KYNAR® & KYNAR FLEX® PVDF

PERFORMANCE CHARACTERISTICS & DATA

THERMOPLASTICS FOR ENGINEERING APPLICATIONS

ARKEMA

The world is our inspiration

KYNAR® & KYNAR FLEX® PVDF

THERMOPLASTICS FOR ENGINEERING APPLICATIONS

KYNAR® polyvinylidene fluoride is a tough engineering thermoplastic that offers a balance of performance properties. It has the characteristic stability of fluoropolymers to resist harsh thermal, chemical and ultraviolet environments. KYNAR® resins, in addition to being readily melt-processed by standard methods, can be dissolved in polar solvents, such as organic esters and amines, for coating applications.

CHEMICAL PROCESSING

Because it has high temperature resistance, low permeability and high mechanical strength, KYNAR® PVDF is used as a contact surface for the production, storage and transfer of corrosive fluids. KYNAR® PVDF resin is used in mechanical components, fabricated vessels, tanks, pumps, valves, filters, heat exchangers, tower packing, piping systems, and many other applications.

ELECTRICITY & ELECTRONICS

Its fire-resistance, abrasion resistance, low-smoke emission, chemical and mechanical properties make KYNAR® PVDF resin suitable for protective sheathing, plenum and communications wiring insulation and binder resin for battery manufacture.

HIGH PURITY

Semi-conductor and pharmaceutical production require increasingly pure materials. High purity KYNAR® PVDF resin grades meet industry needs. KYNAR® PVDF resin regulatory listings include food and water use certifications as well as listings for use in industries such as healthcare.

TRANSPORTATION

KYNAR® PVDF resin is used in both public and private transport vehicles as a barrier liner for automotive fuel line and gas station fuel pipes, in decorative films, as as binder in HEV/EV batteries, as molded and thermoformed body components (weathering, anti-grime/graffiti), and as tanker trailer linings for corrosion protection. KYNAR® PVDF resin has strength, durability and versatility that make it a preferred material in automotive wiring harnesses, general coatings, electrochromic technology and plastic optical fibers.

ARCHITECTURE

The excellent outdoor aging and weathering properties of KYNAR 500® PVDF resin led to its use in long-lasting paints for coating metal sheet for the past 40 years. KYNAR 500® can also be used to protect thermoplastics through coextrusion or film lamination techniques to obtain anti-grime and anti-graffiti surfaces with excellent weathering properties.

CONTENTS

APPLICATIONS

INDUSTRIAL

KYNAR® PVDF components are used extensively in:

- *the high-purity semiconductor market (low extractable values)*
- *the pulp and paper industry (chemically resistant to halogens and acids)*
- *nuclear waste processing (radiation and hot-acid resistant)*
- *the general chemical processing industry (extreme chemical and temperature applications)*
- *water treatment membranes (industrial and potable water uses)*

KYNAR® fluoropolymers also meet specifications for food and pharmaceutical processing industries.

KYNAR® homopolymer resins are strong engineering fluoropolymers. KYNAR FLEX® resins are a series of PVDF-based copolymers, similar to KYNAR® homopolymer resins in purity and chemical resistance, that also have chemical compatibility in high pH solutions, increased impact strength at ambient and low temperatures, and increased clarity.

KYNAR® and KYNAR FLEX® resins can be fabricated into a wide range of components including:
Pipes, fittings and valves
Pump assemblies
Sheet and stock shapes
Films
Tubing (flexible & rigid)
Tanks and vessels
Nozzles
Membranes and filter housing
Powder coatings
Foams

FOAM

KYNAR® PVDF closed-cell foams are available in sheets or rolls. KYNAR® PVDF foams have very high purity, very low flammability and are UV and corrosion resistant.

FILM

KYNAR® PVDF film can be used for applications requiring long-term protection. The film is produced by monolayer or multilayer technology as thin (from 10 to 175 µm), thick, wide or narrow, allowing great freedom of design. The commercial range includes both mass-tinted and transparent films, which can be printed with a variety of designs. KYNAR® PVDF film can be laminated onto thermoplastic, thermoset or coated-metal supports.

BATTERY

KYNAR® PVDF homopolymers and KYNAR FLEX® copolymers are used in the battery industry as binders for cathodes and anodes in lithium-ion batteries and as battery separators in lithium-ion polymer batteries. Arkema has more than forty years of experience in PVDF coatings and films and can help design thinner, smaller lithium-ion batteries.

POWDER COATINGS

KYNAR FLEX® 2850 PC is a functional powder coating system which enables a thick spray coating of KYNAR® PVDF resin to be applied to metals for optimum corrosion resistance.

Manufactured with no additives and inherently very pure, KYNAR FLEX® 2850 PC complies with United States Pharmacopeia (USP) requirements (Class VI) and Food & Drug Administration (FDA) regulations, and is suitable for coating equipment used in the pharmaceutical, food, chemical and semi-conductor industries.

KYNAR® ADX powder coatings can be applied without primer.

PLENUM

Select grades of KYNAR® resin easily achieve the flame spread/smoke developed rating of 25/50 when tested in accordance with ASTM E 84.

A wide variety of KYNAR FLEX® resin grades are offered for use in the plenum cable industry. Cables produced using KYNAR® PVDF resin have have almost no smoke generation and no flame spread when tested to NFPA 262 (UL 910) standards.

POLYMER PROCESS AIDS (PPA)

KYNAR FLEX® PPA are additives designed to aid in the extrusion of thermoplastic resins. KYNAR FLEX® PPA can be used in blown film, cast film, blow molding, wire and cable jacketing, pipe and tube extrusion, and extruded fiber processes. When used at very low levels of 100–1000 ppm, KYNAR FLEX® PPA can provide benefits to a wide range of resins, particularly polyolefins. These benefits include elimination of melt-fracture (sharkskin), reduction of die build-up, increased output, reduced energy consumption, and faster start-up or changeover time.

PHOTOVOLTAIC

Arkema produces KYNAR® film for use in the protection of back sheet and for front sheet glazing. KYNAR® Film provides exeptional solar transmittance and also has excellent dirt shedding and fire resistance properties.

MEMBRANE

KYNAR® PVDF resin is a respected membrane material for applications ranging from bioprocess separations to water purification because it is extremely chemically resistant and well suited to aggressive chemical environments. KYNAR® PVDF has a high temperature resistance, which makes it appropriate for applications which require high temperature cleaning. KYNAR® PVDF tolerates ozone and chlorine (an oxidant increasingly used for water purification) very well. Grades with FDA approval and/or NSF listing are compatible with direct food/beverage contact applications.

KYNAR® PVDF resin is soluble in n-methylpyrrolidone, dimethylacetamide, dimethylsulfoxide, and dimethylformamid and can be conveniently solution-cast into porous membranes by phase inversion. It is used to manufacture flat sheet, hollow fiber, and thermal-induced-phase-separation (TIPS) process membranes.

KYNAR® ADX

KYNAR® ADX resins are a functionalized PVDF offering strong adhesion to various substrates. KYNAR® ADX can be used in automotive, chemical processing, battery, coatings and packaging applications.

In co-extrusion, KYNAR® ADX resin can be combined with other polymers (PE, PA, etc.) to achieve mechanical, chemical and barrier properties.

ROTOMOLDING

Rotomolding, or rotational molding, is a highly versatile manufacturing option that allows for a wide range of design possibilities at low production costs. KYNAR FLEX® RG resins are specifically designed for rotational molding and offer excellent abrasion resistance and toughness.

Rotolining allows customers to use KYNAR® resin to protect complex geometric and/or enclosed shapes that cannot be lined or coated in a conventional manner.

PRODUCT RANGE

POWDER
White, nonhygroscopic, approximately 5 micrometer particles loosely agglomerated: sieve size-through 14 mesh. Bulk density approximately 18 lbs/ft^3.

PELLETS
Natural resin: translucent, off-white hemispheres. Bulk density approximately 60 lbs/ft^3.

LATEX
Approximately 18.6 lbs/gal of nominal 18% (by weight) solids with a density of 1.10 ± 0.1 g/cc.

TABLE I

These are typical values, not to be construed as sales specifications.

KYNAR® PVDF GRADE	FABRICATION	MELT VISCOSITY METHOD (ASTM D3835) 450°F K POISE @100 SEC-1	MELT FLOW RATE (ASTM D1238) 450°F g/10 MIN	MELT FLOW RATE LOAD lb (kg)	MELTING POINT	SPECIAL CHARACTERISTICS POINT RANGE
PELLETS						
340	Injection Molding & Extrusion		3.0 - 8.0	22 (10)	165 - 172°C	Conductive
370	Injection Molding	8.0 - 13.0			165 - 172°C	Low melt shrinkage, carbon filled
460	Injection Molding & Extrusion	23.5 - 29.5	6.0 - 14.0	47.5 (21.6)	155 - 165°C	Broad molecular weight distribution
710, 710 HDP	Injection Molding	4.0 - 8.0	19.0 - 35.0	8.36 (3.8)	165 - 172°C	HDP indicates higher color stability
720	Injection Molding & Extrusion	6.0 - 12.0	5.0 - 29.0	8.36 (3.8)	165 - 172°C	
740	Injection Molding & Extrusion	15.0 - 23.0	6.0 - 25.0	27.5 (12.5)	165 - 172°C	
740-02	Injection Molding & Extrusion	14.0 - 22.0	7.0 - 28.0	27.5 (12.5)	165 - 172°C	Flame & smoke suppressant
740 Black/Red	Injection Molding & Extrusion	15.0 - 23.0	6.0 - 25.0	27.5 (12.5)	165 - 172°C	Pigmented
1000 HD	Injection Molding & Extrusion	15.0 - 20.0	1.5 - 2.5	11.0 (5.0)	165 - 172°C	
6000 HD	Injection Molding	7.0 - 11.0	2.0 - 4.0	11.0 (5.0)	165 - 172°C	
9000 HD	Injection Molding	5.0 - 8.0	16.0 - 40.0	11.0 (5.0)	165 - 172°C	
EXAD 3000	Extrusion	12.0 - 18.0	2.0 - 7.0	11.0 (5.0)	140 - 145°C	Extrusion aid, lubricated
2750-01	Extrusion & Molding	20.0 - 25.0	4.0 - 14.0	27.5 (12.5)	130 - 138°C	Very flexible, lubricated
2800-00	Extrusion	22.0 - 27.0	3.0 - 8.0	27.5 (12.5)	140 - 145°C	Flexible
2800-20	Extrusion & Molding	12.0 - 20.0	1.0 - 6.0	11.0 (5.0)	140 - 145°C	Flexible
2850-00	Extrusion & Molding	23.0 - 27.0	3.0 - 8.0	27.5 (12.5)	155 - 160°C	150°C temperature rating
2850-02	Extrusion	16.0 - 20.0	10.0 - 20.0	27.5 (12.5)	155 - 160°C	150°C temperature rating
2850-04	Extrusion & Molding	4.0 - 8.0	8.0 - 25.0	8.36 (3.8)	155 - 160°C	150°C temperature rating
2850-07	Extrusion & Molding	16.0 - 20.0	10.0 - 20.0	27.5 (12.5)	155 - 160°C	150°C temperature rating
2850 Black	Extrusion & Molding	16.0 - 28.0	4.0 - 18.0	27.5 (12.5)	155 - 160°C	150°C temperature rating, pigmented
2900-04	Extrusion & Molding	5.0 - 12.0	4.0 - 17.5	8.36 (3.8)	140 - 145°C	Flexible, flame & smoke suppressant
2950-05	Extrusion & Molding	5.0 - 12.0	4.0 - 17.5	8.36 (3.8)	130 - 138°C	Very flexible, flame & smoke suppressant
3120-15	Extrusion & Molding	5.0 - 12.0	4.0 - 17.5	8.36 (3.8)	161 - 168°C	Flexible, flame & smoke suppressant
3120-50	Extrusion & Molding	20.0 - 26.0	2.5 - 7.5	27.5 (12.5)	161 - 168°C	Flexible, 150°C temperature rating
2500-20	Extrusion & Molding	5.0 - 16.0	1.0 - 15.0	8.36 (3.8)	117 - 125°C	Highest flexibility
POWDER						
201	Toners	28.0 - 34.0	2.0 - 6.0	47.5 (21.6)	155 - 165°C	
301-F	Toners, Dispersion Coatings	28.0 - 34.0	2.0 - 6.0	47.5 (21.6)	155 - 165°C	Fine milled powder
451	Membranes	28.0 - 34.0	2.5 - 5.5	47.5 (21.6)	155 - 165°C	
461	Membranes, Binders	23.5 - 29.5	6.0 - 14.0	47.5 (21.6)	155 - 165°C	
711	Binders, Additives, etc.	4.0 - 8.0	19.0 - 35.0	8.36 (3.8)	165 - 172°C	
721	Binders, Additives, etc.	5.0 - 12.0	5.0 - 29.0	8.36 (3.8)	165 - 172°C	
741	Binders, Additives, etc.	15.0 - 23.0	6.0 - 25.0	27.5 (12.5)	165 - 172°C	
761	Binders, Additives, etc.	23.0 - 29.0	2.0 - 6.0	27.5 (12.5)	165 - 172°C	
761A	Binders, Additives, etc.	30.0 - 34.0	2.0 - 6.0	27.5 (12.5)	165 - 172°C	
2751-00	Binders, Additives, etc.	20.0 - 25.0	4.0 - 14.0	27.5 (12.5)	130 - 138°C	Flexible
2801-00	Binders, Additives, etc.	23.0 - 27.0	3.0 - 8.0	27.5 (12.5)	140 - 145°C	Flexible
2821-00	Binders, Additives, etc.	12.0 - 20.0	1.0 - 6.0	11.0 (5.0)	140 - 145°C	Flexible
2501-20	Binders, Additives, etc.	6.0 - 15.0	2.0 - 14.0	8.36 (3.8)	117 - 125°C	Very flexible, very soluble
LBG	Binders, Additives, etc.	33.0 - 39.0	3.0 - 8.0	(21.6)	148 - 155°C	Li ion battery applications, membrane
HSV	Binders, Additives, etc.	40.0 - 56.0	N/A	N/A	160 - 169°C	Li ion battery applications, membrane
OTHER						
2850 PC	Spray Coating Powder	4.0 - 8.0	8.0 - 25.0	27.5 (12.5)	155 - 160°C	Electrostatic spray
Latex 32	Impregnating Fabrics				155 - 160°C	Water base, fine particle size
5300	Process Additive				<170	Pellets or Powder

KYNAR® HOMOPOLYMER SERIES

TABLE II

PHYSICAL PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	460	1000 SERIES[2]	700 SERIES[2]	370[3]
Refractive Index	D542/at Sodium D line 77°F (25°C)		1.42	1.42	1.42	—
Specific Gravity	D792/73°F (23°C)		1.75 - 1.77	1.76 - 1.78	1.77 - 1.79	1.84 - 1.88
Water Absorption	D570/68F (20°C) Immersion/24 Hours	%	0.02 - 0.04	0.01 - 0.03	0.01 - 0.03	0.04 - 0.06

MECHANICAL PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	460	1000 SERIES[2]	700 SERIES[2]	370[3]
Flexural Strength @ 5% Strain	D790/73°F (23°C)	psi (MPa)	7,000 - 9,000 (48 - 62)	8,500 - 11,000 (58 - 76)	8,500 - 11,000 (58 - 76)	20,000 - 30,000 (138 - 207)
Flexural Modulus	D790/73°F (23°C)	psi (MPa)	200,000 - 260,000 (1379 - 1792)	240,000 - 335,000 (1655 - 2310)	200,000 - 335,000 (1655 - 2310)	800,000 - 1,000,000 (5515 - 6895)
Tensile Yield Elongation	D638/73°F (23°C)	%	10 - 15	5 - 10	5 - 10	0 - 4
Tensile Yield Strength	D638/73°F (23°C)	psi (MPa)	5,000 - 7,500 (34 - 52)	6,500 - 8,000 (45 - 55)	6,500 - 8,000 (45 - 55)	5,000 - 8,000 (34 - 55)
Tensile Break Elongation	D638/73°F (23°C)	%	50 - 250	20 - 100	20 - 100	0 - 20
Tensile Break Strength	D638/73°F (23°C)	psi (MPa)	4,500 - 7,000 (31 - 48)	5,000 - 7,000 (34 - 48)	5,000 - 8,000 (34 - 55)	5,500 - 8,000 (38 - 55)
Tensile Modulus	D638/73°F (23°C)	psi (MPa)	150,000 - 200,000 (1034 - 1379)	200,000 - 335,000 (1379 - 2310)	200,000 - 335,000 (1379 - 2310)	450,000 - 750,000 (3102 - 5171)
Compressive Strength	D695/73°F (23°C)	psi (MPa)	8,000 - 10,000 (34 - 69)	10,000 - 15,000 (69 - 103)	10,000 - 15,000 (69 - 103)	20,000 - 25,000 (138 - 172)
Deflection Temperature	D648/at 264 psi (1.82 MPa)	°F (°C)	176 - 194 (80 - 90)	220 - 230 (104 - 110)	221 - 239 (105 - 115)	230 - 260 (104 - 127)
Deflection Temperature	D648/at 66 psi (0.45 MPa)	°F (°C)	234 - 284 (112 - 140)	—	257 - 284 (125 - 140)	270 - 300 (132 - 149)
Impact Strength Notched Izod	D256/73°F (23°C)	Ft-Lb/In	1.8 - 4	1.8 - 4	8 - 25	0.75 - 1.50
Impact Strength Unnotched Izod	D256/73°F (23°C)	Ft-Lb/In	15 - 40	20 - 80	20 - 80	5 - 10
Hardness	D2240/73°F (23°C)	Shore D	75 - 80	77 - 82	76 - 80	74 - 79
Tabor Abrasion	CS-17 1000g:pad	mg/1000 cycles	7 - 9	5 - 9	5 - 9	—
Coefficient of Friction - Static vs. Steel	ASTM D 1894 73°F (23°C)		0.23	0.22	0.20	0.18
Coefficient of Friction - Dynamic vs. Steel	ASTM D 1894 73°F (23°C)		0.17	0.15	0.14	0.12

THERMAL PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	460	1000 SERIES[2]	700 SERIES[2]	370[3]
Melting Temperature	D3418	°F (°C)	311 - 320 (155 - 160)	337 - 340 (169 - 171)	329 - 342 (165 - 172)	329 - 338 (165 - 170)
Tg (DMA)	@ 1 Hz	°F (°C)	-41 - -37 (-40 - -38)	-41 - -37 (-40 - -38)	-41 - -37 (-40 - -38)	-41 - -37 (-40 - -38)
Coefficient of Linear Thermal Expansion	D696	10E-5/°F	5.0 - 7.0	6.6 - 8.0	6.6 - 8.0	2.0 - 2.5
Thermal Conductivity	ASTM D433	BTU-in/hr.ft^2.°F	1.18 - 1.32	1.18 - 1.32	1.18 - 1.32	—
Specific Heat	DSC	BTU/Lb.°F	0.28 - 0.36	0.28 - 0.36	0.28 - 0.36	—
Thermal Decomposition TGA	1% wt. loss/in air	°F (°C)	707 (375)	707 (375)	707 (375)	707 (375)
Thermal Decomposition TGA	1% wt. loss/in nitrogen	°F (°C)	770 (410)	770 (410)	770 (410)	770 (410)

ELECTRICAL PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	460	1000 SERIES[2]	700 SERIES[2]	370[3]
Dielectric Strength 73°F	D149/73°F (23°C)	KV/Mil	1.6	1.6	1.7	—
Dielectric Constant 73°F	D150/100MHz - 100 Hz		4.5 - 9.5	4.5 - 9.5	4.5 - 9.5	28.8 - 33.5
Dissipation Factor 73°C	D150/100 Hz		0.01 - 0.21	0.01 - 0.25	0.01 - 0.21	0.06 - 0.08
Volume Resistivity	D257/DC 68F (20°C)/65% R.H.	ohm-cm	2×10^{14}	2×10^{14}	2×10^{14}	1×10^{11}

FLAME & SMOKE PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	460	1000 SERIES[2]	700 SERIES[2]	370[3]
Burning Rate	UL/Bulletin 94		V - 0	V - 0	V - 0	V - 0
Limiting Oxygen Index (LOI)	D2868	% O_2	44	60	75	44

1. Typical property values. Should not be construed as sales specifications.
2. The KYNAR® 700 PVDF and KYNAR® 1000 PVDF series span a wide range of melt viscosities (see page 3). Please contact an Arkema representative for typical values of specific grades.
3. Filled with graphite powder to reduce mold shrinkage.

KYNAR FLEX® COPOLYMER SERIES

TABLE III

PHYSICAL PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	2500	2750/2950	2800/2900	2850	3120
Refractive Index	D542/at Sodium D line 77°F (25°C)		1.40	1.41	1.41	1.42	1.41
Specific Gravity	D792/73°F (23°C)		1.80 - 1.82	1.78 - 1.80	1.76 - 1.79	1.77 - 1.80	1.76 - 1.79
Water Absorption	D570/68F (20°C) Immersion/24 Hours	%	—	0.03 - 0.06	0.03 - 0.05	0.03 - 0.05	0.03 - 0.05

MECHANICAL PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	2500	2750/2950	2800/2900	2850	3120
Flexural Strength @ 5% Strain	D790/73°F (23°C)	psi (MPa)	1,500 - 2,500 (10 - 17)	2,000 - 3,500 (14 - 24)	3,000 - 5,000 (20 - 34)	3,000 - 5,000 (20 - 34)	3,000 - 5,000 (20 - 34)
Flexural Modulus	D790/73°F (23°C)	psi (MPa)	28,000 - 40,000 (192 - 276)	40,000 - 60,000 (276 - 414)	70,000 - 110,000 (620 - 827)	150,000 -180,000 (1034 - 1241)	90,000 - 120,000 (620 - 827)
Tensile Yield Elongation	D638/73°F (23°C)	%	17 - 25	15 - 25	10 - 20	5 - 15	10 - 20
Tensile Yield Strength	D638/73°F (23°C)	psi (MPa)	1,700 - 2,800 (12 - 19)	2,000 - 3,100 (14 - 21)	2,900 - 5,000 (20 - 34)	4,500 - 6,000 (31 - 41)	3,500 - 5,000 (24 - 34)
Tensile Break Elongation	D638/73°F (23°C)	%	500 - 800	200 - 400	100 - 300	30 - 200	300 - 550
Tensile Break Strength	D638/73°F (23°C)	psi (MPa)	2,000 - 4,500 (14 - 24)	2,900 - 4,000 (20 - 27)	2,500 - 5,000 (17 - 34)	4,000 - 7,000 (27 - 48)	5,000 - 7,000 (34 - 48)
Tensile Modulus	D638/73°F (23°C)	psi (MPa)	35,000 - 55,000 (241 - 379)	40,000 - 65,000 (276 - 448)	80,000 - 130,000 (551 - 896)	150,000 - 220,000 (1034 - 1517)	100,000 - 170,000 (689 - 1172)
Compressive Strength	D695/73°F (23°C)	psi (MPa)	2,000 - 3,000 (14 - 20)	3,500 - 4,500 (24 - 31)	4,500 - 6,000 (31 - 41)	6,000 - 8,500 (41 - 58)	4,500 - 6,000 (31 - 41)
Deflection Temperature	D648/at 264 psi (1.82 MPa)	°F (°C)	80 - 100 (27 - 38)	95 - 125 (35 - 51)	104 - 131 (40 - 55)	100 - 131 (38 - 55)	110 - 130 (43 - 54)
Deflection Temperature	D648/at 66 psi (0.45 MPa)	°F (°C)	—	120 - 150 (49 - 65)	140 - 167 (60 - 75)	140 - 167 (60 - 75)	130 - 170 (54 - 77)
Impact Strength Notched Izod	D256/73°F (23°C)	Ft-Lb/In	NO BREAK	NO BREAK	10 - 20	2 - 8	NO BREAK
Impact Strength Unnotched Izod	D256/73°F (23°C)	Ft-Lb/In	NO BREAK	NO BREAK	NO BREAK	NO BREAK	NO BREAK
Hardness	D2240/73°F (23°C)	Shore D	55 - 60	57 - 62	65 - 70	70 - 75	65 - 70
Tabor Abrasion	CS-17 1000g:pad	mg/1000 cycles	28 - 33	21 - 25	16 - 19	6 - 9	16 - 19
Coefficient of Friction - Static vs. Steel	ASTM D 1894 73°F (23°C)		0.49	0.55	0.33	0.26	0.31
Coefficient of Friction - Dynamic vs. Steel	ASTM D 1894 73°F (23°C)		0.54	0.54	0.33	0.19	0.30

THERMAL PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	2500	2750/2950	2800/2900	2850	3120
Melting Temperature	D3418	°F (°C)	242 - 257 (117 - 125)	266 - 280 (130 - 138)	284 - 293 (140 - 145)	311 - 320 (155 - 160)	322 - 334 (161 - 168)
Tg (DMA)	@ 1 Hz	°F (°C)	-46 - -40 (-43 - -40)	-44 - -40 (-42 - -40)	-42 - -39 (-41 - -39)	-41 - -37 (-40 - -38)	-42 - -39 (-41 - -39)
Coefficient of Linear Thermal Expansion	D696	10E-5/°F	8.5 - 10.8	9.0 - 12.0	7.0 - 10.3	7.0 - 10.3	7.0 - 10.3
Thermal Conductivity	ASTM D433	BTU-in/hr.ft^2.°F	1.00 - 1.25	1.00 - 1.25	1.00 - 1.25	1.00 - 1.25	1.00 - 1.25
Specific Heat	DSC	BTU/Lb.°F	0.28 - 0.36	0.28 - 0.36	0.28 - 0.36	0.28 - 0.36	0.28 - 0.36
Thermal Decomposition TGA	1% wt. loss/in air	°F (°C)	707 (375)	707 (375)	707 (375)	707 (375)	707 (375)
Thermal Decomposition TGA	1% wt. loss/in nitrogen	°F (°C)	770 (410)	770 (410)	770 (410)	770 (410)	770 (410)

ELECTRICAL PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	2500	2750/2950	2800/2900	2850	3120
Dielectric Strength 73°F	D149/73°F (23°C)	KV/Mil	0.8 - 1.1	1.1 - 1.3	1.3 - 1.5	1.3 - 1.6	1.3 - 1.5
Dielectric Constant 73°F	D150/100MHz - 100 Hz		4.5 - 13.5	3.8 - 12.1	3.5 - 10.6	3.5 - 10.2	3.2 - 10.2
Dissipation Factor 73°C	D150/100 Hz		0.05 - 0.29	0.02 - 0.24	0.02 - 0.21	0.01 - 0.22	0.02 - 0.19
Volume Resistivity	D257/DC 68F (20°C)/65% R.H.	ohm-cm	2×10^{14}	2×10^{14}	2×10^{14}	2×10^{14}	2×10^{14}

FLAME & SMOKE PROPERTIES[1]	STANDARD/CONDITIONS	UNITS	2500	2750/2950	2800/2900	2850	3120
Burning Rate	UL/Bulletin 94		V - 0	V - 0	V - 0	V - 0	V - 0
Limiting Oxygen Index (LOI)	D2868	% O_2	42/95[2]	43/95[2]	42/75[2]	43/75[2]	42/95[2]

1. Typical property values. Should not be construed as sales specifications.
2. Optional products available with higher LOI.

GENERAL PHYSICAL & MECHANICAL PROPERTIES

KYNAR® and KYNAR FLEX® PVDF resin grades give the design professional the option to combine rigid and flexible materials when processing. As a material of construction for pumps and pipe, KYNAR® resins exhibit excellent resistance to abrasion. KYNAR® PVDF can also be manufactured in thin, flexible and transparent films, filament, and tubing. KYNAR® resins are unaffected by sunlight. For information on the ability of KYNAR® PVDF to withstand ultraviolet radiation, please contact an Arkema Fluoropolymer Representative. Tables II and III (pp. 4-5) list typical properties of KYNAR® and KYNAR FLEX® fluoropolymer resin grades, which display excellent flexural and tensile creep properties.

STRENGTH & TOUGHNESS

KYNAR® and KYNAR FLEX® PVDF fluoropolymers are inherently strong and tough as reflected by their tensile properties and impact strength. An ambient temperature tensile strength at yield of 35-55 MPa (5,000-8,000 psi) and an unnotched impact strength of 800-4270 kJ/m (15-80 ft-lbs/in) offered by select resins demonstrate this quality. These characteristics are retained over a wide range of temperatures, as shown in Figures 1 and 2.

FLEXURAL CREEP

Compared to many thermoplastics, KYNAR® fluoropolymers have excellent resistance to tensile creep and fatigue. The long-term resistance of KYNAR® resins to flexural creep at elevated temperatures is shown in Figure 3, which illustrates that KYNAR® resins are suitable for many applications in which load bearing characteristics are important. Likewise, the short-term flexural creep resistance of KYNAR® homopolymer resins reflects excellent load bearing performance.

TENSILE CREEP

KYNAR® fluoropolymers are rigid and resistant to creep under mechanical stress and load. KYNAR® resins are able to maintain a low tensile creep when subjected to constant stress. For example, when KYNAR® resin is subjected to a stress of 0.69 MPa (100 psi), the resin is able to maintain outstanding resistance even at temperatures as high as 140°C (284°F).

THERMAL PROPERTIES

KYNAR® resins exhibit high thermal stability, as illustrated in Tables II and III. Prolonged exposure of KYNAR® resin at 250°C (482°F) in air does not lead to weight loss. No oxidative or thermal degradation has been detected during continuous exposure of KYNAR® resins to 150°C (302°F) for a period of ten years. As thermogravimetric analysis (TGA) thermograms indicate in Figure 4, KYNAR® homopolymer resins are thermally stable up to 375°C (707°F) when heated in air at the rate of 5°C/min (9°F/min). KYNAR® resins thermally decompose at temperatures greater than 375°C (707°F). (Please review KYNAR® Material Safety Data Sheet for details and recommendations.) However, the melt processing range of unfilled KYNAR® homopolymer resins is very broad – from slightly above the melting point of 155°C-170°C (311°F-338°F) up to 300°C (572°F). Under certain conditions, KYNAR® resin can be processed at higher temperatures. Please consult a technical representative for more information. KYNAR® homopolymer is typically processed at temperatures from 180°C-265°C (356°F-509°F).

In general, KYNAR® resins are some of the easiest fluoropolymers to process. KYNAR® resins can be recycled up to three times without detriment to their mechanical properties because KYNAR® resin is inherently thermally stable and does not contain additives. Like most thermoplastics, KYNAR® resins discolor and degrade during processing if the processing temperature is too high, the residence time is too long, or the shear rate is too high. Please review the safety precautions on page 15 for more information.

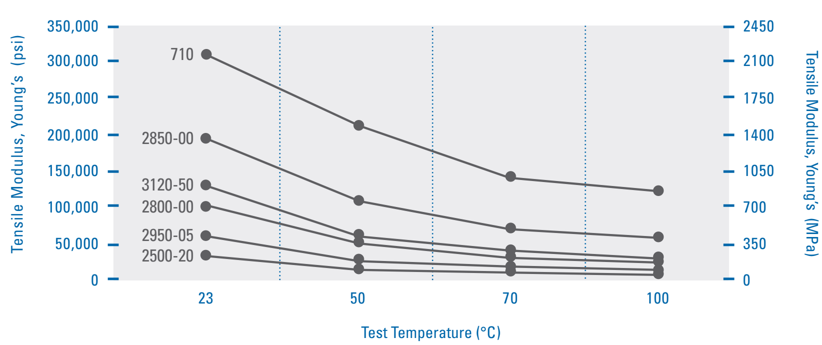
LINEAR EXPANSION

Table IV illustrates the linear expansion of various KYNAR® and KYNAR FLEX® resins for the temperature range of -120°C to 160°C (-184°F to 320°F).

CRYSTALLINITY

The degree of crystallinity of the final KYNAR® part depends on the resin grade and processing conditions. Rapid cooling (quenching) of the melt impedes crystallization and promotes a smaller crystallite size. Slow cooling or heating below the melting point (annealing) perfects the crystallization process and relaxes stresses. In addition, re-orientation by annealing increases crystallization and long-term performance and stability. With increased crystallinity, parts will have a higher yield strength, modulus and hardness.

Tensile Modulus vs. Temperature for Various KYNAR® Grades FIGURE 1



COEFFICIENT OF LINEAR THERMAL EXPANSION (x 10^{-5}/C) TABLE IV

RESIN GRADE	-40°C	-20°C	0°C	23°C	70°C	85°C
KYNAR® 710	8.9	10.8	12.2	13.4	18.3	20.4
KYNAR® 740	8.6	10.2	11.4	12.4	16.7	18.8
KYNAR FLEX® 2800-00	9.7	12.9	15.7	18.5	27.4	32.6
KYNAR FLEX® 2950-05	9.7	13.6	17.1	20.2	31.3	37.0
KYNAR FLEX® 3120-50	10.2	13.1	15.5	17.5	23.0	24.7

ELECTRICAL PROPERTIES

The electrical properties of KYNAR® PVDF resins are shown in Tables II and III. Its combination of high dielectric strength and excellent mechanical properties over a broad temperature range has led KYNAR® resin to be used for thin-wall primary insulation and as a jacket for industrial control wiring. KYNAR® PVDF resin has a high dissipation factor which lends an advantage as a material for parts requiring dielectric high heating strengths such as impedenace welding. With proper shielding, KYNAR® PVDF resin can be used as jacketing for high frequency data cables because of its excellent flame and smoke performance.

STABILITY TO WEATHER & UV EFFECTS

Many years of outdoor exposure in direct sunlight have little effect on the physical properties of KYNAR® PVDF. Some increases in tensile strength and reduction in elongation do occur over time.

OUTGASSING UNDER HIGH VACUUM

KYNAR® PVDF resin is a polymer with inherently low outgassing and low condensable film formation. KYNAR® homopolymer resins exhibit extremely low weight loss when exposed to high vacuum. At 100°C (212°F) and a pressure of 5×10^{-6} torr, the measured rate of weight loss is only 13×10^{-11} g/cm^{2}s.

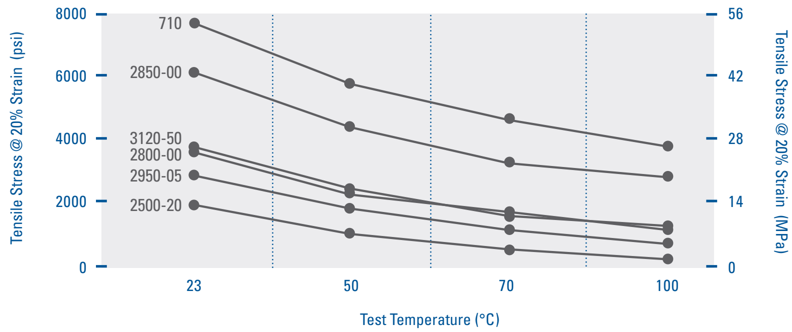
FUNGUS RESISTANCE

KYNAR® resins do not support growth of fungi when tested as described in Method 508 of Military Standard 810B (June 15, 1967).

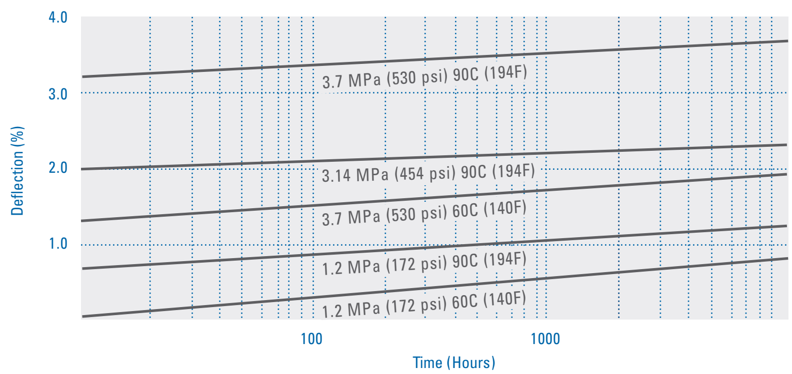
OZONE RESISTANCE

Ozone is a powerful oxidizing agent characterized by a high degree of chemical instability. KYNAR® PVDF offers excellent chemical resistance to ozone exposure. Please contact an Arkema Fluorochemicals representative for additional information.

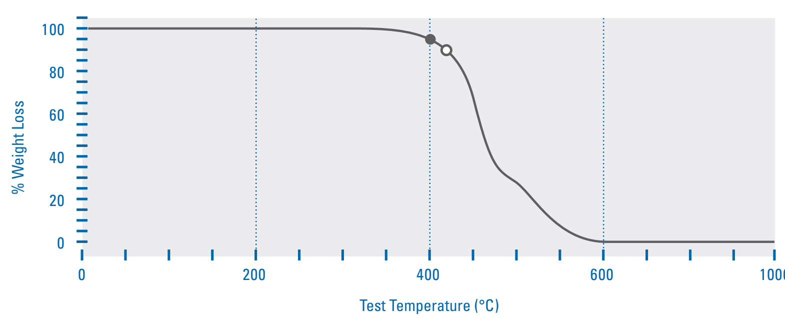
Tensile Stress @ 20% Strain vs. Temperature FIGURE 2



Flexural Creep of KYNAR® Homopolymer Resins at High Stresses as a Function of Time + Temperature FIGURE 3



TGA KYNAR® 740 FIGURE 4



DESIGN PROPERTIES FOR SPECIAL APPLICATIONS

SOLUBILITY

KYNAR® PVDF resins have limited solubility. Tables V and VI list active and latent solvents. Generally, KYNAR® resins are not soluble in aliphatic hydrocarbons, aromatic hydrocarbons, chlorinated solvents, alcohols, acids, halogens, and basic solutions. KYNAR FLEX® PVDF copolymer tends to be slightly more soluble than the KYNAR® PVDF homopolymer due to its lower crystallinity.

RESISTANCE TO NUCLEAR RADIATION

The resistance of KYNAR® fluoropolymers to nuclear radiation is excellent. The original tensile strength of the resin is essentially unchanged after exposure to 100 megarads (Mrads) of gamma radiation from a Cobalt-60 source at 50°C (122°F) and in high vacuum (10^{-6} torr). The impact strength and elongation are slightly reduced due to cross-linking. This stability to effects of radiation, combined with chemical resistance, has resulted in the successful use of KYNAR® components in nuclear reclamation plants. Tables VII and VIII show minimal changes in tensile properties of KYNAR® homopolymer and KYNAR FLEX® copolymer resins exposed to electron beam radiation in doses up to 20 Mrads according to ASTM D882 testing.

RADIATION CROSS-LINKING

The different grades of KYNAR® homopolymer and copolymer resins are readily cross-linked and do not degrade when irradiated with moderate doses of high energy electron or gamma radiation. The efficiency of cross-linking is influenced by the grade; that is, molecular weight variations are important. Examples of KYNAR® PVDF-fabricated products utilizing radiation technology are heat-shrinkable tubing and insulated wire capable of withstanding high temperatures.

ACTIVE* SOLVENTS — TABLE V

SOLVENT	BOILING POINT °C	FLASH POINT °C
Tetrahydrofuran	65	-17
Methyl Ethyl Ketone	80	-6
Dimethyl Formamide	153	67
Dimethyl Acetamide	166	70
Tetramethyl Urea	177	65
Dimethyl Sulfoxide	189	35
Trimethyl Phosphate	195	107
N-Methyl-2-Pyrrolidone	202	95

*Solvent will dissolve at least 5-10 weight percent KYNAR® resin at ambient temperature.

LATENT** SOLVENTS — TABLE VI

SOLVENT	BOILING POINT °C	FLASH POINT °C
Acetone	56	-18
Methyl Isobutyl Ketone	118	23
Glycol Ethers***	118	40
Glycol Ether Esters***	120	30
N-Butyl Acetate	135	24
Cyclohexanone	157	54
Diacetone Alcohol	167	61
Diisobutyl Ketone	169	49
Ethyl Acetoacetate	180	84
Butyrolactone	204	98
Isophorone	215	96
Triethyl Phosphate	215	116
Carbitol Acetate	217	110
Propylene Carbonate	242	132
Glyceryl Triacetate	258	146
Dimethyl Phthalate	280	149

** As a rule, latent solvents do not dissolve or substantially swell KYNAR® homopolymer resin at room temperature.

*** Based on ethylene glycol, diethylene glycol, and propylene glycol.

TENSILE MODULUS VS. RADIATION DOSE EXPOSURE (PSI) — TABLE VII

RESIN GRADE	0	2 MRADS	4 MRADS	8 MRADS	20 MRADS
KYNAR® 460	170	180	170	200	190
KYNAR® 720	230	220	230	220	240
KYNAR® 740	200	230	200	220	220
KYNAR® 760	200	190	190	210	220
KYNAR FLEX® 2850	130	130	120	130	130

ULTIMATE TENSILE STRENGTH VS. RADIATION DOSE EXPOSURE (PSI) — TABLE VIII

RESIN GRADE	0	2 MRADS	4 MRADS	8 MRADS	20 MRADS
KYNAR® 460	6200	6300	6000	6900	7200
KYNAR® 720	7400	7400	7300	7300	8400
KYNAR® 740	6900	6900	6900	7200	7900
KYNAR® 760	6300	6500	6700	7400	7800
KYNAR FLEX® 2850	4700	4700	4900	4900	5600

BASIC WELDING PRINCIPLES

In order to produce a high quality weld, three parameters must be controlled:
Temperature: within a specified range in order to produce the proper melting of the resin.
Pressure: excessive pressure must be avoided to avoid forcing the melted resin out of the weld interface.
Time: to provide uniform heating throughout the weld zone as the material's low thermal conductivity slows the heat transfer.

After reaching the proper melt conditions, slow cooling is necessary to reduce stress and permit the intermolecular diffusion of the polymer. Testing of welds for physical characteristics such as tensile, bend angle, etc. within 12 hours after completion of the weld will produce erroneous results. The weld zone should be allowed to cool to ambient temperature prior to the next weld pass. If the weld zone is not allowed to cool, excessive stress will result, which may cause distortion of the weldment.

In order to produce the highest quality weld, the surfaces to be welded must be clean. The surface should be scraped just prior to every weld pass. Wiping with a solvent only spreads the contamination!

WELDING METHODS

Several methods of fusion welding KYNAR® PVDF components are possible. The most common and successful approaches to welding KYNAR® PVDF components are heat contact and hot gas welding using a welding rod. Ultrasonic, hot lamination, infrared (IR), resistance heating, spin and radio frequency welding are all methods suitable for bonding KYNAR® resin to itself.

HOT GAS WELDING

The welding of KYNAR® PVDF can be performed using conventional hot gas welding equipment. It is highly recommended that automatic temperature welding equipment be utilized. This type of equipment greatly reduces the possibility of substandard welds due to temperature variations during the welding process. A suitable weld can be defined as one capable of meeting the Deutscher Verband fur Schweissen und verwandte Verfahren E.V. (DVS) requirements for welder certification. The values in Table IX are the current conditions accepted by the DVS as the optimal welding parameters.

The welding area should be well ventilated so that heat and fumes generated during the welding process are drawn away from the welder. Drafts, excessive air movement and similar conditions that would cause the weld to cool rapidly must be avoided. The weld area must be clean and free of particles that will be attracted to the weld.

BUTT WELDING OF KYNAR® PVDF

The conditions listed in Table X are recommended starting points for the welding of KYNAR® slab. Optimal conditions may vary slightly from these conditions.
The welding/cooling times are the suggested times for welding rolled sheets. Flat sheets may be removed sooner because they will not tend to distort if kept flat until cool.

HOT GAS WELDING CONDITIONS AS PER DVS

TABLE IX

WELDING PROCESS	WELDING TEMPERATURE	VOL AIR	FORCE** 3MM		FORCE** 4MM		WELDING SPEED
	°C*	L/MIN	N	LBS	N	LBS	CM/MIN
Fan Welding WF	300 - 320 (570 - 610°F)	40 - 60	10 - 15	2.5 - 3.5	15 - 20	3.5 - 4.5	10 - 15
High Speed WZ	365 - 385 (690 - 725°F)	40 - 60	12 - 17	3 - 4	25 - 35	6 - 8	25 - 40

*Temperature measured 5 mm inside main outlet of the welding tip. **Force applied to weld zone through welding gun.

RECOMMENDED WELDING CONDITIONS FOR BUTT WELDING*

TABLE X

THICKNESS	TEMPERATURE	MELT PRESSURE	HEATING		WELDING/COOLING	
MM (IN)	°C	N/CM²	TIME (MIN)	PRESSURE N/CM²	TIME (MIN)	PRESSURE N/CM²
3 3.2 (1/8) 4	235 - 240	15	1:00 1:07 1:15	1.0	6:00 7:00 8:00	30
4.8 (3/16) 5 6 6.4 (1/4)	230 - 235	15	1:29 1:30 1:45 1:50	1.0	9:45 10:00 12:00 12:45	30
7.9 (5/16) 8 9.5 (3/8) 10	225 - 230	15	2:00 2:00 2:35 2:45	1.0	15:45 16:00 18:30 20:00	30
12 12.7 (1/2) 15 15.9 (5/8) 19.1 (3/4) 20	220 - 225	15	3:10 3:15 3:52 4:08 4:53 5:07	1.0	24:0 24:40 30:00 31:00 38:00 40:00	30
22.5 (7/8) 25.4 (1)	215 - 220	15	5:38 6:18	1.0	44:00 50:00	30

*For processing KYNAR® 740 on a Wegener machine.

PROCESSING EQUIPMENT & MATERIALS OF CONSTRUCTION

EXTRUSION

Smooth KYNAR® PVDF products of all types can be extruded at high rates without extrusion aids, lubricants or heat stabilizers. KYNAR® resins can be processed on standard equipment with materials of construction similar to those used to process PVC or polypropylene. Drying of KYNAR® is usually not required; however, it has been shown to reduce some surface blemishes in film, sheet and pipe extrusion.

Polyethylene (PE) can be used as a purge compound at the end of a production run. Cast acrylic can also be used as a purge compound. However, if the extrusion equipment is not properly cleaned after purging, PE or cast acrylic will act as a contaminant in subsequent runs, creating weak weld lines. Unfilled KYNAR® can be used to purge flame-retardant KYNAR® grades.

PIPE EXTRUSION

KYNAR® 740 resin and KYNAR® 1000 resin are the primary grades used in chemical pipe applications. KYNAR® 740-02 contains a smoke suppressant package and is primarily used for waste drainage pipe and fittings. KYNAR FLEX® 2850 copolymer can be used for applications requiring higher impact and stress crack resistance.

Standard metering screws with an L/D ratio of 24/1 and a compression ratio of 3/1 are commonly used. The screw should have an even flight distribution between the feed, transition and metering zones. Enhanced temperature and output stability can be achieved by using a barrier-type screw. Maddox and spiral mixers are also acceptable, but pin type mixers are not recommended. Good temperature control of the extruder and tooling is required for optimal processing.

It is important to eliminate areas of melt accumulation, or hang-up points, to prevent KYNAR® resin from discoloring. Common areas of melt accumulation include behind the breaker plate, at undercuts and in any other stagnant areas. Screen packs are not typically used.

In-line spider dies are commonly used for producing KYNAR® pipe. The design should minimize material inventory in the head and be streamlined to eliminate material hang-up. Spiral dies should be designed similarly and can provide better weld line strength.

The draw down ratio (DDR) for tip and die selection generally ranges from 1.3 - 2.1 (area DDR), or 1.05 - 1.5 (OD DDR), but varies based on the dimensions of the finished pipe. The optimum land length will vary based on pipe size, process conditions and material grade. Extrusion temperatures range between 200°C- 240°C (392°F- 464°F), but vary depending on material grade as well as pipe and tooling size. Lower melt temperatures provide a "stronger" melt and are used when product whiteness is of primary concern.

Pipe is typically sized using a vacuum calibration system equipped with either a solid brass or a brass disk caliper, which is oversized to accommodate material shrinkage. See Table XII for common pipe processing temperatures.

TUBE EXTRUSION

The technical information mentioned for pipe extrusion (equipment, processing temperatures, etc.) also applies to tube extrusion.

KYNAR® homopolymers can typically be calibrated using standard contact sizing equipment similar to that used to produce pipe. The OD DDR used for contact sizing of tubing can range from 1.2 - 1.5.

All other KYNAR FLEX® PVDF resin grades, as well as thin-walled tubing, are best processed using non contact sizing calibrators. See Table XIII for common tube processing temperatures. Please contact Arkema's Fluoropolymer technical group for more information on this process.

INJECTION MOLDING

Standard injection molding equipment and tooling can be used to process KYNAR® resin. No specialty materials of construction are required, but chrome or nickel plating of polymer contact surfaces is recommended to prevent pitting.

Melt temperatures will vary based on the part geometry, tooling and resin grade. In general, lower melt and mold temperatures can be used effectively with low viscosity KYNAR® copolymer grades.

KYNAR® resin is best processed with a large sprue or edge gates. To produce the best quality parts, fill the sprue, runners and gates slowly and then ramp up the injection speed until the screw reaches its transfer position. Small pins or subgates can be used for smaller parts and will require faster injection speeds and higher melt temperatures to fill the part. If a process calls for use of a hot runner system, please contact a technical representative before committing to this practice.

KYNAR® PVDF resin requires generous venting at the end of the filling process or a burning phenomenon known as dieseling can occur.

KYNAR® PVDF resin is a highly crystalline material and will exhibit significant shrinkage. Shrinkage rate is a function of part thickness, flow direction (which is a function of gate type and location) and processing conditions. (See Table XI.)

Voiding is a common problem when molding KYNAR® resin due to the polymer's high crystallinity. Good part design practices are required to prevent voiding in thick sections of the part. See Table XIV for common injection molding temperatures.

Arkema technical service is available to discuss tooling and processing of KYNAR® PVDF.

MOLD SHRINKAGE DATA TABLE XI

GRADE	% SHRINKAGE*	
	IN FLOW DIRECTION	CROSS FLOW DIRECTION
KYNAR® 370	1.2 - 3.5	0.8 - 3.0
KYNAR® 710	1.9 - 3.5	1.6 - 3.0
KYNAR® 720	2.0 - 3.5	1.6 - 3.0
KYNAR® 740	2.8 - 3.5	1.9 - 3.0
KYNAR FLEX® 2850-04	1.9 - 3.5	1.6 - 3.0
KYNAR FLEX® 2800-00	2.5 - 3.5	1.6 - 3.0

*Measurements taken after 24 hours at ambient conditions.
Actual shinkage percent is related to size of the part and its geometry.

PIPE EXTRUSION

TABLE XII

GRADE	BARREL TEMPERATURE °C				
	REAR	MIDDLE	FRONT	HEAD	DIE
KYNAR® 460	200 - 230	220 - 240	230 - 250	230 - 250	230 - 260
KYNAR® 740	190 - 220	200 - 230	210 - 240	210 - 240	210 - 250
KYNAR® 1000	190 - 220	200 - 230	210 - 240	210 - 240	210 - 250
KYNAR FLEX® 2850	190 - 220	200 - 230	210 - 240	210 - 240	210 - 250

TUBE EXTRUSION

TABLE XIII

GRADE	BARREL TEMPERATURE °C				
	REAR	MIDDLE	FRONT	HEAD	DIE
KYNAR® Homopolymer	195 - 220	210 - 240	210 - 240	210 - 240	210 - 250
KYNAR FLEX® 3120	195 - 220	210 - 240	210 - 240	210 - 240	210 - 250
KYNAR FLEX® 2850	195 - 220	210 - 240	210 - 240	210 - 240	210 - 250
KYNAR FLEX® 2800	195 - 220	210 - 240	210 - 240	210 - 240	210 - 250
KYNAR FLEX® 2750	195 - 220	220 - 240	220 - 250	220 - 250	220 - 250
KYNAR SUPERFLEX® 2500	195 - 220	220 - 240	230 - 250	230 - 250	230 - 250

INJECTION MOLDING

TABLE XIV

GRADE	BARREL TEMPERATURE °C				
	REAR	MIDDLE	FRONT	NOZZLE	MOLD
KYNAR® 460	200 - 230	210 - 240	220 - 250	230 - 255	50 - 90
KYNAR® 710	190 - 210	200 - 220	200 - 240	200 - 240	50 - 90
KYNAR® 720	190 - 210	200 - 220	200 - 240	200 - 240	50 - 90
KYNAR® 740	200 - 220	210 - 230	210 - 245	210 - 245	50 - 90
KYNAR® 1000	200 - 220	210 - 230	210 - 245	210 - 245	50 - 90
KYNAR® 6000	190 - 210	200 - 220	200 - 240	200 - 240	50 - 90
KYNAR® 9000	190 - 210	200 - 220	200 - 240	200 - 240	50 - 90
KYNAR® 370	190 - 210	200 - 220	200 - 240	200 - 240	50 - 90
KYNAR SUPERFLEX® 2500	170 - 220	170 - 230	170 - 245	170 - 245	50 - 90
KYNAR FLEX® 2750-01	200 - 220	210 - 230	210 - 245	210 - 245	50 - 90
KYNAR FLEX® 2800-20	200 - 220	210 - 230	210 - 245	210 - 245	50 - 90
KYNAR FLEX® 2850-04	190 - 210	200 - 220	200 - 240	200 - 240	50 - 90
KYNAR FLEX® 3120-10	190 - 210	200 - 220	200 - 240	200 - 240	50 - 90

BURNING STUDIES

KYNAR® PVDF resins have been tested and meet many standards. Table XV lists test standards for which KYNAR® resin has approval. KYNAR® 740-02 and KYNAR® 1000HD homopolymer, and KYNAR FLEX® 2850-02 copolymer, were the first thermoplastics to meet the ASTM E84 flame spread and smoke development requirement for materials installed in plenums. These resins meet the criteria by having a flame spread/smoke
developed index of less than 25/50, respectively. Foamed KYNAR® parts with a density of 0.03 g/cc meet ASTM E84 with a 10/30 rating.

KYNAR® 740 PVDF homopolymer piping, tested in accordance with Underwriters Laboratories Canada (ULC) S102.2M88, meets the flame and smoke criteria with a zero flame spread and 45 smoke generation. KYNAR® 740-02 resin meets the Underwriters Laboratories (UL) 1887 Steiner Tunnel Test with a zero flame propagation, 0.02 peak average optical density, and a zero average optical density (0, 0.02, 0).

KYNAR® and KYNAR FLEX® resins meet or exceed the requirements for NFPA 262 (UL 910 Modified Steiner Tunnel Test for Wire and Cable). KYNAR® grades that pass the more stringent NFPA 255 (Steiner Tunnel Test for Limited Combustible Applications) are also available. Select KYNAR FLEX® resins also comply with UL 2024, a test designed for fiber-optic conduit used in plenums.

Testing in accordance with ASTM D2863 indicates that KYNAR® homopolymer resin has a limiting oxygen index (LOI) of 43, that is, a 43% oxygen environment is needed for the polymer to continue to burn. Special KYNAR® PVDF products are available with an LOI of nearly 100%. KYNAR® homopolymer resins have a vertical burn rating of V-O per UL 94. Also, sheets of metal coated with KYNAR 500® resin exhibit zero flame spread and zero smoke developed when tested in accordance with the ASTM E84 tunnel test.

KYNAR® homopolymer resins and KYNAR FLEX® 2850-00, 2750-01, 3120-10 resins meet Factory Mutual 4910 (FM 4910) test criteria. These flame and smoke standards were established for semi-conductor clean room environments where fires can cause high value losses, making it essential that fire be contained within the ignition zone.

KYNAR FLEX® 2950-05 and KYNAR SUPERFLEX® 2500-20 were tested and met Federal Aviation Regulations (FAR) 25.853 testing standards designed for Federal Aviation Administration (FAA) smoke density and toxicity performance. Please feel free to contact an Arkema Fluoropolymer sales representative for further information related to specific requirements.

CERTAIN GRADES OF KYNAR® PVDF MEET THE FOLLOWING TEST STANDARDS* TABLE XV

TEST METHOD	PROPERTIES
ASTM E 84 (NFPA 255, UL 723)	Surface Burning Characteristics of Building Materials
ULC S102.2	Canadian Surface Burning Characteristics of Building Materials
NFPA 262 (UL 910)	Flame Travel and Smoke of Wires and Cable for Use in Air-Handling Spaces
UL 2024	Optical Fiber Raceway
FM 4910	Cleanroom Materials Flammability Test Protocol
UL 2360	Combustibility Characteristics of Plastics Used in Semi-Conductor Tool Construction
FAR 25.853	Federal Aviation Administration Smoke Density and Toxicity Performance
ASTM E 662	Optical Density of Smoke Generated by Solid Materials
ASTM E 162	Surface Flammability of Materials Using a Radiant Heat Energy Source
BS 476:7 Class 1Y	British Standard: Fire Tests on Building Materials and Structures
UL Bulletin 94 (V-O)	Test for Flammability of Plastic Materials for Parts in Devices and Appliances
UL 1887	Fire Test of Plastic Sprinkler Pipe for Visible Flame and Smoke Characteristcs

*Specific grades and test standards are available from Arkema.
Please contact your Arkema Fluoropolymer sales representative for details.

CHEMICAL RESISTANCE

CHEMICAL RESISTANCE OF KYNAR® PVDF FLUOROPOLYMERS

KYNAR® PVDF resins are resistant to a wide range of chemicals. Most acids and acid mixtures, weak bases, halogens, halogenated solvents, hydrocarbons, alcohols, salts and oxidants pose little problem for KYNAR® PVDF. At ambient temperatures KYNAR® PVDF homopolymers are generally resistant to chemicals with a pH up to 12 and KYNAR FLEX® copolymers are generally resistant to chemicals with a pH up to 13.5.

Many factors can affect a material's chemical resistance. These include, but are not limited to, exposure time, chemical concentration, extreme temperature and pressure, frequency of temperature and pressure cycling, attrition due to abrasive particles, and the type of mechanical stress imposed. Combinations of chemical exposure and mechanical load can induce stress cracking in many otherwise chemically resistant materials, both metallic and nonmetallic. In general, the broad molecular weight distribution of KYNAR® resins results in greater resistance to stress cracking when compared to other plastics and some metals.

Factors such as permeability and adhesion affect the chemical resistance of KYNAR® PVDF coatings. Consequently, coatings may not exhibit exactly the same properties as melt-processed KYNAR® resin. Maximum use temperature for dispersion-applied or powder coatings should not exceed 100°C (212°F). However, assuming chemical resistance is still adequate, laminated systems can be used from 120°C-135°C (248°F-275°F).

Operating parameters are dependent on the particular application of KYNAR® resin and differ from those experienced in either laboratory testing or apparently similar field service. Because corrosive fluids or vapors are often mixtures of various individual chemicals, it is strongly recommended that trial installations be evaluated under actual service conditions. For example, immersion testing of KYNAR® resins in individual chemicals at a specific operating temperature will not necessarily predict the performance of KYNAR® PVDF-fabricated components when they are exposed to an exothermic reaction between the individual chemicals.

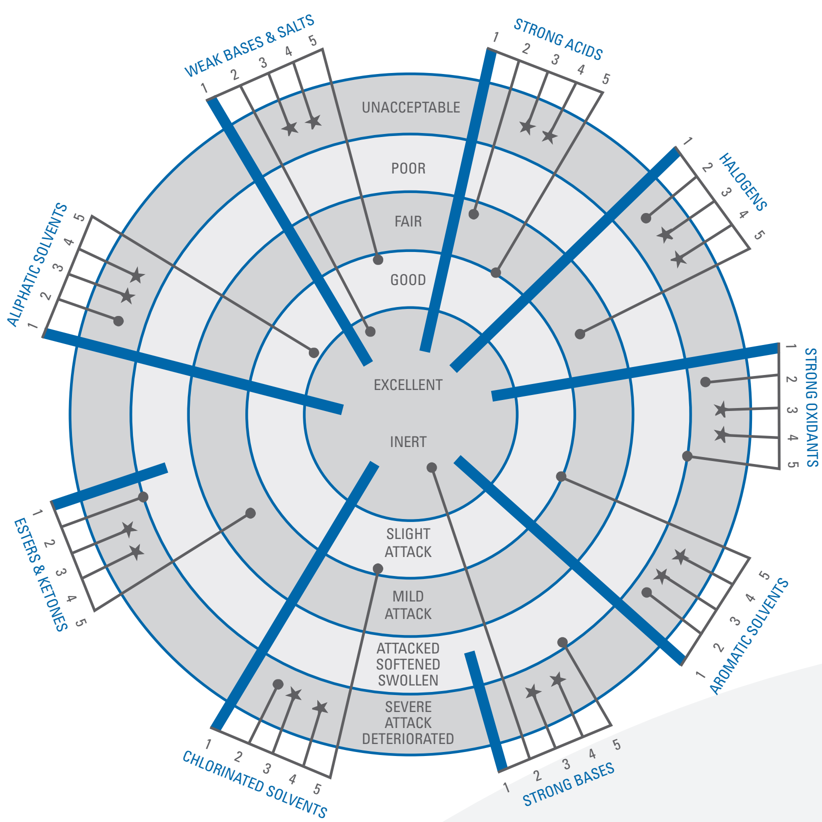
The chemical resistance of KYNAR® fluoropolymer is indicated in Figure 5. In this chart, the behavior of KYNAR® homopolymer resin at 93°C (200°F) in contact with nine general chemical species is compared with that of other well-known plastics. The rating system ranges from unacceptable severe attack in the outer segment of the circle to excellent (inert) in the bull's-eye.

An alphabetic listing of chemicals and their maximum usage temperature with KYNAR® resins is available upon request from Arkema's Fluoropolymers business unit. An additional chemical resistance guide for short term drain pipe applications is also available. Chemical applications can be complex and the information provided here should be considered a general guideline. For more information, contact a Technical Service Representative.

KYNAR® resin ratings are based on long-term immersions assuming worst-case scenarios.

Chemical Resistance of KYNAR® Homopolymer Resin vs. Other Well-Known Plastics at 93°C (200°F)

FIGURE 5



1 KYNAR® Polyvinylidene fluoride – Type I
2 Polypropylene
3 Polyvinylidene chloride
4 Polyvinyl chloride* – Type I
5 Polyester (glass fiber reinforced)

*Above recommended operating temperature of plastic

Typical Chemicals* Handled by KYNAR® PVDF

- Chlorine
- Methyl Chloroform
- Hydrochloric Acid
- Salt Water
- Chlorobenzene
- Sodium Hypochlorite
- Hot Sugars
- Sulfuric Acid <98%
- Chlorinated Salts
- Phosphoric Acid
- Hydrofluoric Acid
- Bromine (Gaseous)
- Bromine Water
- Hydrobromic Acid
- Bromobenzene
- Brominated Salts
- Iodine
- Salicylic Acid
- <50% Acetic Acid
- Methyl Alcohol
- Chromic Acid
- Nitric Acid

Mixtures of chemicals can create aggressive by-products.

*Chemical Resistance Chart Available from Arkema Inc.

FUEL AND OFFSHORE APPLICATIONS

PERCENT RETENTION IN THE TENSILE STRENGTH OF KYNAR® RESINS AFTER EXPOSURE TO FUEL AT 40°C FOR SIX MONTHS

TABLE XVI

FUEL	KYNAR® 740	KYNAR FLEX® 2850	KYNAR FLEX® 2800
C	110.7	107.8	104.4
CE10a	97.8	94.6	91.0
CE85a	99.4	98.2	99.2
B20	115.5	114.2	117.9

Fuel C is a 50/50 mixture of toluene and iso-octane

Fuel CE10a contains 10% ethanol

Fuel CE85a contains 85% ethanol

B20 is 20% biodiesel fuel

"a" at the end of the name denotes aggressive version of the fuel containing peroxide and copper ions.

KYNAR® and KYNAR FLEX® resins are used all along the petroleum supply chain, from oil and gas exploration and production to transportation and distribution. Examples include flexible pipes and umbilicals for offshore exploration, pipe for natural gas distribution, underground pipe for gas stations, and fuel lines in trucks and automobiles.

In addition to improved corrosion resistance over metals in fuel service, KYNAR® and KYNAR FLEX® resins have the broadest range in fuel service among the commonly used plastics. Many traditional materials are unsuited for the new fuels and fuel blends. KYNAR® and KYNAR FLEX® resins can be used to handle even aggressive blends like gasoline/MTBE blends, gasoline/ethanol blends, and diesel/biodiesel blends.

KYNAR® and KYNAR FLEX® resins also exhibit low permeability to most fuels while demonstrating good dimensional stability and low weight gain. KYNAR® resin retains its physical properties in fuel service and offers extended service life compared to other materials. Table XVI shows that KYNAR® and KYNAR FLEX® maintain their tensile strength after six months of exposure to a variety of fuels. Bondable grades of KYNAR® are also available to create multilayer structures for fuel service wherein KYNAR® resin is used as a barrier layer, tied to other materials like PE, PP, TPU, TPE, rubber, and metals.

REGULATORY STATUS OF KYNAR® POLYVINYLIDENE FLUORIDE

KYNAR® PVDF homopolymer resins may be safely used in articles intended for repeated contact with food per Title 21, Code of Federal Regulations, Chapter 1, part 177.2510. KYNAR FLEX® PVDF copolymer resin meets part 177.2600.

KYNAR® homopolymer resins are acceptable for use in processing or storage areas in contact with meat or poultry food products prepared under federal inspection according to the United States Department of Agriculture (USDA).

KYNAR® homopolymer resins comply with the criteria in "3-A Sanitary Standards for Multiple-Use Plastic Materials Used as Product Contact Surfaces for Dairy Equipment, Serial No. 2000."

KYNAR® homopolymer and KYNAR FLEX® copolymer resins have been tested and are in compliance with United States Pharmacopeia (USP) Classification VI. KYNAR® homopolymer resin grades are listed with the National Sanitation Foundation (NSF) under Standard 61 for potable water applications, NSF-51 for food equipment, and NSF-14 for pressure-rated piping.

KYNAR® homopolymer and copolymer resin grades also meet FDA regulations part 177.1520 for single use in polyolefins to 1% concentrates.

Please contact Arkema to learn which grades of KYNAR® homopolymers and copolymers meet these regulatory approvals.

RECOMMENDED SAFETY PRECAUTIONS FOR MELT PROCESSING

KYNAR® resins are relatively non-toxic and non-hazardous under typical handling conditions. Mechanical malfunctions or human error, however, may lead to thermal decomposition with evolution of hydrogen fluoride (HF).

Precautions must be taken to prevent excessive inhalation and physical contact with hydrogen fluoride should decomposition take place. Unlike PVC, KYNAR® resins will stop decomposing when the heat source is removed and the temperature of the melt is allowed to fall to normal processing temperature.

Additives, such as mica, asbestos, glass fibers, certain formulations of titanium dioxide, and very finely divided metals, may catalyze thermal decomposition rates during processing and should be used with caution. It is strongly recommended that the fabricator consult with the local Arkema Fluoropolymer sales representative before using any additives.

Please refer to Table XVII for a brief summary of regulatory listings and approvals. For more details, read "Product Safety Bulletins KYNAR® Fluoropolymer Products" and the appropriate Material Safety Data Sheet available at www.kynar.com.

SELECT KYNAR® AND KYNAR FLEX® PVDF GRADES HAVE THE FOLLOWING REGULATORY LISTINGS AND APPROVALS TABLE XVII

AUTHORITY	REGULATION
National Sanitation Foundation (NSF)	NSF-61 Potable Water, NSF-51 Food Equipment, NSF-14 Plumbing System Components
Food & Drug Administration (FDA)	177.2510 & 177.2600 Repeated Contact with Food, 177.1520 Single-Use Adjuvant for Use in Polyolefins 1% Concentration
United States Department of Agriculture (USDA)	Use in Process or Storage Areas to Contact with Meat or Poultry Food Products
3-A Sanitary Standards Inc. (3-A SSI)	Multiple-Use Plastic Materials Used as Product Contact Surfaces for Dairy Equipment
United States Pharmacopeia	Class VI
Chicago Rabbinical Council (CRC)	Kosher Certified

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ARKEMA
The world is our inspiration

Lined Glove Box

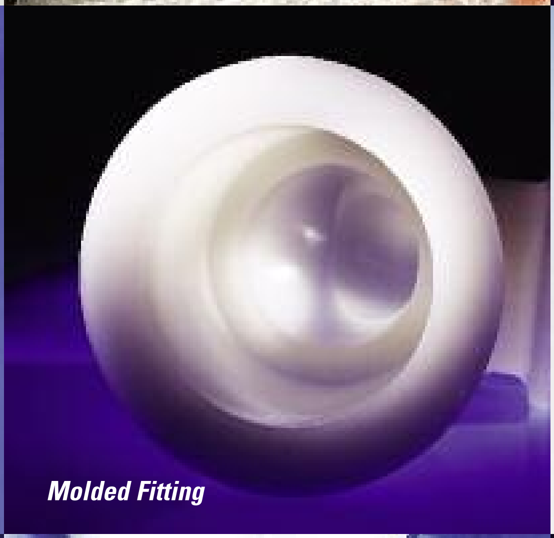
High Purity Pipe

Film

Tower Packing

Flexible Tubing

Nozzle



Molded Fitting

Plastic-Lined Steel

Rotomolded Container

Flame Retardant Pipe

KYNAR® PVDF Foam

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The chemical, physical, and toxicological properties of these chemicals may not have been fully investigated. You must use due caution in handling of any such material and follow appropriate, good industrial hygiene and safety precautions to prevent human exposure. Carefully read and understand the information on the Material Safety Data Sheet (MSDS) before beginning work with the materials described in this brochure.

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