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Product Range, Properties, and Application of Fluoropolymers Manufactured in Kirovo-Chepetsk Chemical Industrial Complex

Z. L. Baskin, D. A. Shabalin, E. S. Vyrazheikin, and S. A. Dedov

Limited Liability Co "Polymer Plant of the Konstantinov Kirovo-Chepetsk Chemical Industrial Complex,"
a/ya 7, Kirovo-Chepetsk, Kirovskaya obl., 613040 Russia
phone/fax: (83361)9-44-01
e-mail: zampol@kckk.ru

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Abstract—The main historical stages of development in the USSR of industrial production of fluoroplastics and organofluorine materials are outlined. Physical, chemical and biological properties of fluoroplastics and fluoroelastomers are described. Examples of efficient application of fluoropolymers in chemical and natural gas industry, power production, and medicine are cited. The review is intended for specialists in fluoropolymers application.

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Some Aspects of the History of Development of Fluoropolymers Production at Russian Plants

Fluorine-containing products, Freons, fluoromonomers, fluoroplastics, fluororubbers, fluorocarbon fluids and lubricants, fluoroderivatives of hydrocarbons, found extensive applications in science and engineering [1].

The first industrial production of a fluorpolymer, Teflon, poly(tetrafluoroethylene), was started in nineteen forties in the USA. The product was intended for the use in the chemical and electrochemical industry and for the research laboratories taking part in the development of the nuclear weapon.

In the USSR the research on designing a pilot plant for production of fluoroplast-4 (F-4) started in 1948. On a command of the Council of Ministers of the USSR the State Institute of Applied Chemistry (GIPKh, Leningrad) was ordered to develope a tetrafluoroethylene production of a capacity 10 kg daily, and the Research Institute of Polymerized Plastics (NIIPP) was ordered to design and mounte an installation capable to polymerize tetrafluoroethylene and produce 10 kg daily of poly(tetrafluoroethylene). NIIPP must also develop the procedures for processing the poly(tetrafluoroethylene) powder into plastic goods. It concerned first of all the production of flange gaskets in keeping with the technical requirements and designs of the Laboratory no. 2 of the Academy of Sciences of the USSR headed by I.V. Kurchatov (now the Russian Scientific Center "Kurchatovskii Institute") [2].

In 1951 the staff of the plant no. 752 in Kirovskaya oblast (this number belonged then to the Kirovo-Chepetsk Chemical Plant, KChKhZ) together with the scientists of GIPKh and also in collaboration with NII-42 (now FGUP "GosNIIOKhT," Moscow) began the implementation of the industrial production of Freon-11 and Freon-12 to be used as cooling agents in industrial and domestic refrigerators, and also of Freon-22, necessary for the production of tetrafluoroethylene and fluoroplast-4. The preliminary work began at KChKhZ for building up the large-scale production of F-4 [3].

A complex ofa high-tech production installations was built providing hydrogen fluoride, chlorine, chloroform, difluoromethane (Freon-22), and tetrafluoroethylene. To maintain the building and to guaranty the stable functioning of the chemical complex a powerful mechanical-repair department, a construction-repair, an electrical-repair shops and a department for repair of monitoring devices were erected. To support the new production lines competent services were organized: the central laboratory of the plant, the design department, the experimental design office for monitoring devices and production automation, the laboratory for testing fluoroplastics, and experimental mechanical laboratory.

A significant contribution into the refining of fluoropolymers production was made by a number of academical and industrial research centers (GIPKh, NIIPP, Ioffe Physicotechnical Institute of RAS, Semenov Institute of Chemical Physics of RAS etc.).

In September 1956 at KChKhZ the first in the USSR large-scale industrial production of fluoroplast-4 was started, and in April 1961, the production of fluoropolymers [4]. The fluoroplastics were considered the best of plastics. Academician I.L. Knunyants, one among the leadings domestic specialists in the field of the chemistry of fluorine and its compounds, said that "The fluoroplastics are materials with the eagle heart and rhinoceros skin" [5].

In 1966 Ural Chemical Plant (now Public Joint-Stocks Co "Galogen," Perm) started to produce fluoroplastics-4 and 4D. At KChKhZ, Ural Chemical Plant, Nizhnii-Tagil Plastics Plant "Uralkhimplast" and in some other places were built shops for goods production from fluoroplastics. KChKhZ and Ural Chemical Plant learned to produce fluoropolymer articles for atomic, cosmic, aircraft, electrical engineering, chemical industries and other industrial branches. By the production capacity, products range, and quality the fluoropolymers of KChKhZ and Ural Chemical Plant reached the level of world standards.

In 1973 owing to the building of the chemical fertilizers plant KChKhZ was reorganized into the Kirovo-Chepetsk Chemical Industrial Complex (KChKhK). The KChKhK is combined of four plants: polymer plant, fertilizer plant, mechanical and repair plant, and construction and repair plant. Kirovo-Chepetsk Chemical Industrial Complex is one of the largest chemical enterprises of Russia possessing its own research, design, mechanical, electrical engineering, construction, repair, and transportation facilities.

Product Range and Properties of Fluoropolymers

The KChKhZ manufactures on an industrial scale a wide range of fluoroplastics and fluororubbers, as follows:

– fluoroplastic-4 [suspension poly(tetrafluoroethylene)];

– fluoroplastic-4D [emulsion poly(tetrafluoroethylene)];

– fluoroplastic-4NTD [low-molecular finely dispersed poly(tetrafluoroethylene)];

– fluoroplastic-4MB (copolymer of tetrafluoroethylene and hexafluoropropylene);

– fluoroplastic-40 (copolymer of tetrafluoroethylene and ethylene);

– fluoroplastic-42 (copolymer of tetrafluoroethylene and vinylidene fluoride);

– fluoroplastic-2 [poly(vinylidene fluoride)];

– fluoroplastic-2M [modified poly(vinylidene fluoride)];

– fluoroplastic-50 (copolymer of tetrafluoroethylene and perfluoroalkyl ether);

– fluoroplastic-1 [poly(vinyl fluoride)];

– fluoroplastic-3 [poly(trifluorochloroethylene)];

– fluoroplastic-3M [modified poly(trifluorochloroethylene)];

– fluoroplastic-32 (copolymer of trifluorochloroethylene and vinylidene fluoride);

– fluororubber SKF-32 (high-molecular elastic copolymer of trifluorochloroethylene and vinylidene fluoride);

– fluororubber SKF-26 (high-molecular elastic copolymer of vinylidene fluoride and hexafluoropropylene) [6].

Fluoroplastics are characterized by unrivaled chemical stability, outstanding insulating properties, and best among the plastics heat and frost resistance, they are very stable against atmospheric influence, biologically inert, possess low friction constant and low thermal diffusivity [6].

The fluoropolymeric products manufactured at the polymer plant of the Kirovo-Chepetsk Chemical Complex are characterized by a complex of unique physical, chemical, and biological properties, among them the following:

– unmatched chemical, heat and frost resistance, dielectric properties, and biological inertness of items manufactured from fluoroplastic-4;

– high radiative stability of goods from fluoroplastics-40, -30, -2M;

– enhanced adhesion to metals of articles from fluoroplastic-4M and porous articles of F-4;

– selective solubility and opportunity to apply anticorrosion, anti-adhesion, and anti-icing coatings based on fluoroplastic lacquers LF-42L, LF-32L, FPR;

– constant in time diffusion permeability of films and membranes of fluoroplastics F-4MB, F-40;

– transparency in the infrared region (from 1 to 5 μm) of films and plates of F-3M, F-3, F-4, F-10, F-50, F-100, F-400;

– transparency in the visible region of goods of F-3M, F-3, F-32L, F-4MB, F-50, F-10, F-100,F-400;

– transparency in the ultraviolet region (200–400 nm) of goods of F-3M, F-32L, F-3, F-10, F-100, F-400;

– sufficient for many applications thermal and electric conductivity of articles from composites of F-4 and F-40 with carbon;

– ion-exchange properties of sulfocationite fluoropolymer membranes: films MF-4SK and tubes TF-4SK;

– considerable specific surface of powders from fluoroplastics F-40B and F-4DRS making them suitable for chromatographic sorbents and carriers;

– efficiency of some fluorocarbon and fluorochlorocarbon fluids as stationary phases for gas chromatography providing for selective separation of gas mixtures [6–9].

Porous articles manufactured from fluoroplastic-4 are applied as filteres, sampling devices, throttles, membranes in diffusion batchers, dilutors, leak valves, simulators of gas and vapor leakage [10—12]. The properties of fluoropolymers produced at the polymer plant of KChKhK are compiled in Tables 1 and 2 [7].

Fluoroplastics F-10, F-100, F-400, and also fluoroplastic lacquer FPR and other, fluoroplastic films with ion-exchange properties MF-4SK and tubes TF-4SK were developed at ONPO "Plastpolymer" and put into production at its pilot plant.

The polymer plant of KChKhK manufactures a wide range of fluororubbers based on copolymers of trifluorochloroethylene with vinylidene fluoride, SKF-32, and of vinylidene fluoride with hexafluoropropylene, SKF-26. They were designed in NIIRP (Moscow) and NIISK (Leningrad) in collaboration with KChKhZ. The industrial production was implemented at KChKhZ. The fluororubbers of KChKhZ found industrial-scale application in various branches of engineering, science, agriculture, and municipal construction [13]. The chemical resistance of fluororubbers produced at KChKhZ is higher than that of any known elastomer. They are stable against concentrated and diluted mineral acids, many aliphatic and aromatic hydrocarbons, their chloro- and fluoroderivatives, gasoline, various oils, lubricants, natural gas. Owing to the solubility of fluororubbers in some ketones and esters they are used in the manufacture of sealants and adhesives. Fluororubber lattices are applied to making protective coatings and to impregnating fabrics and leather to supply them with hydrophobicity.

The specific features of the fluorocarbon elastomers based on fluororubbers SKF-26 and SKF-32 and on their modifications are the high heat resistance (up to +250°C for SKF-26) exceeding that of all known rubbers save silicones, high frost resistance (down to –50°C for SKF-260); high weather-resistance and ozone-resistance; chemical and biological inertness, exceeding these characteristics of all other elastomers; good wear-resistance and abrasion resistance; fair dielectric properties, incombustibility; resistance to ageing at high temperature [13, 14].

The quality parameters of manufactured fluororubbers and the comparison of vulcanized rubber characteristics obtained from fluororubbers and natural rubber are presented in Tables 3 and 4 [7].

Application of Fluoropolymers

Fluoroplastic Equipment for Chemical Industry

The industrial production of fluoroplastic-4, fusible fluoroplastics, and fluororubbers at KChKhZ and further at the polymer plant of KChKhK made it possible to start a production of fluoroplastic apparatuses, pipes, fittings, pumps, seals, construction materials and goods for anticorrosion protection of technological equipment. The manufacture of these products was performed in a specially constructed shop of capacity reaching several thousand tons of fluoroplastic articles annually. The specification of the manufactured goods, they technical parameters, and application fields are compiled in catalogues [15–17], the processing of fluoroplastics into articles is described in the book [18].

Table 1. Chemical resistance of fluoropolymers[a]

Environment	Temperature, °C	F-4	F-4MB	F-4M	F-4D	F-2M	F-50	F-50
				Acid				
Nitric	Any	20–150	S	S	S	S		
Boric	Any	Boiling	S	S	S	S		
Hydrobromic	40–50		S/S	S/S	S/S	S/S		
Fluorosilicic	Up to 35		S/S	S/S	S/S	S/S		
Arsenic		25	S	S	S	S		
Sulfuric	Any	20–150	S	S	S	S	S	S
Hydrochloric	1–37	100	S	S	S	S	S	
Phosphoric	Any	20–130	S/S	S/S	S/S	S/S		
Hydrofluoric	Up to 50–60 and higher		S/S S/S	S/S S/S	S/S S/S	S/S S/S		
Perchloric	Up to 60		S/S	S/S	S/S	S/S		
Hypochlorous			S/S	S/S	S/S	S/S	S/S	S/S
Chromic	Up to 10 50		S/S S/S	S/S S/S	S/S S/S	S/S S/S		
Hydrocyanic			S/S	S/S	S/S	S/S		
Benzoic	Up to 2.2		S/S	S/S	S/S	S/S		
Acetic	Any Glacial		S/S S/S	S/S S/S	S/S S/S	S/S S/S		
Acetic anhydride			S/S	S/S	S/S	S/S		S/S
Oxalic			S/S	S/S	S/S	S/S		S/S
Concentrated alkali			S/S	S/S	S/S	S/S	S/S	S/S
Ammonia (gas)			S/S	S/S	S/S		S/S	S/S
Hydrogen			S/S	S/S	S/S		S/S	S/S
Oxygen			S/S	S/S	S/S		S/S	S/S
Carbon monoxide			S/S	S/S	S/S		S/S	S/S
Fluorine			S/S	S/S	S/S		S/S	S/S
Hydrogen chloride			S/S	S/S	S/S		S/S	S/S
Acetone		20	S	S	S	S	S	S
Benzene		Up to 60	S	S	S	S		S
Benzene		20	S	S	S	S	S	S
Dichloroethane			S/S	S/S	S/S		S	S/S
Kerosene			S	S	S			S
Hydrogen sulfide		Up to 25	S	S	S			S
Diethyl ether		Up to 60	S	S	S	S		S
Toluene		Up to 70	S	S	S		S	S

Table 1. (Contd.)

Environment	Temperature, °C	F-4	F-4MB	F-4M	F-4D	F-2M	F-50	F-50
		20	S	S	S	S		S
			S/S	S/S	S/S		S	S/S
Concentrated acids	S	S	S	S	S	S	S	S
Organic solvents	S	S	S	VS	S	S	S	VS
Alkali	S	S	S	S	S	S	S	S
Oxidants	S	S	S	–	S	S	S	S
Combustibility	Incombustible	Incombustible	Incom-bustible	Incom-bustible	Self-extinc-tion	Incom-bustible	Incom-bustible	Incom-bustible
Combustibility by oxygen index, %	95	100	30	75	100	100	100	–

[a] S means "stable." The stability at room temperature is given in the numerator, in the denominator, the stability at 60°C and higher, up to the highest temperature where this material is capable to operate.

Table 2. Electrical, thermophysical, and mechanical properties of fluoropolymers

Characteristics	F-4	F-4D	F-4MB	F-40 F-40M	F-42	F-2M	F-3	F-3M	F-32L
				Electrical properties					
Specific volume electric resistance, Ω m^{-1}	10^{15}–10^{18}	10^{14}–10^{18}	> 10^{15}	5×10^{14}–10^{15}	10^{9}–10^{10}	(0.5–9)×10^{11}	10^{15}–10^{18}	5×10^{14}–10^{15}	> 10^{14}
Specific surface electric resistance, Ω	> 10^{17}	>10^{17}	> 10^{16}	10^{12}–10^{14}	10^{10}–10^{11}	–	10^{16}–10^{17}	(0.5–1)×10^{17}	–
Dielectric loss tangent									
at 1 kHz	(2–2.5)×10^{-4}	(2–3)×10^{-4}	(2–3)×10^{-4}	(2–3)×10^{-3}	(2–3)×10^{-2}	(1.2–2)×10^{-2}	2×10^{-2}	(1–1.5)×10^{-2}	(1–2)×10^{-3}
at 1 MHz	(2–2.5) × 10^{-4}	(2–3)×10^{-4}	(6–8)×10^{-4}	(6–8)×10^{-3}	0.1–0.2	0.17	(0.7–1)×10^{-2}	< 0.02	(1.5–2)×10^{-2}
Dielectric con-stant									
at 1 kHz	1.9–2.1	1.9–2.2.	1.9–2.1	2.5–2.6	9–11.3	8–10	2.8	2.7	2.5–2.7
at 1 MHz	1.9–2.1	1.9–2.2	1.9–2.1	2.5–2.6	8,2	7	2.3–2.8	2.5–.0	2.5–2.7
Electric strength (sample thickness 2 mm), MV m^{-1}	25–27 (4 mm)	25–27 (4 mm)	25–35	20–25	10.6–17	18–22	20–25	23–26	20–30
Arcresistance, s	250–700	250–700	165	72	–	> 350	> 350	–	–
				Physical properties					
Temperature of de-composition start	Over 415	Over 415	Over 380	Over350	Over 360	Over 350	Over 315	Over 315	–
Thermal stability (mass loss), %	0.2 (420°C, 3 h)	–	0.1–0.4 (300°C, 3 h)	0.2–0.3 (275°C, 5 h)	0.2–0.6 (275°C, 5 h)	0.05–0.2 (270°C, 5 h)	0.05–0.2 (270°C, 5 h)	0.1–0.3 (270°C, 5 h)	0.1–1.0 (270°C, 5 h)
Density, kg m^{-3}	2150–2190	2190–2260	2140–2170	1650–1700	1900–2000	1750–1800	2090–2160	2020	1920–1950

Table 2. (Contd.)

Characteristics	F-4	F-4D	F-4MB	F-40 F-40M	F-42	F-2M	F-3	F-3M	F-32L
					Physical properties				
Melting point of crystals, °C	327	327	230–250	250–270	150–160	142–156	210–215	170–190	105
Glass transition, °C	–120	–120	–90	–100	–45		50	46	30
Vicat softening point, °C	110		90–120	140	97–105	95–118	130	46	30
Specific heat capacity, kJ kg^{-1} K^{-1}	1.04	1.04	1.17				0.92		
Heat conduction, W m^{-1} K^{-1}	0.25	0.29	0.26	0.24			0.2–0.4		
Temperature coefficient of linear expansion α×10–5, 1/°C	8–25	8–25	9	6–9	9–12	8–12	6–12	7–12	
Operating temperature, °C									
minimum	–269	–269	–180	–100	–60	–55	–195	–195	–60
maximum	260	260	200	200	200	150	125	125	150–170
Weather resistance					Excellent				
					Mechanical properties				
Tensile strength, MPa	14.7–33	12.7–30	15.6–28	20–42	14.6–45.1	34.3–55	26.5–44,1	23,5–44	8.3–27.5
Relative ultimate elongation, %	250–500	250–500	270–360	100–350	200–580	350–550	60–200	150–250	150–300
Elastic modulus, MPa									
At expansion/ compression	410/680	410/680	340–400/–	1200/625–1270			1340–1580/1470		
At static bend									
at 20°C	460–830	440–830	540–590	770–1500	390–490	930–1370	1140–2540	940–2260	490–690
at –60°C	1290–2700	1370–2700	940	1440–1730	1170–2740	3920–4420	2550	2060–2260	2750–3140
Breaking stress, MPa									
At compression/ at static bend	11.8/10–14	11.8/10–14	15–16/20–29	50/29–33	–/29–39	–/54–83	49–59/60–75	–/34–58	
Impact strength, kJ m^{-2}	125	125	> 125	> 125	134–190	147–210	20–150	Stable	Stable
Brinell hardness, MPa	29–39	29–39	29–49	55–66	39–49	68–88	100–130	68–78	29–39
Coefficient of friction on steel	0.04	0.04	0.05–0.2	0.09	0.04		0.30	0.15	0.04
Resistance against radiation, Gy	0.5–2×10^{4}	0.5–2×10^{4}	10^{4}	(1–3)×10^{6}	0.5–2×10^{4}	10^{5}	–	24×10^{4}	–

Table 3. Characteristics of fluororubbers manufactured at Kirovo-Chepetsk Chemical Complex

Parameter	SKF-32	SKF-26	SKF-26NM	SKF-26ONM	SKF-26/3-8	SKF-264/3-8	SKF-264V/3-6 64V/3-6
Mooney viscosity:							
MB (4–4) 160°C	70–95	[a]	[a]	[a]	[a]	[a]	[a]
MB (4–4) 150°C	[a]	80–105	[a]	[a]	[a]	[a]	[a]
MB (1–10) 120°C	[a]	[a]	[a]	[a]	30–85	30–89	30–90
MB (4–4) 100°C	[a]	[a]	40–95	[a]	[a]	[a]	[a]
Dynamic viscosity of 40% solution in acetone, MPa s	[a]	[a]	[a]	40–79	[a]	[a]	
Moisture content, % (wt), not exceeding	0.15	0.15	0.5	0.5	0.5	0.5	0.5
Thermal stability (mass loss at 270 °C), % (wt), no more than	0.15	0.20	1.5	2.0	[a]	[a]	[a]
Shrinkage, %	16–25	16–25	[a]	[a]	[a]	[a]	[a]
Iron content, % (wt), not exceeding	0.0005	0.0005	[a]	[a]	[a]	[a]	[a]
F content, % (wt)	66–67	54–55	Nonstandardized		66–67	68–69	70–71
Cl content, % (wt)	14–16	Nonstandardized			Nonstandardized		
Glass transition temperature, °C	–17	–17		–50	–17	–13	–5

[a] By Mooney procedure the dynamic viscosity of rubber is measured by rotation of a ram in the sample; MB is Mooney B method. The numbers 4–4 and 1–10 indicate the time of heating the sample (min) and time of the measurement (min) at the indicated temperature.

Table 4. Comparison of properties of vulcanized fluororubbers and natural rubber

Characteristics	Cured fluororubber			Cured natural rubber
	SKF-32	SKF-26	SKF-264/8	
Tensile strength	190–300	140–180	140–180	180
Elongation at brake, %	100–300	130–300	200–350	550
Shore hardness	65–75	65–75	65–75	–
Frost resistance, °C	from –20 to –30	from –20 to –30	from –13 to –20	–55
Heat resistance, °C	+200	+250	+250	+100
Resistance against oils and ozone	Stable	Stable	Stable	Unstable

The workup parameters and application fields of fluoroplastics are given in Tables 5 and 6 [7].

KChKhK already for 40 years develops, produces, and applies fluoroplastic flow gauges, liquid level and pressure gauges, sensors of gas and liquid concentration. In the development department for monitoring devices and automation over 100 types of fluoroplastic gauges and sensors and automation facilities were developed and implemented in chemical, atomic, and other branches of industry [19].

Fluoropolymers in Eectrical Pwer Egineering

The largest power failure in electricity supply network of Mosenergo in May 2005 revealed the necessity to refine the construction of tank

Table 5. Thermal processing conditions and application fields of fluoroplastic-4

Sort of fluoroplastic	Parameters of material		Thermal processing conditions, °C	Application
	Average particle size, μm	Packed density, kg m^{-3}		
Suspension poly(tetrafluoroethylene)				
F-4PN	100–180	450–520	20–390	Electricals and high reliability articles
F-4PN90	46–135	450–500	20–390	High reliability articles
F-4PN40	25–45	350–420	20–390	Thin films, sheets, profiled articles
F-4PN20	6–20	350–420	20–390	Same
F-4NM	120–250	450–530	320–380	General-purpose articles
F-4M	70–110	450–550	20–390	High reliability articles stable against alternating load
F-4A	550–780	650–800	20–390	Articles produced by automatic molding and piston extrusion
F-4TG	600–800	600–800	320–380	Articles produced by plunger extrusion
Compositions of poly(tetrafluoroethylene)				
F-4K20 F-4K15M5			375±5	Antifriction articles: sliding bearings, glands operating at temperature from–60°C to +260°C
Fine-dispersed poly(tetrafluoroethylene)				
F-4NTD-2	5–20	200–800	375±5	Thickener of lubricant greases, filler of dyes, lubricants, rubbers, dry lubricant in friction joints for increasing wear resistance and decreasing the coefficient of friction
Emulsion poly(tetrafluoroethylene)				
F-4D	650–900	450–500	320–390	SKL[a], FUM[b], tubes, pipes, rods
F-4DM	400–600	400–500	320–390	Thin-walled and thick-walled pipes, insulation of wires and cables at high compression degree

[a] Raw calandered ribbon. [b] Fluoroplastic sealing material.

transformers, high-voltage switches, and other power electrical equipment for enhancing the reliability of its operation and environmental safety. This problem can be fundamentally solved by the use of fluorinated fluids and fluoropolymers as cooling agents, construction, insulating, and sealing materials, anticorrosion, anti-adhesion and anti-icing coatings.

These functional materials based on fluorocarbons and fluoroderivatives of hydrocarbons already for over 40 years have been used in the military engineering. The thermodynamic and physical characteristics of a series of incombustible dielectric heat-conducting organofluorine fluids of boiling points from 100°C to 180°C are fit for use as efficient cooling agents in power tank transformers instead of combustible hydrocarbon transformer oil. The cooling of transformer's windings occurs due to the evaporation of the fluorinated fluid without its forced stirring. In these transformers the least part of winding is immersed into the fluid. The vapor of fluorocarbons at excessive pressure 1 at possesses the same dielectric constant as the fluid, therefore the transformer can be partially filled without risking the break-down of windings insulation [20].

In powerful tank transformers the winding is constantly sprinkled with the fluorinated fluid that evaporating from the heated surfaces removes the heat, then the vapor is condensed in a tank, and the fluid returns to the vessel for supplying to the nozzles sprinkling the winding. In this case the cooling of a transformer requires some liters of the fluorinated fluid, and no forced circulation is necessary. The

Table 6. Thermal processing conditions and application fields of fusible fluoropolymers

Fluoroplastic	Grade	IMF,[a] g/10 min	Processing temperature, °C	Operating temperature, °C		Application
				upper	lower	
F-4MB	A	2–7	220–380	–196	200	Electrical insulating goods, seals, lining of chemical apparatuses, pipes, laboratory vessels, elastic vessels
	B	4.5–8	220–380	–196	200	
	VN	0–8 (at 300°C)	220–380	–196	200	
F-4-F-40M	P	0.01–4	200–380	–100	200	Molded gaskets and seals, insulation of wires and cables
	Sh	4–60	200–380	–100	200	
	LD		200–380	–100	180	
F-2M	B	7– 20	135–270	–55	150	Sels, gaskets, lining, taping for cables, protecting coatings of constructions
	V	4–7	135–270	–55	150	
	E	3–8	135–270	–55	150	
	G	2–8	135–270	–55	150	
F-42	V	Viscosity of solution		–60	120	Fibers for working clothes, gland packing, gaskets, pipes, anticorrosion and heat insulating coatings
	LD-1			–60	120	
	LD-2			–60	120	
	L			–60	120	
	P			–60	120	
F-3	B	240–260 (TSL[b])	220–300	–195	170	Sight glasses, molded articles, wear-resistant coatings
	V	265–285 (TSL)				
F-3M	A	0.3–5	190–270	–195	125	Articles and film coating for operation in aggressive media
F-50	P	1– 20	230–390	–195	250	Flexible tubes, pump parts, films for anti-adhesion and anticorrosion protection, wire insulation, chemically stable fibers, pipe lining
F-32L	V	Viscosity of solution		–60	150–170	Coatings stable against aggressive media. Moisture-protection films (extrusion procedure). High quality concentrated lacquers
	H			–60	150–170	

[a] Index of melt flow ability. [b] Temperature of strength loss.

hazard of inflammation of this transformer oil is totally excluded. The other advantages of the fluorocarbon transformer oil is low melting point, low viscosity and surface tension, high density, heat conductivity, and self-extinction capacity [20, 21].

The efficiency and operation reliability is known of winding and connecting wires and cables with the fluoroplastic insulation, of glands from cured fluororubber, anticorrosion fluoropolymeric coatings on equipment and metal constructions for military purposes.

The polymer plant of KChKhK can supply the following fluoropolymer products for electrical power engineering:

– incombustible dielectric fluorinated fluids based on trifluorochloroethylene and perfluoroethers possessing high dielectric constant, heat and frost resistance, chemical and biological inertness for application instead of combustible transformer oil;

– fluoroplastic insulation made of fluoroplastics F-4, F-4D, F-2M, F-4MB exhibiting unrivaled electrical insulating characteristics, heat and frost resistance, chemical resistance instead of paper insulation of wires and windings;

– cured rubber, sealants, and adhesives based on fluororubbers SKF-26, SKF-260 remarkable for their excellent chemical resistance, wear resistance, weather resistance, heat and frost resistance for sealing the cases and cable lead-ins of electrical equipment;

– lacquers based on soluble fluoroplastics F-32L, F-42L, and fluoroplastic lacquer FPR for anticorrosion, anti-adhesion and anti-icing protection of the equipment.

The complex use of fluoropolymers makes it possible to increase the interrepair life of the electrical power equipment up to 30 years and more approaching it to the life time of the equipment, and also to ensure the environmental safety of its operation.

Fluoropolymers in the Natural Gas Industry

Fluoropolymers are essentially better in the chemical stability, heat and frost resistance, weather resistance, dielectric properties and operation life than polyethylene, rubber, lacquers, and sealants employed in the natural gas industry for anticorrosion protection, sealing the pipe lines, compressors, tanks, fittings, and devices.

For instance, fluoroplastic-2M [poly(vinylidene fluoride) modified with hexafluoropropylene] exceeds the fluoroplastic-4 in mechanical strength, hardness, lack of creep under load. It exhibits high stability against chemicals, vapors, and weather, wear and abrasion resistance, stability against radiation. It can be processed by all procedures known for the thermoplastics. Fluoroplastic-2M is used as lining of pipe lines, apparatuses, fittings, for manufacturing films and enamels, insulation of wires and cables operating in corrosive environment in the temperature range from –50 to +150°C.

Fluoroplastic-1 [poly(vinyl fluoride)] possesses a high mechanical strength, flexibility, abrasion resistance, stability to multiple bends, good adhesion to various materials, excellent weather and radiation resistance. It is manufactured in the form of films, sheets, and lacquers. In the chemical and natural gas industries the poly(vinyl fluoride) coatings are effective for anticorrosion protection of pumps, stopping fittings, pipe lines, and tanks for the transportation and storage of aggressive liquids. The poly(vinyl fluoride) is also used as anti-adhesive coatings for metallic constructions and as electrical insulating material operating in the temperature range from –60 to +150°C. F-1 possesses a higher operation reliability than F-2M and is cheaper.

Fluoroplastics F-1 and F-2M can successfully replace polyethylene in the anticorrosion protection of gas pipe lines, tanks and the other equipment of the natural gas industry. The application of coatings is possible both in the shops during manufacturing of the equipment and in the field at the mounting and repair of the equipment [9, 20, 22].

The lacquer FPR exhibits an exceptional stability, it retains its functional qualities under sever operating conditions: weather resistance for 30 years, heat resistance up to +150°C, frost resistance down to –60°C, chemical stability against sweat and sea water, oils, gasoline, acids, and alkalis. The coatings based on FPR lacquer are characterized by high elasticity, low slip coefficient, and the capability to conserve its properties in the operating temperature range within the whole life time. The lacquer FPR can be employed in the natural gas industry, in particular, by the Limited Liability Co "Severgasprom," for the anticorrosion protection of the joints of gas pipes of the gas mains, pipe lines, fittings, metallic constructions, in particular, tangent towers, at the gas and gas condensate plants, both operating and under construction [23].

Fluoropolymers in Medicine

Fluoropolymers are efficient as construction material and articles of medical facilities. In a special designing department for technical medical equipment, in the designing department for monitoring devices, and in the laboratory of studying fluoropolymers at the polymer plant of the Kirovo-Chepetsk Chemical Complex in collaboration with Bakulev Institute of Cardiovascular Surgery and the other leading medical institutions of the USSR were developed, and introduced into manufacture and clinical practice fluoroplastic prostheses of blood vessels, knitted fabric, medical felt, capillaries, catheters, and also filters, diffusion membranes, wide choice of laboratory vessels, integral automatic samplers of air [24] and water, special industrial gas chromatographs [25] for sanitary, epidemiologic, and toxicological monitoring.

The industrial manufacturing of prostheses of blood vessels from porous (expanded) poly(tetrafluoroethylene) is performed at NPK "Ekoflon" (St. Petersburg) [26].

An urgent State problem is the condition of Blood Service of the Russian Federation operating by the principle of need satisfaction. It is extremely cost and resources consuming, economically inefficient and noncompetitive. Due to the unsuitable storage of the blood resource Russia loses annually over 100 000 liters of blood components [27]. At Kirovo-Chepetsk Chemical Complex in collaboration with Kirov Research Institute of Hematology and Blood Transfusion was developed and successfully tested a series of fluoroplastic goods for cryomedicine: cryocontainers, cryo test-tubes, filters, catheters, tubes, vessels, connection and sealing adapters for stationary and portable devices for transfusion of blood components and bone marrow. A nontoxic cryoprotector that required no removal was developed for bone marrow stem cells, peripheral blood, platelets, and leucocytes. The industrial manufacturing of goods of fluoroplastics for cryomedicine and blood services will provide for the treatment of patients needing transplantation of stem cells and blood components transfusion, make it possible to build a strategic blood bank required in case of technogeneous accidents and disasters, and to have a resource of blood components at all the blood transfusion stations in the Russian Federation.

CONCLUSION

The Limited Liability Co "Polymer Plant of Kirovo-Chepetsk Chemical Complex" is a unique enterprise where is performed synthesis, processing, and application of fluoropolymers, research and development in this field. One of the main goals of the plant nowadays alongside the production of fluoroplastics and articles thereof possessing small added cost is the introduction into the manufacture of high-tech fluoropolymer products with a large added cost for electric power industry, atomic, chemical, and natural gas industrial branches, for medicine and biotechnology.

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