Stability and Compatibility

Thermal stability

Dry, air free FLUTEC® vapours are unaffected after many hours exposure to temperatures exceeding 400ºC. A suggested maximum working temperature for some perfluorocarbon liquids is given in Table 1.

Table 1 *Maximum Temperature (perfluorocarbon vapour in inert or passivated container)*

FLUTEC	Max. Temp. (ºC)
Perfluorohexane	440
Perfluoromethylcyclohexane	450
Perfluoro-1,3-dimethylcyclohexane	450
Perfluorodecalin	400
Perfluoromethyldecalin	400

Thermal breakdown may occur in the vapour phase, or on metal surface, probably with initial breaking of carbon-carbon bonds. The resulting fragments recombine to form other fluorocarbons, generally of lower molecular weight than the original material, but including some polymer. Chemical reaction may also occur between perfluorocarbon and the surface of the container.

Table 2 summarises the results of tests in autoclaves of Nimonic 75, nickel/chromium alloy. There was an inevitable handling loss of up to 2%, so that the figures may overstate the true rate of decomposition (a rise in pressure will be due to molecular fragmentation, a fall will be caused by leakage or formation of non-volatiles such as carbon etc.).

Stability in naked flames

Perfluorocarbon liquids have flame extinguishing properties, however, where combustion of a hydrocarbon fuel continues in the presence of FLUTEC™ liquid, it has been found that considerable amounts of hydrogen fluoride are evolved. Appropriate safety precautions should therefore be taken.

Table 2 *Thermal stability*

The quoted loss is the maximum figure, after deducting all fragmentation products from the mass of the recovered input material.

The pressure change is calculated:

$$\frac{Final\ pressure - Initial\ pressure}{Initial\ pressure \times time} \times 100$$

Perfluorocarbon liquid	Time (hr.)	Temp. (ºC)	Loss (%/hr)	Pressure (%/hr)
Perfluorohexane	336	440	0.015	-0.006
	48	445	0.063	+0.25
	168	450	0.05	+0.01
	48	490	0.48	+0.16
	168	500	0.37	+0.07
Perfluoromethyl-cyclohexane	48	395	0.021	0.0
	168	400	0.018	+0.026
	4457	400	0.0007	+0.006
	912	405	0.0011	+0.015
	388	440	0.0052	0.0
	1152	440	0.0043	+0.0015
	48	445	0.021	-0.061
	168	450	0.0060	0.0
	334	490	0.102	+0.033
	48	500	0.104	+0.14
Perfluoro-1,3-methyl-cyclohexane	48	445	0.104	+0.065
	168	445	0.036	+0.009
	48	475	0.146	+0.34
	168	480	0.185	+0.093
	48	495	0.646	+0.53
	168	500	0.315	+0.150
Perfluorodecalin	338	395	0.021	+0.0098
	1006	395	0.002	-0.00046
	48	400	0.00	+0.012
	109	400	0.028	+0.016
	3243	400	0.0012	+0.0015
	1010	415	0.028	+0.0098
	3025	415	0.0003	+0.0007
	48	420	0.042	+0.0
	168	420	0.0	+0.019
	353	420	0.017	-0.0011
	48	440	0.0	+0.0048
	1483	440	0.019	+0.0038
	168	445	0.042	+0.032
	336	445	0.048	+0.0046
	640	460	0.036	+0.001 6
Perfluoromethyldecalin	50	300	0.04	0.0
	168	300	0.0	-0.025
	50	375	0.16	0.0
	46	380	0.043	-0.048
	164	380	0.006	-0.024
	46	420	0.24	-0.043

Thermal stability in the presence of metals

Copper based alloys have been observed to have tarnished after long exposure to FLUTEC™ liquids. This is attributed to oxidation by dissolved oxygen.

Lewis acids (such as many metal oxides) are known to promote the decomposition of FLUTEC™ liquids at high temperatures. In the presence of water it is not unlikely that hydrogen fluoride (HF) will ultimately result from the by-products, which may react with the metal oxide to form the metal fluoride. This will be a much stronger Lewis acid and will accelerate the decomposition process.

We estimate that the FLUTEC™ liquids could be used in the presence of iron, copper and aluminium up to about 300° without significant decomposition. In a sealed system it would be worthwhile: degassing the perfluorocarbon liquid to remove oxygen; ensuring metal surfaces are clean and non-oxidised; and guarding against water ingress.

Perfluoroperhydrophenanthrene is a high boiling perfluorocarbon liquid that has been used as a medium for vapour phase reflow soldering for manyyears. In conjunction with this, work has been undertaken to investigate its stability at its boiling point (215ºC) in the presence of metals.

Perfluoroperhydrophenanthrene, refluxed in the presence of water for 60 hours discoloured stainless steal and copper slightly, but without forming HF; no increase in available fluoride was detected. Experiments with various solder fluxes over 12 hours gave similar results, though fluoride availability of the perfluoroperhydrophenanthrene did rise significantly in one case. Other work has indicated that no PFIB is formed in perfluoroperhydrophenanthrene at its boiling point, though up to 2.4 ppb was detected in the presence of certain solder fluxes.

***Table 3** Effect of prolonged reflux on FLUTEC™ PP11*

Reaction with copper filings (1 g in 200 ml of fluid) using another VPS fluid as a control

	Control		Perfluoroperhydrophenanthrene	
	Reactive fluoride µg/ml	Acidity (HF) µequiv/ml	Reactive fluoride µg/ml	Acidity (HF) µequiv/ml
Initial	2	ND	1	ND
After 2 days reflux	68	0.54	1	ND

Plastics and Elastomers

For plastics perfluorocarbons have good compatibility, though some swelling is seen in some cases, specifically silicones and fluoropolymers, such as PTFE. There is no evidence of attack by the perfluorocarbon; we routinely use PTFE on the plant.

Table 4 *Tests on perfluoromethyldecalin done at 12 weeks at 20°C*

Material	% length change	% weight change
Acetal	-0.1	0.2
Acrylic	0.1	0.0
Nylon 6	0.1	0.3
Nylon 66	-0.2	0.3
Nylon 610	0.0	0.1
Perspex	0.2	0.0
Polypropylene	0.1	0.1
Polyethylene	-0.2	0.3
PTFE	0.3	3.0
PVC	-0.2	0.1
Polystyrene		
Polystyrene/acrylonitrile		
Butyl rubber	-0.2	-0.7
Viton A	0.6	0.9
Silicone (Midland 2463)	1.7	1.7

Table 5 *Tests on perfluoro-1,3-dimethylcyclohexane done at 14 weeks at 110°C*

Material	% volume change	% weight change	Hardness change
Natural*	1.46	0.97	1
Styrene-butadiene*	0.37	0.19	2
Butyl	1.21	0.81	6
Chloroprene	0.64	0.48	-2
Nitrile	-1.13	-0.41	4
'Hypalon'	-0.92	-0.13	6
Epichlorohydrin	1.42	0.36	5
Silicone	2.14	0.04	-2
Ethylene-propylene	1.53	0.82	-6
Fluorosilicone	-1.32	-0.28	-1
Polysulphide	1.31	0.92	-1
Polyacrylate	4.31	4.71	-1
Fluorocarbon	1.32	1.21	-1

* Tested at 80°C

Hardness is measured in International Rubber Hardness degrees

Miscellaneous

Testing and experience at F2 has shown that perfluorocarbons have no effect on glass at high temperatures, on paper (tested at 20°C), on cotton and adhesive plastic tape (at 75°C).

AKJ

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