PCTFE **TECHNICAL BROCHURE**

VOLTALEF®

BY ARKEMA

ARKEMA

INNOVATIVE CHEMISTRY

INDEX

PRESENTATION

The polymer chlorotrifluoroethylene or PCTFE is among the oldest industrially manufactured fluoropolymers. ARKEMA manufactures VOLATLEF® PCTFE on the site of Pierre-Bénite near Lyon, France since more than fourty years.

Because of its very special properties :

- good performance at vey low temperatures,
- perfect resistance to oxygen,

VOLATLEF® PCTFE has become irreplacable for specific applications which will be described in this notice.

There are two families of VOLTALEF® :

1. Polymers in the shape of powders or ranules for injection, compression molding or extrusion
2. Oligomers – oils and greases.

The present brochure describes the properties and applications of VOLTALEF® polymers granules and powders.

➤ **The key properties of VOLTALEF® PCTFE are :**

- very broad temperature range of application which includes extremely low temperatures : from – 255°C to + 150°C in continuous use and up to + 200°C as peak temperature,
- high mechanical resistance and in particulat very low creep under compression,
- non-flammable, even in presence of high oxygen concentration (limiti,g oxygen index = 100%),
- very high chemical inertness towards all inorganic chemicals and towards most organic chemicals,
- excellent resistance to ultra-violet and X-ray radiation,
- insensitive to water and moisture,
- very good impermeability to liquids and gases even at low temperatures,
- good thermoplastic properties which allow a transformation according to all classic technologies such as injection molding, extrusion or compression molding,
- transparency even in pieces up to 4 mm thickness in the amorphous state which depends on the transformation conditions.

COMMERCIAL GRADES

The chemical structure of VOLTALEF® series 300 et 302 is the following :

$$(CF_2 - CFCl)_n$$

They correspond to type I, grade 3 according to ASTM D 1430-95 : Homopolymer with ZST at 250°C between 300 and 450.

Grade Dsignation	Presentation	Apparent density	Utilisation	Unit conditioning
VOLTALEF® 302	dense powder 700 microns	1,0	all methods and in particular compression molding	cardboard box with inner sack PE 50 kg

MECHANICAL PROPERTIES

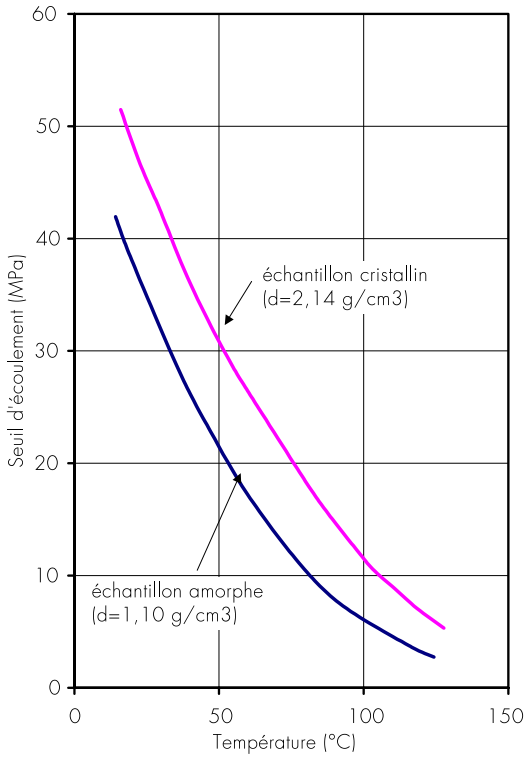
	VOLTALEF® PCTFE	Unit	Test method
Density	2,11 - 2,16		ASTM D1050-68
Yield strength (23°C) Strength at	34 – 50	MPa	ASTM D638
rupture (23°C) Yield strength	32 – 40	MPa	
(120°C) Strength at rupture	3 – 6	MPa	
(120°C) Elongation at rupture	13 - 16	MPa	
(23°C) Tensile modulus (23°C)	100-250	%	
Flexural modulus	1400	MPa MPa	
Modulus in compression	1400	MPa	ASTM D790-80
	1400		ASTM D695-80
Resistance to compression (23°C)			
0,2% off set		MPa	ISO 604
1% deformation	40 – 45	MPa	
	11 - 14		
Module de rigidité en flexion -			
183°C		MPa	ASTM D747-70
- 100°C		MPa	
0°C		MPa	
+ 100°C		MPa	
+ 200°C		MPa	
IZOD impact resistance, notched (23°C)		J/m	
Shore hardness		échelle D	ASTM D526-81
Hardness DIN H 358 (30 sec)		MPa	ASTM D676 DIN
Friction coefficient			53456
			on polished steel
Deformation under load 7 MPa 24 h +			
25°C			ASTM D621
+ 70°C		%	
+ 125°C		%	
		%	

Crystalline and amorphous state

VOLATLEF® is a semicrystalline polymer whose type and degree of crystallinity depend strongly on its molecular weight and thermal history.
Practically it is impossible to obtain after some transformation either 100 % crystalline or 100 % amorphous polymer. It has become conventional to call amorphous a polymer which has been obtained by a rapid cooling in water from its molten state and crystalline a piece which has been cooled slowly. In reality, pieces quneched in water have a degree of crystallinity of approx 30 % and annealed pieces of about 70 %.
The crystallinity of a piece can also be increased by annealing at a temperature between 160 and 200°C.
Amorphous pieces with high transparency have a slightly lower specific mass. Crystalline pieces are opaque and have higher mechanical strength as well as better creep resistance.

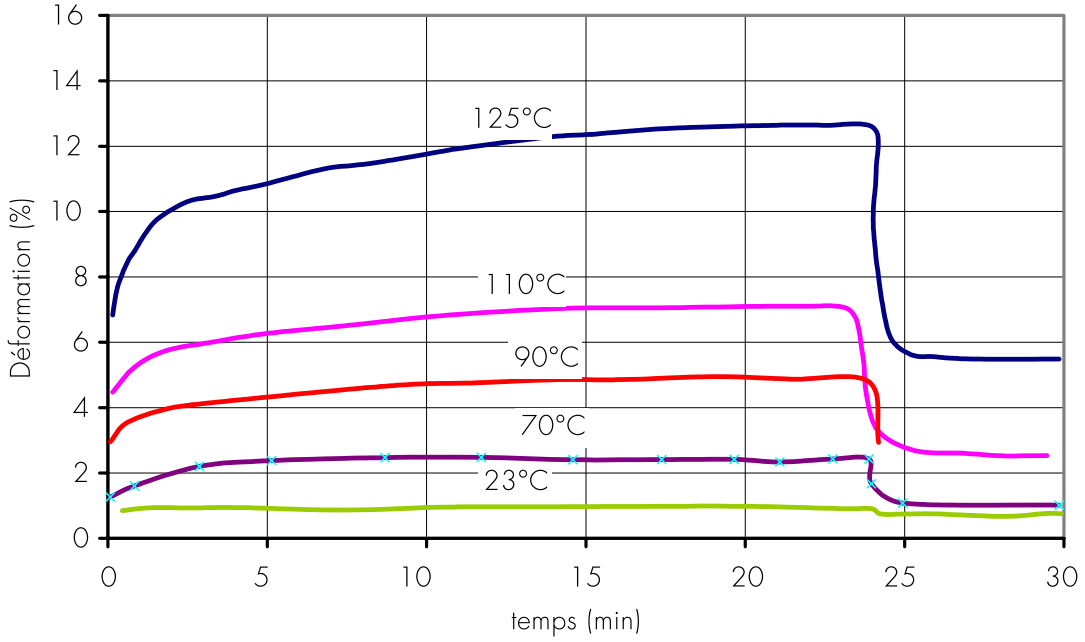
MECHANICAL PROPERTIES

Résistance au seuil d'écoulement à 23°C



Module de compression

Fluage en compression à 7MPa



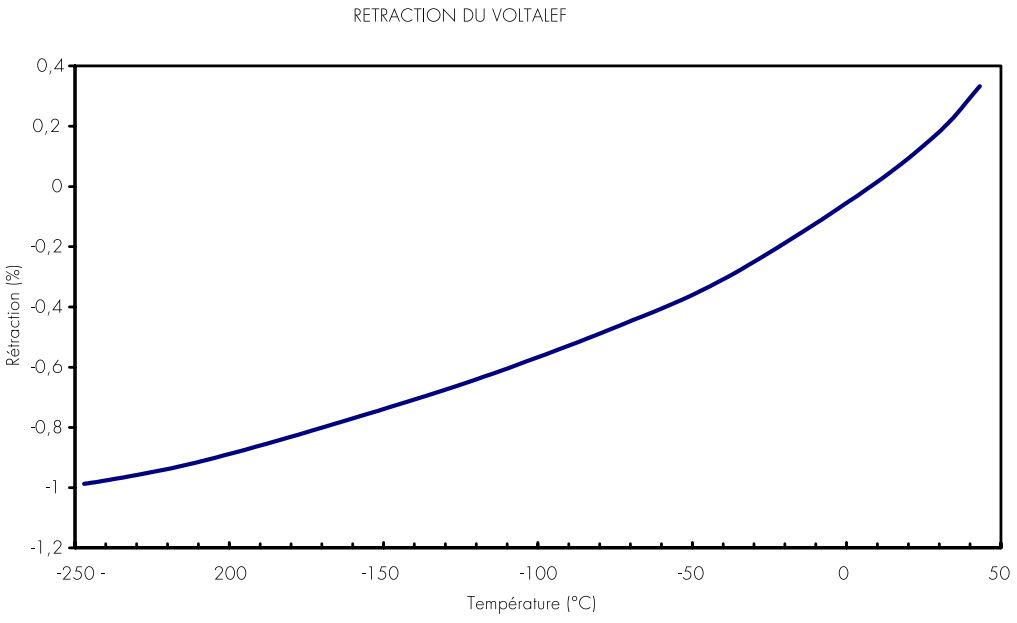
THERMAL PROPERTIES

	VOLTALEF® PCTFE	Unit	Test method
Thermal conductivity	0,135	W / mK	F 433
Specific heat	900	J / kg.K	
Linear expansion coefficient			ASTM D638
from – 80 to + 70°C from	$5,5 \times 10^{-5}$	K^{-1}	ASTM D686-79
+ 70 to + 150°C	25×10^{-5}	K^{-1}	
Heat rsistance			
continuous service	150	°C	
peak temperature	200	°C	
Limiting oxygen index	100	%	
Flammability	non-flammable		

Useful temperature range for applications

The useful temperature range for applications for VOLTALEF® series 300 and 302 is very broad. It starts at a temperature lower than the boiling point of liquid hydrogen (-255°C), and reaches + 150°C in continuous service with allowable peak temperatures up to + 200°C.
For this reason VOLTALEF® PCTFE is considered as the ideal cryogenic polymer. Other its excellent chemical stability which allows its use in the presence of oxygen, VOLTALEF® preserves good properties at low temperatures.

VOLTALEF® has a very low thermal rextraction at low temperatures which is shown in the following graph :



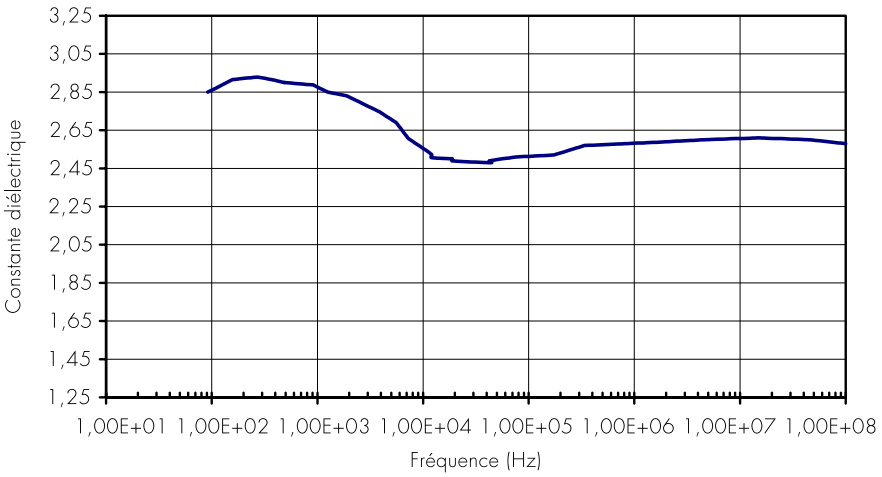
ELECTRICAL PROPERTIES

VOLTALEF® is especially well suited for electric isolation in difficult conditions : tropical climats, arine atmospheres and other. Its electric properties such as a low dielectric constant extremely stable as a function of temperature or frequency are not modified due to a negligible water absorption. Furthermore, VOLTALEF® is not wetted by water. These qualities allow a reduction of the dimensions of the isolating parts.

The electric arc resistance determined according to ASTM D 495-73 is superior to 360 seconds without carbonisation of the electrodes. The Corona effect and sparking are reduced to a minimum thanks to the absence of water absorption.
These advantages are completed by a remarkabledimensionla stability of VOLATLEF® pieces.

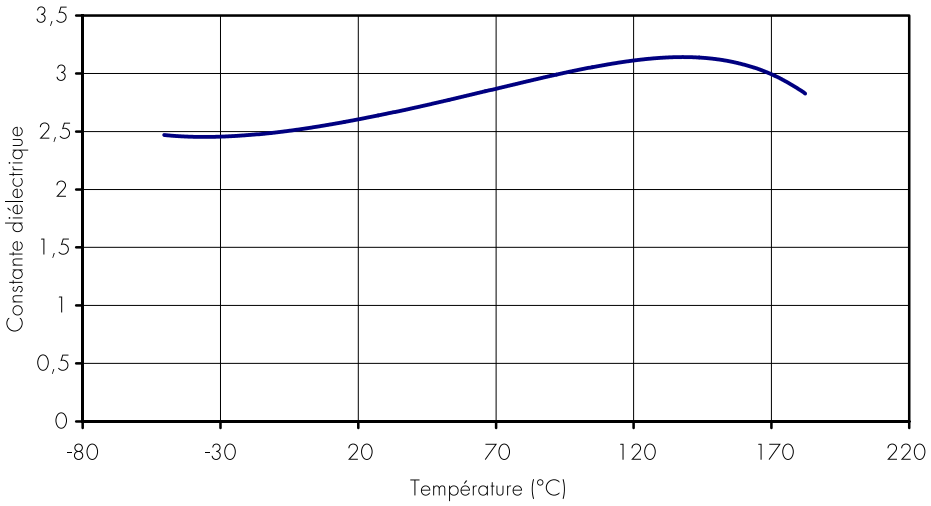
	VOLTALEF® PCTFE	Unit	Test method
Resistivity Arc resistance	$1,2 \times 10^{18}$ 360	Ohm / cm secondes	ASTM D257-78 ASTM D495-73
Electric rigidity			ASTM D149-75
Continuous tension:			
sample 1,6 mm	21	kV / mm	
stepwise tension increase :			
sample 3,2 mm	15	kV / mm	
0,76 mm	48	kV / mm	
0,13 mm	200	kV / mm	
Dielectric constant from 10^2 to 10^8 Hertz	2,4 – 3,0		ASTM D150

CONSTANTE DIELECTRIQUE en fonction de la fréquence à 25°C

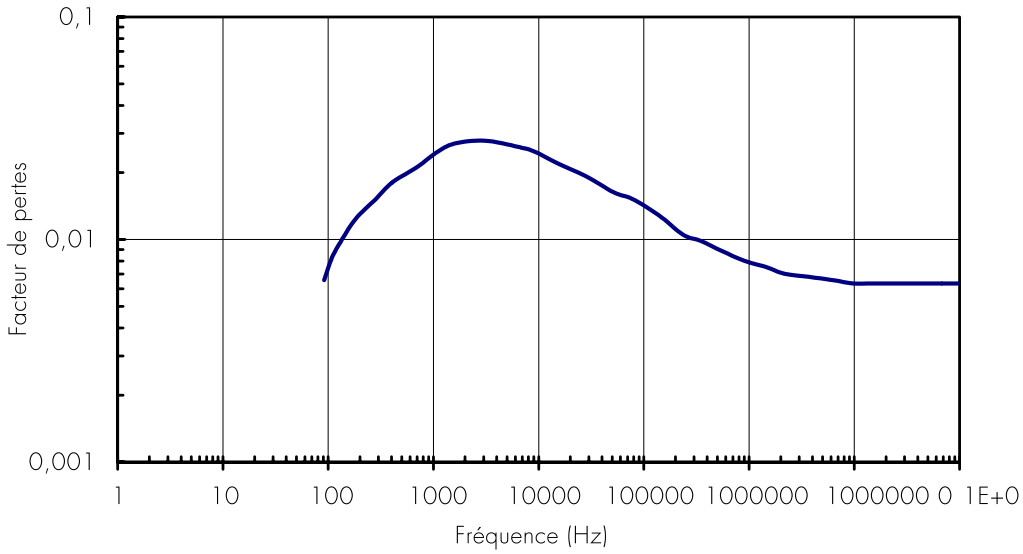


ELECTRICAL PROPERTIES

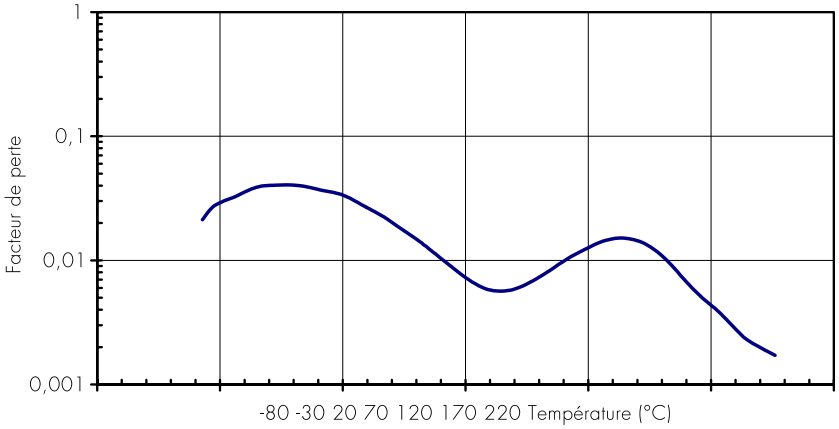
CONSTANTE DIELECTRIQUE = Fonction de la température à 60Hz



FACTEUR DE PERTES en fonction de la fréquence à 25°C



FACTEUR DE PERTES en fonction de la température à 60Hz



No influence of water or moisture

The non wettability and negligible water absorption of VOLTALEF® are two of ots outstanding properties. In water contact or very moist conditions thermal stability remains unaffected and the electrical properties don't change.

Permeability

VOLTALEF® is a very high barrier polymer. Towards air, water, water vapor or numerous other fluids the permeability of VOLTALEF® is among the lowest when compared to other polymers, as shown in the following table :

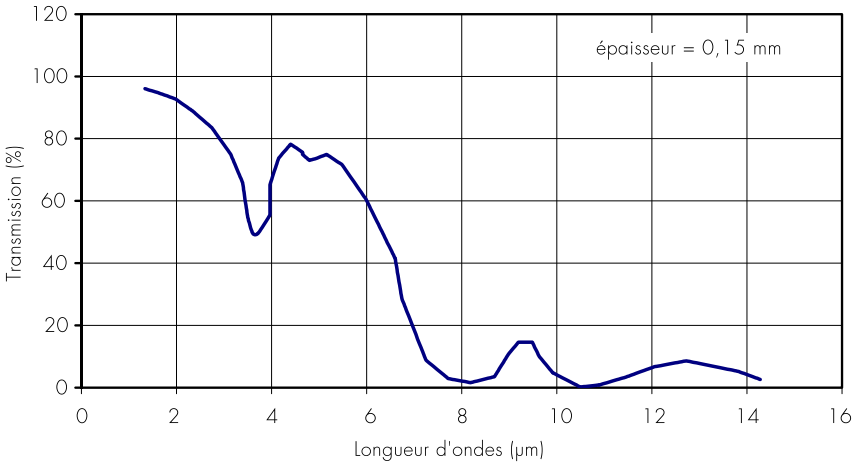
Temperature in °C	N_2	O_2	CO_2	H_2	H_2S	H_2O vapour
0	-	0,07	0,35	3,20	-	-
25	0,05	0,40	1,40	9,80	-	1
50	0,30	1,40	2,40	24,80	0,35	10
75	0,91	5,70	15,00	-	2,00	28
100	-	-	-	-	-	100

permeability unit 10^{10} cm^2 / cm^3 / mm /s / cmHg

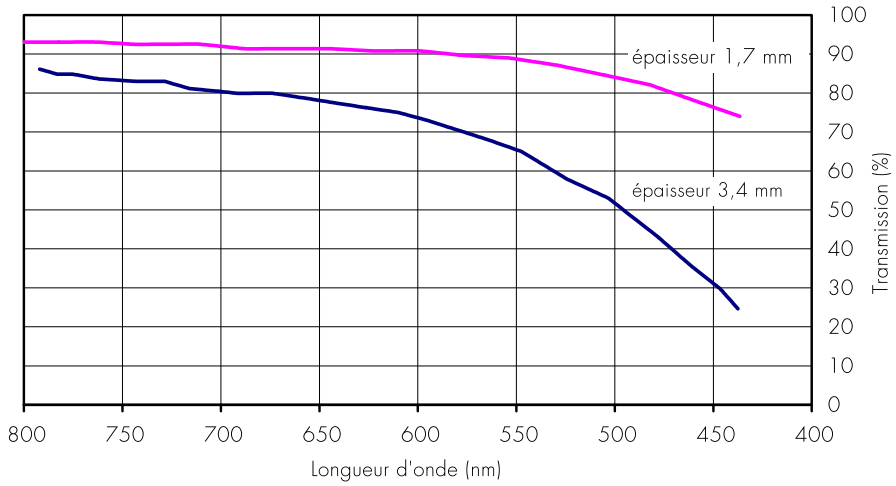
Radiation resistance

The chemical structure of VOLTALEF® results in excellent resistance to different environments and ultraviolet radiation.
When irradiated by intense UV light combined or not with X-rays from a high vacuum lamp mechanical and electric properties are preserved. Certain properties may, nevertheless, be affected when the pieces are subect to ionizing radiation. For instance, a decrease of 50 % in ten,sile resistance is observed after an irradation dose of 50 megarads.

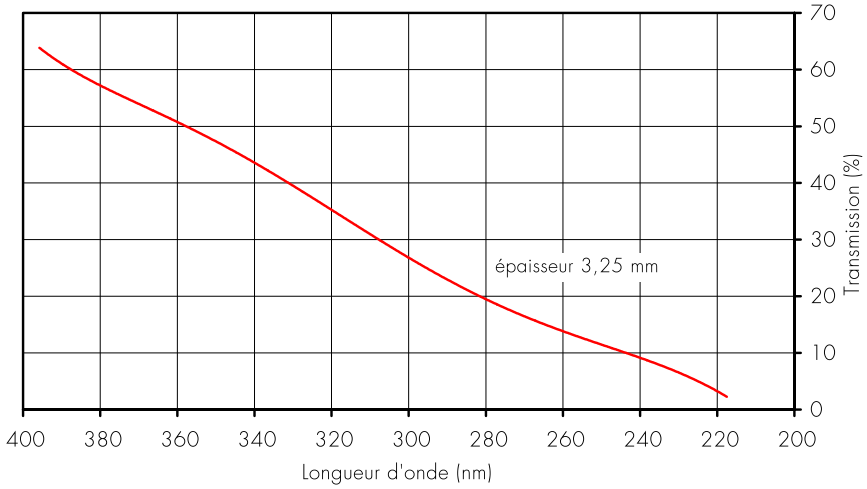
SPECTROSCOPICAL PROPERTIES



SPECTRE LUMIERE VISIBLE



SPECTRE UV



CHEMICAL PROPERTIES

VOLTALEF® presents exceptional chemical resistance properties due to its stable molecular structure. The table below gives a resistance evaluation according to ISO 4433 to various chemicals, the main factor affecting the properties of VOLTALEF® being swelling. The tests were conducted on "amorphous" samples and represent thus the worst case, the crystalline phase being more resistant to chemicals, in particular to swelling.

Chemical	Resistance						
	25°C	50°C	70°C	90°C	100°C	135°C	175°C
Water (ASTM D 570-42)	+	+	+	+	+	+	+
Mineral acids							
Hydrochloric 30%	+	+	+	+	+	+	+
Hydrochloric 37%	+	+	+	+	+	+	+
Chromic	+	+	+	+	+	+	+
Nitric 30%	+	+	+	+	+	+	+
Nitric 53%	+	+	+	+	+	+	+
Nitric 96%	+	+	+	+	+	+	+
Fuming nitric 99,8%	+	+	+	+	+	+	+
Anhydruous hydrofluoric	+	+	+	+	+	+	+
Hydrofluoric 50%	+	+	+	+	+	+	+
Fluorosilicic	+	+	+	+	+	+	+
Eau régale	+	+	+	+	+	+	+
Oleum 20% SO_3 Oleum	+	+	+	+	+	+	+
65% SO_3 Perchloric	+	+	+	+	+	+	+
Sulfuric 96%	+	+	+	+	+	+	+
Sulfuric 50%	+	+	+	+	+	+	+
Sulfuric 30%	+	+	+	+	+	+	+
Sulfuryl chloride	+	+	+	+	+	+	+
Sulfur chlorohydrine	0	0	-				
Anhydrous sulfinic Thionyl	+	+		+	+	+	+
chloride Sulfuric	+	+		+	+	+	+
(saturated) Hydrobromic	+	+		+	+	+	+
48% Arsenic 30%	+	+		+	+	+	+
Phosphoric 100%	+	+		+	+	+	+
Phosphoric 85%	+	+		+	+	+	+
Phosphoric 30%	+	+		+	+	+	+
	+	+		+	+	+	+
	+	+		+	+	+	+

CHEMICAL PROPERTIES

Chemicals	Resistance						
	25°C	50°C	70°C	90°C	100°C	135°C	175°C
Alcohols glycols phenols							
Methanol	+	+					
Ethanol Isopropanol	+	+	+	+	+		
Alcool n butanol	+		+	+			
Ethylene glycol Alcool	+	+	+	+			
furfurylique Glycerol	+	+	+	+	+	+	+
Isoamylic alcohol	+						
Benzylic alcohol	+	+	+	+	+	+	+
Monochloro-glycol	+	+	+	+	+	+	
Cresol	+	+	+	+	+	+	+
Phenol	+	+	+	+	0		
Phenol 5% in water	+						
	+	+	+				
Organic acids	+	+	+	+	+	+	+
Formic 100%							
Formic 37%							
Acetic 100%	+	+	+	+	+		
Acetic 50%	+	+	+	+	+	+	+
Gallic (saturated)	+	+	+	+	+	+	0
Benzoic Trichloracetci	+	+	+	+	+	+	+
Salicylic (saturated)	+	+	+	+	+	+	+
Pyrogallic (saturated)	+	+	+	+			
Oleic	+	+	+	+	+	+	+
Oxalic (sol.10%)	+	+	+	+	+	+	+
	+	+	+	+	+	+	+
Anhydrides and acid	+	+	+	+	+	+	+
chlorides	+	+	+	+	+	+	+
Acaetic anhydride							
Acetoyl chloride							
Benzoyl chloride							
Lauroyl chloride	+	+	+	+	0	-	
Trichloroacetoyl chloride	+						
	+						
Sulfonic acids	+	+		+			
Benzene sulfonic	+	0					
Phenol sulfonic							
	+	+		+	+		
	+	+		+	+		

CHEMICAL PROPERTIES

Réactifs	25°C	50°C	70°C	90°C	100°C	135°C	175°C
Esters							
Acétate de méthyle	+	0					
Formiate de méthyle	+						
Propionate de méthyle	+						
Formiate d'éthyle Acétate	+						
d'éthyle Propionate	+	+	0				
d'éthyle	+						
N butyrate d'éthyle	+						
Laurate d'éthyle Myristate	+	+	+	+	+		
d'éthyle Oléate d'éthyle	+	+	+	+	+		
Ricinoléate d'éthyle	+	+	+	+	+		
Acrylate d'éthyle Formiate	+	+	+	+	+		
de n propyle Acétate de	+	+					
n propyle Propionate de n	+						
propyle Myristate	+						
d'isopropyle Oléate	+						
d'isopropyle Palmitate	+	+	+	+	+		
d'isopropyle Acétate de	+	+	+	+	+		
butyle Sébacate de butyle	+	+	+	+	+		
Acétate d'amyle Phtalate	+	+	0	0	0		
de dibutyle Sébacate de	+						
dibutyle Oléate de	+	+	+				
glycérol Estervitamine F	+	+	+	+	+		
Acétate d'éthylglycol	+	+	+	+	+		
Acétate de vinyle	+	+	+	+	+		
Phosphate de tricrésyle	+						
	+						
	+	+	+	0			
	+	+	+	+	+	+	

CHEMICAL PROPERTIES

Réactifs	Résistance Chimique						
	25°C	50°C	70°C	90°C	100°C	135°C	175°C
Bases minérales							
Ammoniac	+	+	0	-	-		
Ammoniaque 28%	+	+	+	+	+	+	0
Soude 30% Potasse	+	+	+	+	+	+	0
10% Potasse 41%	+	+	+	+	+		
	+	+					
Sels minéraux anhydres							
Tétrachlorure de titane							
Pentachlorure d'ammimoine	+	+	+	0			
	+						
Eléments							
Ozone 5% dans l'oxygène							
Brome		+	+	+	+	+	
Chlore anhydre liquide							
Chlore anhydre gazeux							
Mercure		+	+	+	+		
Soufre		+	+	+	+		
Fluor gazeux		+	+	+	+	+	
		+	+	+			
Agents oxydants							
Eau oxygénée : 100 vol							
Bichromate de potassium		+	+	+	+		
N_2O_4		+	+	+	+	+	+
Sels minéraux en solution							
Aluminium chlorure (sat.25°C)							
Aluminium sulfate 5% Ammonium		+	+	+	+	+	+
chlorure (sat.25°C) Ammonium		0					
sulfate (sat.25°C)		+	+	+	+	+	+
Calcium chlorure (sat.)		+	+	+	+	+	+
Cuivreux chlorure (sat.)		+	+	+	+	0	-
Cuivrique sulfate (sat.) Etain		+	+	+	+	+	+
chlorure		+	+	+	+	+	+
Ferreux chlorure(sat.)		+	+	+	+	+	+
Ferreux sulfate(sat.) Ferrique		+	+	+	+	+	+
chlorure(sat.)		+	+	+	+	+	+
Mercureux chlorure (sat.25°C)		+	+	+	+	+	+
Nickel et ammonium sulfate		+	+	+	0	-	-
Potassium bichromate Sodium		+	+	+	+		+
bisulfate 30% Sodium		+	+	+	+		+
borate(sat.25°C) Sodium		+	+	+	+		+
carbonate 2% Sodium chlorure		+	+	+	+		
10% Sodium phosphate (sat.)							
Zinc sulfate (sat.)		+	+	+	+		+
		+	+	+	+		+
		+	+	+	+		+

CHEMICAL PROPERTIES

Réactifs	Résistance Chimique						
	25°C	50°C	70°C	90°C	100°C	135°C	175°C
Hydrocarbures							
Hexane n	+	+	0	-			
Heptane n	+	+	+	0			
Huile minérale	+						
Cyclohexane	+	+	+	+	0		
Benzène	+	+	0	0	0	-	
Toluène	+	0	0	0	0		
Xylène	+	0	0	0	0	-	
Solvant naphta	+						
Kérosène	+	+	+	+	+		
Dicyclopentadiène	+						
Tetrahydronaphtalène	+	+	+	+	0		
Dérivés halogénés							
Chloroforme	+						
Chlorure de méthylène	+						
Tetrachlorure de carbone	+		-	-	-	-	
Forane 11	-						
Forane 12	0						
Forane 22	0						
Dichloréthane Bromoforme	+	+	+	0	-		
Tétrabromoéthane (sym.)	+	+	+	+	+	0	
Tétrachloéthane (sym.)	+	+	+	+	+		
Tétrachloréthylène Trichloro	+	+	+	0	-		
1.1.2 éthane	+	-	-	-	-	-	
Trichloroéthylène	+						
Forane 122	-	-	-	-	-		
Forane 113	0	-	-	-	-		
Chlorure d'éthylène	0	-	-	-			
Méthylchloroforme	+	-	-				
Pentachloréthane Chlorure de	+						
propylène Chlorure d'allyle	+						
Chloro2propane	+						
Dichloro 1.2 butane Trichloro	+						
1.2.3 propane Chlorure de	+						
benzyle Chlorobenzène	+						
Chlorotoluène (o et p)	+						
Bromobenzène	+	+	+	+	+		
Dichloro1.2hexafluorocyclobuta	+	0	0	-	-		
ne	+						
Dichlorotoluènes (2.4)	+	+	+				
(3.4)	+						
dichlorotrifluorométhylbenzène							
O-dichlorobenzène	+						
	+						
	+	0	-	-	-		
	+	0	0	-	-		

CHEMICAL PROPERTIES

Réactifs	Résistance chimique						
	25°C	50°C	70°C	90°C	100°C	135°C	175°C
Aldéhydes et cétones							
Formol 30%	+	+	+	+	+		
Formol anhydre Chloral	0						
(hydrate de)	+	+	+	+	+		
Benzaldéhyde Acétone	+	+					
Méthyléthylcétone	+	+	0				
Méthylisobutylcétone	+						
Diisobutylcétone	+	+	0	-	-		
Cyclohexanone	+	+	+	+			
Acétophénone	+						
	+						
Ethers oxydes							
Oxyde de méthyle							
Oxyde d'éthyle Oxyde	-						
d'isopropyle Oxyde de	-	-					
n propyle Oxyde de n		+	0				
butyle Furane							
Tétrahydrofurane Dioxane							
Ether dichloréthylique							
Ether diéthylique de l'éthylène		-					
glycol		+	+	+	-		
Dérivés nitrés et soufrés							
Sulfure de carbone							
Nitrométhane Nitrobenzène							
Chloro 1 nitro 1 propane							
Nitrate d'isopropyle							
Diméthylsulfoxyde							
Amines							
Diéthylamine		+	+	+	+	+	
Triéthylamine 25%							
Triéthylamine							
Perfluorotriéthylamine							
Diéthylène triamine							
Aniline							
Xylidine							
Ethylène diamine							
Triéthalonamine		+	+	+	+		
		+	+	+	+		

CHEMICAL PROPERTIES

Réactifs	Résistance chimique						
	25°C	50°C	70°C	90°C	100°C	135°C	175°C
Divers							
Diméthylacétamide	+	+	+	+	+	0	
Diméthylformamide	+	+	+	+	+	0	
Acétonitrile	+	+	+	+	+		
Diméthylhydrazine	+						
Pipérazine	+	+					
Pyridine	+	+	+	0	-		
Pipéridine Benzonitrile	+						
N méthyl pyrolidone	+						
	+	+	+	+	+		
Produits industriels							
Huile Voltalef 1S							
Huile Voltalef 3S Huile	+	0	-	-	-		
Voltalef 10S Fluide	+	+		-	-		
silicone DC 200	+	+					
Skydrol 500	+	+					
Solvant naphta Essence	+	+				+	+
(60-95)	+						
	+	+					

LIMITING THERMAL PROPERTIES AND SAFE HANDLING

Decomposition due to heat

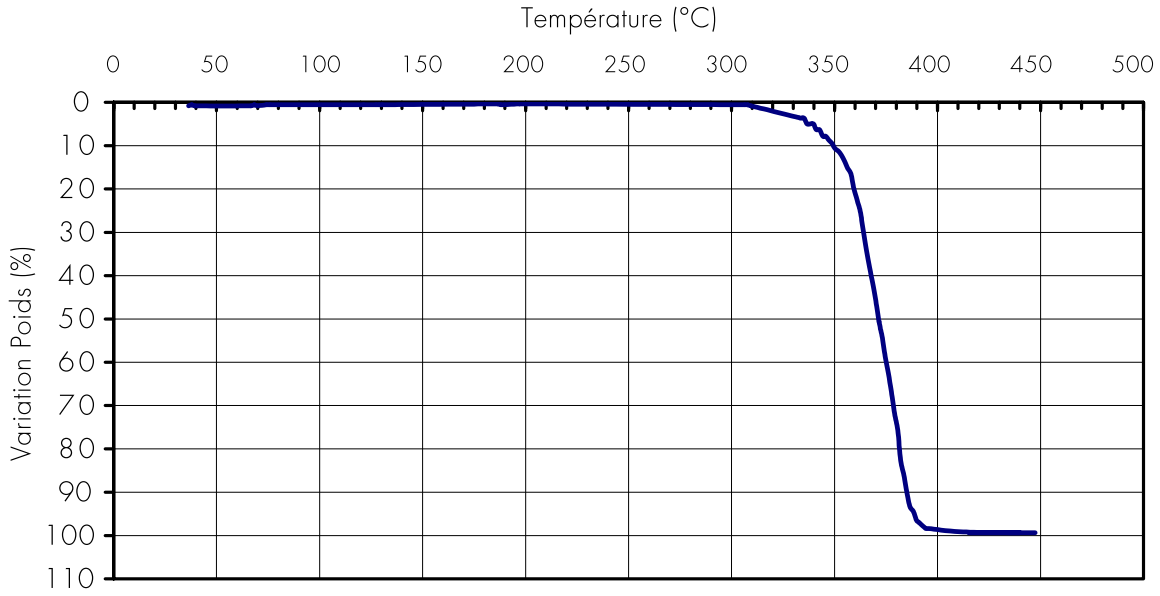
When VOLATLEF® is subject to temperatures superior to 300°C (570°F) a progressive degradation may follow. This decomposition starts around 310°C (590°F) as can be seen in the figure.

This decomposition may create the formation of toxic gases. In the presence of oxytgen and moisture also acids may form. Therefore, during transformation the following basic rules should be followed :

- ensure good ventilation to eliminate all gases ;
- for the machines use only corrosion resistant noble metals just as Hastelloy, Xalloy, Chrome.

Remark : Copper and its alloys may accelerate the decomposition of VOLTALEF® due to a catalytic action and should be avoided.

ATG du VOLTALEF
Conditions opératoires : Montée linéaire 25°C/heure dans l'air



Physiological properties and sanitary precautions

During transformation of VOLTALEF® in particular heating over longer times at or above 300°C (570°F) can result in its decomposition. Certain acid components formed are toxic. Therefore, in particular when working continuously over a period of time, any vapours should be ventilated efficiently. The most efficient way is to suck the vapours where they are created, that is at the places where VOLTALEF® is heated most, such as the orifice of the extruder or the valves of the injection molding press.

1/ Compression molding

The advantage of this technology is allows to manufacture pieces from VOLTALEF® powder with maximized mechanical properties. This technique does not lead to overheating of the material, and it does not induce any preferential orientation. Furthermore, the technique is realized without costly equipment. As a drawback, productivity is small. therefore, the method is applied to the realisation of small or medium series or for the manufacture of massive shapes.

2/ Extrusion

Extrusion of Voltalef®302 allows to obtain pipes or profiles with different shapes. This transformation method implies higher temperatures, thus necessitating a control of the ZST of the extrudate in order to insure that no excessive molecular weight loss has occured.

3/ Injection molding

The technique of injection molding requires a well adapted equipment associated with a high level quality control of the manufactured pieces. Injection molding implies to maintain the molten polymer at an elevated temperature which induces a risk of polymer property degradation which only the measurement of the ZST can reveal easily.
The fundamental principle to be applied in order to prvent the deterioration of the VOLTALEF® polymer is to use a machine press capable of high pressures necessary to inject the polymer at the lowest temperature possible and thus in a very viscuous state.

4/ Machining of semi products

VOLTALEF® polymers thanks to their thermoplasticity can be manufactured directly into the final shape. nevertheless, in many cases (prototypes or small series) it is necessary to shape the finished VOLTALEF® pieces by using different machining techniques and to apply them on available semi products:

Mechanical machining

All techniques habitually applied on metals can also be applied on VLTALEF® : sawing, turning, drilling, milling, grinding, polishing.
Cutting angles should be those of bronze. Cutting speed may be high.

Thermforming

Using either sheets or pipes from VOLALEF® it is easily possible to obtain elbows, fittings, basins and other. The temperature for thermoforming is 240°C.

Welding

Under certain conditions welding is possible. In the case of contact welding the pieces are pressed
for 5 minutes with a pressure of 0,6 bars against the heating mirror at 280°C and then cooled for 5 minutes with an applied pressure of 2 bars. Hot air gun welding is also possible, but very tricky

IMPORTANT APPLICATIONS

Cryogeny and other sectors implying great cold

VOLTALEF® is a thermoplastic which is perfectly suited for all kinds of objects used in the handling of liquid gases and in particular oxygen : joints, pump bodies, valves, seals.
It can be utilized in all types of installations for use in great cold. For instance, an important application is as joints in gasoducts in siberian climats.

Chemical process industry

Other its resistance to great cold and to radiation, VOLTALEF® has a very good compatibility with most inorganic reactants including such strong agressors as fuming nitric acid or hydrofluoric acid.
Moreover, VOLTALEF® has an excellent resistance to creep under compression.

Medical

Its transparency to UV, near IR and X-rays, its insensitivity and impermeability to oxygen allow the use of VOLTALEF® for the protection of drugs or pharmaceuticals sensitive to oxygen, or which need to be sterilized in their packaging : different types of diagnostic apparatus such as blood analyzers.

Military

The insensitivity to oxygen and moisture combined with its wide range of application make VOLTALEF® the material of choice for connectors, antenne isolators and joints in amphibic vehicles, tanks or submarine equipment.

Electricity

Its good electrical insulating properties combined with its zero moisture absorption of VOLTALEF® allow the construction of miniature electrical or electronical comonents with a high reliability for marine or tropical climats or corrosive environments.
Furthermore, the good temperature resistance makes it possible to work intensively with a soldering iron without risk of deformation of the support. Pricipal applications are crossbars and flanges, spigots, adapter plugs and pins, antenna supports and different kind of connectors.

Aerospace, aviation

A special attention must be given for those applications which always require materials of extreme performances.
VOLTALEF® presenting good mechancial and electrical properties even after exposure to intensive UV or X-ray radiation, its excellent thermal resistance and a very low outgasing in high vacuum often provide new solutions to difficult problems.
Also, VOLATLEF® resists to all agents used in propulsion, either liquified gases (oxygen or liquid hydrogen) or other components such as nitric acid, hydrazine or kerosene.
According to the NASA document MSCF 106A PCTFE polymer is suitable for use in contact with liquid oxygen.

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