



**FLUOROPOLYMERS.
PROPERTIES AND APPLICATION**



 HaloPolymer



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AND APPLICATION**



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INTRODUCTION

The beginning of fluoroplast production

in OJSC «HaloPolymer» referred to the middle of the XX century. The first product, which was developed industrially in 1955, is homopolymer of tetrafluoroethylene – fluoroplast-4. This polymer still is a bulk product, well-known among Russian and foreign consumers. Then, producing units of other fluorinated polymers and heteropolymers were created one by one.

In parallel producing units of fluorinated monomers were created and developed. At the present time almost all range of important fluoromonomers for production and modernization of current products, and creation of new ones is produced on OJSC «HaloPolymer».

Next step forward was directed to improvement of output good quality, creation of modified products and increase of production scale.

There are some approaches of process of development:

- 1 Updating of current processes of obtaining of fluoropolymer goods for quality improvement.
- 2 Planning of obtaining new products and modernization of current for specified consumer goals.
- 3 Expansion of production range of goods, made of fluoropolymers, and development of processing of fluoroplast into end products.

**POLYTETRA-
FLUOROETHYLENE**



POLYTETRAFLUOROETHYLENE (F-4, F-4M, F-4D, F-4DM, F-4TG, F-4A, F-4NM)

At the present time OJSC «HaloPolymer» produces

different types of Polytetrafluoroethylene, which is characterized by the way of processing into end products and by fields of application.

So, we produce suspended fluoroplast (F-4, F-4M, F-4TG, F-4An), which is referred to Granular type under ASTM D4894; and dispersive fluoroplast (F-4D, F-4DM), which is referred to Fine Power type under ASTM D4895.

1.1 FLUOROPLAST-4

Polytetrafluoroethylene (F-4, F-4NM, F-4PN-90, F-4PN-40, F-4PN-20) is produced by polymerization of tetrafluoroethylene. It is an easily caked powder of white color. Our enterprise produces a number of Polytetrafluoroethylene grades depending on a mean particle size.

Quality indicator	Grade								
	F-4						F-4PN-90	F-4PN-40	F-4PN-20
	S	P	PN	O	T	NM			
Appearance	Easily caked powder of white color, without visible impurities								
Moisture content, %, no more	0,02					0,05	0,02		
Density, g/cm ³ , no more	2,18	2,19	2,20	2,21	2,20	2,19			
Rupture resistance of untempered sample, MPa (kgf/cm ²), no more	27 (270)	26 (260)	25 (250)	23 (230)	15 (150)	Not defined		25 (255)	
Elongation at rupture of untempered sample, %, no more	350			280		350	400	350	
Electric density, kW/mm, no less	50	60	50	Not defined			60		
Packed density, kg/m ³	350-600 (for reference only)					350-600	350-600	320-550	300-500
Mean particle size, micro	100-200 (for reference only)					350-500 (for reference only)	46-135	21-45	6-20

According to chemical durability PTFE leaves behind noble metals, enamels and special steels. The most aggressive chemical substances (acids, alkalis, oxidizers, solvents) do not affect F-4 even at high temperature.

It is known that only alkali metal melts and their solutions in ammonia, chlorine trifluoride and elemental fluoro at high temperature can affect PTFE.

Goods of PTFE can be used at temperatures from minus 269 to plus 2600C and short moment at temperatures up to plus 4000C. Due to excellent dielectric properties PTFE in a wide temperature and frequency range – a unique dielectric. Dielectric resistance, made of it, is very high – exceeds 10^{16} ohm x cm.

PTFE – a material with sufficiently high mechanical properties. At low temperatures it shows overstability, viscosity and a property of self-lubrication; PTFE preserves flexibility beginning with minus 80°C. Under external stress PTFE has a capacity to cold current (flow effect). In comparison with other plastics PTFE has the lowest friction coefficient on steel (0,04).

When heated above 327°C melting of crystallites occurs, but polymer does not transfer to plastic state up to breakdown temperature (plus 415°C).

APPLICATION OF F-4 IN CHEMICAL INDUSTRY

High chemical resistance, wide range of operating temperatures make fluoroplast-4 an indispensable anticorrosive material in chemical industry. Use of fluoroplast-4 can help to obtain products of high degree of purity in many processes.

Of F-4 can be made: devices, rectification towers, pumps, pipes, valves, bellows, facing tiles, stuffing boxes, etc. When using fluoroplast-4 as a constructional material, it is necessary to take into account dependence of its mechanical properties on temperature (cold flow, etc.)

F-4 IN ELECTRIC ENGINEERING

PTFE is widely used in power industry. As a dielectric, PTFE is applied in equipment of high and ultrahigh frequency. For example, rolled fluoroplast tape is used in production of high-frequency cables, wires, capacitors, for coil insulation, slots of electrical machines and other insulating products.

F-4 IN MACHINE INDUSTRY

PTFE has a very low friction coefficient. Its properties improve with charging (see Chapter Antifriction Compositions On the Basis of Fluoroplast-4).

As a constructional material, fluoroplast-4 is applied in production of different components of machines and devices. Fluoroplast is widely used in production of bearings, running dry, with limited lubrication and in the presence of corrosion environment (liquid or gaseous).

F-4 IN MEDICINE

Absolute biological and chemical inertness defines wide and ever-growing use of PTFE products in cardiovascular and other field of plastic surgery.

Clinical practice shows that PTFE products considerably (in 2-3 times compared to other plastic materials) reduce time of reactive tissual processes, and also do not cause fibrin accumulation and thrombosis on its surface.

Fluoroplast-4 is applied for production of tanks for reception of coronal blood and containers with antifoamer to heart-lung machine. Also, fluoroplast-4 is used in production of holders of mitral valve prosthesis, facilitating the replacement of damaged natural valve with artificial ones.

OTHER APPLICATION FIELDS OF FLUOROPLAST-4

Combination of physiological inertness and anti-adhesive allows to apply fluoroplast-4 in food industry (for pastry forming, etc.).

Antiadhesive property can be used in apparatus for production and application of glue matters (e.g. in paint-and-varnish industry).

Good mechanical properties of fluoroplast-4 at subzero temperatures can be used in refrigerating engineering.

1.2 FLUOROPLAST-4M

Fluoroplast-4M (F-4M) is also a product of polymerization of tetrafluoroethylene with modification. F-4M has the same properties as F-4, but along with it has over stability, lesser porosity, higher durability to bending (by alternate loads).

Fluoroplast-4M is applied in the same fields, as fluoroplast-4. Our enterprise produces the following grades of F-4M:

Indicator name	Grade				
	F-4M	F-4ML	F-4MT	F-4MO	F-4MN
Appearance	Easily caked powder of white color, without visible impurities				
Moisture content, %, no more	0,02				
Density, g/cm ³ , no more	2,18	2,19	2,20	2,22	
Rupture resistance of unhardened sample, MPa (kgf/cm ²), no more 28 (287)	28 (287)	24 (245)	15,7 (160)	10 (102)	
Elongation at rupture of unhardened sample, %, no more	310	400	350	150	
Electric density, kW/mm, no less	60	30	Not normalized		

1.3 FLUOROPLAST-4D

Fluoroplast-4D (F-4D) is a product of polymerization of tetrafluoroethylene. It is a finely divided modification of polytetrafluorethylen, having lesser molecular weight than F-4. Properties of F-4D and fluoroplast-4 are almost the same. Our enterprise produces the following grades of F-4D:

Indicator name	Grade of F-4D				
	Sh	L	E	T	U
Appearance	Fine fluffy powder of white color				
Moisture content, %, no more	0,02				
Density, g/cm ³ , no more	2,21		2,23		2,24
Rupture resistance of unhardened sample, MPa (kgf/cm ²), no more	24 (244)	22,5 (230)	20,6 (210)		13,2 (135)
Elongation at rupture of unhardened sample, %, no more	350		340	330	250
Plasticity, %, no less	15		Not normalized		

Fluoroplast-4D unlike F-4 can easily be processed with extrusion. It allows to produce products of F-4D, which can not be obtained of F-4 (thin-walled tubes, film coatings) or only hardly (tubes, bars, etc.).

Application of F-4D allows to make production of goods of Polytetrafluoroethylene more productive and cost effective.

Fluoroplast-4D as a fluoroplast-4 is applied in chemical, electrical, food and other industries. Fluoroplast powder is used for production of fluoroplast sealing material (FSM), thin-walled tubes, wire insulation, thread tapes and other products. Insulating products of F-4D are used in wide temperature and pressure range (FSM – at minus 60°C to plus 150°C and at pressure up to 64 atm).

1.4 FLUOROPLAST-4DM

Fluoroplast-4DM (F-4DM) – modified polytetrafluorethylen, obtained by polymerization of tetrafluoroethylene with modification. We produce the following F-4DM grades:

Indicator name	Grades of F-4DM		
	E	T	O
Appearance	Fine fluffy powder of white color		
Mean particle size, micron	350-650		Not normalized
Moisture content, %, no more	0,02		
Density, g/cm ³ , no more	2,21	2,23	2,30
Rupture resistance of unhardened sample, MPa (kgf/cm ²), no more	21,0 (214)	19,0 (194)	12,0 (122)
Elongation at rupture of unhardened sample, %, no more	330	300	150
Plasticity, %, no less	7,0	4,0	Not normalized
Extrusion pressure, MPa, no more, K com = 1600	660	800	

Modification allows obtaining a polymer, which unlike F-4D can be processed at higher compression ratio (up to 2000:1), that allows to increase productivity of processing and end product quality.

1.5 FLUOROPLAST-4TG

Fluoroplast-4TG by definition is PTFE-SS with subsequent grinding. This grade of fluoroplast is used for processing with ram extrusion method for obtaining of rods and cups of exact size.

At the present time we produce two grades of F-4TG:

Indicator name	Grades of F-4DG	
	Grade 1	Grade 2
Appearance	Grains of white color without visible impurities	
Packed density, g/dm ³	600–800	450–800
Mean particle size, D ₅₀ , micron	600–800	Not normalized
Flowability, sec, no more	Not normalized	7
Flow index, sec	12–16	Not normalized
Fractional makeup, %, no more:		
- fraction more 1 mm;	Not normalized	50
- fraction less 0,25 mm		40

1.6

FLUOROPLAST-4A

Fluoroplast-4A is a free flow polymer and has all properties of F-4. It is more producible in processing, does not cake and stick together in storage and transportation.

F-4A is used for obtaining of products of exact size with methods of automatic, isostatic and compression pressing and ram extrusion. Fluoroplast-4A has the same properties as F-4.

We produce F-4A with the following performance index:

Indicator name	F-4A		
	Grade 1	Grade 2	Grade 3
Appearance	Free flow powder of white color		
Moisture content, %, no more	0,02	0,02	0,03
Packed density, kg/m ³ , no more	710	690	670
Density, g/cm ³ , no more	2,19		
Grain-size composition of polymer, %, no more			
- mass content of sieve residue 1K;	15	20	35
- mass content of residue after screening through sieve 0,20K	5	11	15
Rupture resistance of unhardened sample, MPa (kgf/cm), не менее	26 (265)	21 (214)	21 (214)
Elongation at rupture of unhardened sample, %, no more	310	275	250



**ANTIFRICTION
COMPOSITIONS
ON THE BASIS
OF FLUOROPLAST-4**



OJSC HaloPolymer

produces fluoroplast compositions with various fillers. Products and goods, produced by us, are almost as good as analogues of leading foreign enterprises.

For increasing of hardness, heat conductivity, abrasion hardness, reduction of deformation under load and coefficient of heat expansion, various fillers, which can stand processing temperature of 360°C, are added to fluoroplast-4.

The enterprise produces sub products of antifriction purpose on the basis of fluoroplast-4 with various fillers, that is: F4K20 (filer of 20% charcoal), F4K15M5 (filler of 15% charcoal and 5% molybdenum disulfide), F-4S5 (filler of 15% fiberglass).

Produced compositions have the following performance index:

Indicator name	F-4K20		F-4K15M5		F-4S15		F 4UV15
	Superior quality	First quality	Superior quality	First quality	Superior quality	First quality	
Density, g/cm ³ , no less	2.05	2.00	2.10	2.05	2.18	2.15	1.95
Rupture resistance of untempered sample, MPa (kgf/cm ²), не менее	12,7	11,7	13,7	11,7	12,7	9,8	15
Elongation at rupture of untempered sample, %, no more	120	65	150	100	220	150	
Wear rate (load 2,5 MPa. Linear speed 1m/s), g/h, no more	1,5×10 ⁻³	2,0×10 ⁻³	0,8×10 ⁻³	1,2×10 ⁻³	2,0×10 ⁻³	3,0×10 ⁻³	2,0×10 ⁻³

In agreement with consumers production of sub products of fluoroplast-4 with other fillers is possible



**FLUOROPLAST
SUSPENSION**



Fluoroplast suspensions

are aimed to obtain chemical- and heat-resistant antiadhesive, antifriction and anticorrosive coats, proofing for different materials, unsupported films, enameled wires, elastic containers, film-clad dielectrics, hand hoses for transportation of aggressive liquids and other goods.

They differ from each other by specific combination of properties, conditioning certain application field.

At the present time F-4D, F-4DU, F-4DV, F-4DP suspensions are produced as a commercial product of OJSC HaloPolymer.

F-4D, F-4DU, F-4DV, F-4DP SUSPENSIONS

Fluoroplast suspensions are used for obtaining of coats, proofing and unsupported films. Suspensions are slurry of Polytetrafluoroethylene particles (0.06-0.4 micron) in water with 6-12% of surface-active material (of dry polymer weight).

Our enterprise produces the following types of suspensions on the basis of F-4D:

Наименование показателя	Марки			
	F-4D	F-4DV	F-4DU	F-4DP
Appearance	Liquid from white to light-yellow	Liquid from white to light-yellow	Liquid from white to light-brown	Liquid from white to light-yellow
Mass content of nonvolatile substances, %, no less	50	55	55	55
Funnel viscosity, sec, in limits	Not defined	45-65	Not defined	Not defined
Ion concentration (pH), in limits	Not defined	9,5-10,5	4,0	Not defined
Mass content of stabilizer (to solid), %, in limits	6-12	2-4	Not defined	Not defined
Resistance in rapture of unsupported films, MPa (kgf/cm ²), no less	30 (305)	30 (305)	25 (250)	Not defined
Elongation. %, no less	300	280	300	Not defined

According to appearance this is a milky liquid from white to yellowish color, in which formation of residue is possible, for removal of which suspension should be shaken by hand or in rocking gear. It is prohibited to shake suspension with rabble, as it results in inconvertible coagulation. Coats on metals and other material, which can stand 370°C, can be received from F-4D, F-4DU suspensions. These coats can be used as antifriction, anti-adhesive, anticorrosive (for protection from atmosphere corrosion, but not from aggressive environment), electroinsulating coats. All metals can be covered (steel, nickel, chrome, cadmium, argentums, aluminum) except copper and copper alloys.

Coat of F-4D, F-4DU suspension is spread by dipping, pulverizing, application and by brush. Its thickness usually exceeds 1-15 micron, that's why multiple coating is spread with drying and agglomerating of each layer. Drying is in air, in thermostat or under infrared lamp at temperature not higher 100°C. To obtain uniform and flawless, coat, up to 10 layers of suspension, thickness up to 100 micron should be spread, dried and baked consecutively. In many cases (anti-adhesive and antifriction coats) 2-3 layers of suspension is enough. Film coating after alloying is transparent or cloudy, smooth without cracks, white or light-yellow.

Adhesion of F-4D, F-4DU suspension to metal is not high (adhesion is lower in tempering of coat than cool coat); it can be significantly increased by adding in suspension some fillers.

In application on aluminum to 90 parts by weight 60% suspension 10 parts by weight of chromic acid 100 parts by weight of water are added, at that adhesion increases in about 6 times %, and in application on steel to 70-80 parts by weight 60% suspension 10-15 parts by weight of chromic acid and 10-15 parts by weight of phosphoric acid are added, then adhesion increases in 30-40 times.

Recommended field of Fluoroplast suspension application: grade F-4D, F-4DU – to obtain electroinsulating, antifriction, antiadhesive coats.

APPENDICES

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Polytetrafluoroethylene and Polytetrafluoroethylene compounds

Name	Properties		Application	Analogues
	Mean particle size, micron	Packed density, kg/m ³		
Suspended PTFE				
F-4 (PN)	100-180	450-520	For production of electrical products and safety-first	Algoflon® G10, G50
F-4 NM	120-250	450-530	For production of general-purpose products	NO ANALOGUES
F-4PN90	46-135	450-500	For production of safety-first	Tarflen® SM-2
F-4PN40	21-45	350-420	For production of light films, sheets, field-specific products	Teflon® 7A, 7B, 7C; Tarflen® SM-1, Dyneon® TF1750; Fluon® G155, G163; Algoflon® F5, F5/S, F6, F7
F-4PN20	6-20	350-420	For production of light films, sheets, field-specific products	
F-4M	70-110	150-550	For production of safety-first, resistant to reversed loads	Teflon® NXT70, NXT75, Algoflon® F3140X, Dyneon® TFM 1700, TFM 1705, TFM 1600
F-4A	550-780	400-500	For obtaining of products with automatic pressing and ram extrusion	Teflon® PTFE 8, 8A, 8B, 850-A; Algoflon® S111, S121, S131; Dyneon® TF1620, TF1641, TF1645; Tarflen® SG-1, SG-2; Fluon® G401, G307, G320.
F-4TG	600-800	600-800	For product processing with ram extrusion method	Teflon® 9B; Tarflen ST; Algoflon® E2, E2BP; Fluon® G201, G204; Dyneon® 1105, 1502
PTFE compositions				
F-4K20			For various products of antifriction purpose, friction bearings, sealing cups, operating at minus 60 – plus 260°C	Tarflen® SM-K25, SM-K22G3
F-4K15M5				NO INFORMATION

Name	Properties		Application	Analogues
	Mean particle size, micron	Packed density, kg/m ³		
Finely divided PTFE				
PTFE compositions				
F-4D	650–900	450–500	For production of cable insulation, FSM, pipes, tubes, strips	Teflon PTFE 6, 60,62; Fluon® CD123, CD127, CD141; Polyflon® F-104, F-104U, F-107; Tarflen® DN-R, DN-T
F-4DM	400–600	390–450	For production of thin-walled tubes and cable insulation under high compression from 400:1 to 2000:1	Teflon PTFE 6C; Tarflen® DE; Fluon® CDo84, CDo86, CD126; Dyneon®TF 2025, 2071

Properties of fluoropolymers

Property	F-4	F-4D
Electrical properties		
Volume resistivity, Ohm/m	$10^{15}-10^{18}$	$10^{14}-10^{18}$
Surface resistivity, Ohm	$>10^{17}$	$>10^{17}$
Loss-angle tangent		
at 1 kHz	$(2-2,5) \cdot 10^{-4}$	$(2-3) \cdot 10^{-4}$
at 1 MHz	$(2-2,5) \cdot 10^{-4}$	$(2-3) \cdot 10^{-4}$
Permittivity		
at 1 kHz	1,9-2,1	1,9-2,2
at 1 MHz	1,9-2,1	1,9-2,2
Dielectric strength (sample thickness 2 mm), MV/m	25-27(4 mm)	25--27(4 mm)
Arc resistance, c	250-700	250-700
Physical properties		
Density, kg/m ³	2150-2190	2190-2260
Melting point of crystallites, °C	327	327
Transformation point, °C	-120	-120
Vicat softening point, °C	110	
Specific heat, kJ/kg*K	1,04	1,04
Conductivity factor, W/mK	0,25	0,29
Temperature coefficient of line expansion, $\cdot 10^{-5}$, 1/°C	8-25	8-25
Operating temperature, °C		
minimum	-269	-269
maximum	260	260
Mechanical properties		
Rupture resistance, MPa	14,7-33	12,7-30
Elongation at rupture, %	250-500	250-500

Property	F-4	F-4D
Plastic modulus , MPa		
Under expansion	410	410
Under compression	680	680
Under static bending		
At 20°C	460–830	440–830
At minus 60°C	1290–2700	1370–2700
Breakdown voltage , MPa		
Under compression	11,8	11,8
Under static bending	10–14	10–14
Resilience, kJ/m ²	125	125
Brinell hardness, MPa	29–39	29–39
Friction coefficient on steel	0,04	0,04
Other properties		
Breakdown temperature	More 415	More 415
Heat stability (weight loss), %	0,2 (420 °C, 3 hours)	–
Persistence to chemical agent activity		
Concentrated acids	C	C
Organic solvents	C	C
Alkalis	C	C
Oxidizer (hydrogen dioxide)	C	C
Burning quality	Does not burn	Does not burn
Burning quality under oxygen index, %	95	95
Radioresistance, Gr	0,5–2 * 10 ⁴	0,5–2 * 10 ⁴





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