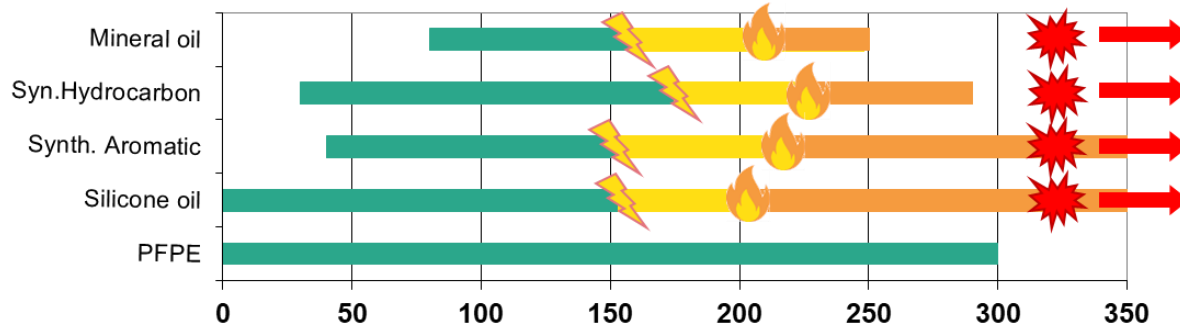
Features	Benefits
Low evaporation rate	Less consumption and lower cost of ownership
Safety	Non-flammable (no flash point), low toxicity
Excellent compatibility	Variety of plastics, metals and elastomers
Wide temperature range	Good viscosity at low temperatures
Electrical Properties	High dielectric strength, high resistivity
Low miscibility with water and solvent	Easy to recover in case of leakage and no residue

Safety First - Flash and Fire Point



Compared to other widely used fluids and oils Galden® PFPEs have no incendiary risk

PFPE have no FLASH, no FIRE and no Autoignition point



Flash Point



Fire Point



Autoignition Point

Flash Point: Temperature above which a fluid emits vapors that can be ignited

Fire Point: Temperature above which a fluid emits vapors that can sustain a flame

Autoignition Point: Temperature above which a fluid combust without external ignition sources

Approved under
FM 6930 Standard

Fire Control System
not
Required

Galden® PFPE vs Polyester Comparison



Property	Galden® EV110 - PFPE	Polyester Oils	Synthetic hydrogenated Oils (alkyl, alkylbenzene, etc.)	Silicone Oils
Flammability	No Flash Point Totally non-flammable Fire extinguishing properties <u>FM6930 Approved</u>	Flash Point present (example: 170°C) Flammable	Flash Point present (example: 142°C) Flammable The less viscous/lower boiling point the more flammable	Flash point present above 250°C Flammable
Stability	No decomposition up to 290°C No degradation over time	Oxidation possible if not inhibited by additives (additives deplete over time)	Oxidation and even carbonization possible if not inhibited by additives (additives may deplete over time)	Tend to change viscosity over time due to oxidation + cross-linking → “gelation”
Compatibility	Excellent Compatibility with rubbers and thermoplastics (excluding only fully fluorinated elastomers)	Fair compatibility with thermoplastics Leach out risk with elastomers and their additives	Fair compatibility with thermoplastics Leach out risk with elastomers and their additives	Good Compatibility with rubbers and thermoplastics Excluding silicones
Water miscibility	<10 ppm	More than 1000 ppm can be absorbed (as reported in producer’s brochure)	Typically tens to hundreds of ppm (50 to 200 ppm)	Typically hundreds of ppm (100 to 900 ppm)

Galden® PFPE vs Polyester Comparison



Property	Galden® EV110 - PFPE	Polyester Oils	Synthetic hydrogenated Oils (alkyl, alkylbenzene, etc.)	Silicone Oils
Recyclability/Reuse	Infinitely recyclable/reusable if kept below its degradation point	Degrades over time and will need to be changed and disposed Recyclability is questionable	Degrades over time and will need to be changed and disposed Recyclability is questionable	Degrades over time and will need to be changed and disposed Recyclability is questionable
Electrical Resistance	Extremely High Very stable over time	Very High <u>but</u> : could be influenced by water absorption	Very High <u>but</u> : carbonization can reduce resistivity	Very High <u>but</u> : could be influenced by water absorption
Breakdown Voltage	40 kV at 2.54 mm	Since dielectric strength depends on humidity rather than on the product insulation quality, the breakdown voltage can vary significantly	Since dielectric strength depends on humidity rather than on the product insulation quality, the breakdown voltage can vary significantly	Since dielectric strength depends on humidity rather than on the product insulation quality, the breakdown voltage can vary significantly
Safety in case of accident/spillage	No odor Can be easily recovered and any minor residues evaporate on their own Non-toxic	Mild odor Soluble in other oils/greases making recovery more challenging Typically non-toxic	Mild to strong odor Soluble in other oils/greases making recovery more challenging Can be toxic to aquatic environment	Mild odor Stains and easily spreads across and permeates surfaces → difficult to recover Typically non-toxic

Material Compatibility (@ 25 °C)



		✓ Good	— Fair	✗ Poor	Synthetics Hydrocarbons	Glycols	Esters	Silicones	Galden® Fluorinated Ethers - PFPE
Plastics	Acetals	✓			✓	✓	✓	✓	✓
	Phenolics	✓			✓	✓	✓	✓	✓
	Terephthalates	✓			✓	✓	✓	✓	✓
	Polycarbonates	✓			✓	✗	✗	✓	✓
	A-b-s Resins	✓			✓	✗	✗	✓	✓
	Polyphenylene Oxides	✓			✓	✗	✗	✓	✓
	Polysulfones	✓			✓	✗	✗	✓	✓
	Nylon (Polyamide)	✓			✓	✓	✓	✓	✓
	Polypropylene	✓			✓	—	—	✓	✓
	Polyethylene	—			—	—	—	✓	✓
Elastomers	Natural Rubber	✗			✗	✗	✗	✓	✓
	Buna S	✗			✗	✗	✗	✓	✓
	Butyl	✗			✗	✗	✗	✓	✓
	Ethylene Propylene	✗			✗	—	—	✓	✓
	Nitrile (Buna N)	✓			✓	—	—	✓	✓
	Neoprene	✓			✓	✗	✗	✓	✓
	Silicone	—			—	—	—	✗	✓
	Fluoroelastomers	✓			✓	✓	✓	✓	✓

Thank you.

Please consider that all data in this presentation is not to be considered subject to specification, it is provided in good faith, for reference purposes only and it does not relieve the customer from using his best judgment and knowledge while selecting, using and processing our materials.

160 YEARS
FOR GENERATIONS TO COME





Progress beyond

“There are no limits to what
science can explore.”

Ernest Solvay