Fluon PFA

Technical Brochure

Ver1.01

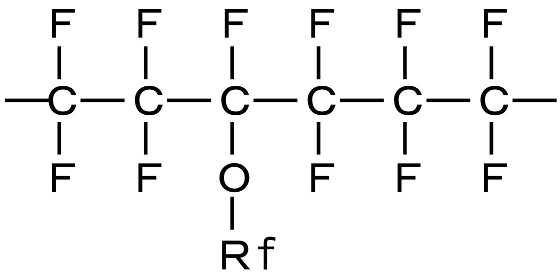
Contents

1. Introduction

Fluon PFA is a copolymer of tetrafluoroethylene (C_2F_4) and perfluoroalkoxyethylene. As the diagram below shows, in the basic structure of Fluon PFA, all of the carbon atoms are strongly bonded to fluorine atoms. As a result, over a wide range of temperatures, PFA has excellent chemical, electrical, mechanical, and surface properties. Moreover, compared with PTFE, it is fluid when molten and so is amenable to injection, extrusion, blow, transfer, and other melt processing methods.

This technical brochure is provided to assist users as they develop various applications that exploit the properties of Fluon PFA; the document gives comprehensive coverage of the material properties of Fluon PFA and information about how to use the resin in molding processes.

Molecular structure of Fluon PFA



–O–Rf denotes perfluoroalkoxy group

The data presented are actual measured values, but no guarantee is provided that users will achieve the same results. For more information about handling, first read the material data safety sheet.

2. Characteristics of Fluon PFA

- Excellent sustained mechanical strength

From –200° to +260°C, Fluon PFA holds its mechanical strength over a wide range of temperature and, within this range, products maintain a stable form.

- Excellent chemical resistance

Able to resist most solvents, Fluon PFA is a material that is highly stable when used with chemicals.

- Excellent electrical characteristics

Displaying an very low dielectric constant and very low dielectric tangent, Fluon PFA is an outstanding material for electrical insulation and has been helping to raise the reliability in the electronics sector.

- Excellent noncombustibility

Fluon PFA has an oxygen index value of more than 95: because of its incombustibility, it is finding widespread application in diverse fields.

- Excellent surface characteristics

Along with low friction, non-stick properties, water and oil repellency and other excellent surface characteristics that can used with good effect, Fluon PFA also is highly reliable and displays low resistance to fluid flow.

- Excellent weatherability

Fluon PFA stands up to direct sunlight, the rigors of the wind and weather, exhaust gas, and other trials without fall off in performance or deterioration: even after long exposure out of doors, its properties are not compromised.

3. Specifications and grades of Fluon PFA

Grade	Form	MFR	Application	Molding method
P-66P	**Cylindrical pellet**	**1 - 3**	**Anti-stress-cracking molded parts Linings**	**Injection, Extrusion, Blow, Compression, Transfer**
P-65P	**Cylindrical pellet**	**3 - 7**	**Ordinary molded parts**	**Injection,Blow, Extrusion,**
P-63P	**Cylindrical pellet**	**7 - 18**	**Ordinary molded parts**	**Injection, Extrusion**
P-62XP	**Cylindrical pellet**	**24 - 36**	**High fluidity molding**	**Injection, Extrusion**

Other items in the line up include powder grade and compounding products. See the end of this document for more information and contact us for more specific enquiries.

Storage of raw materials

Fluon PFA is not hygroscopic and it is not essential to predry the resin. As far as possible, however, resin containers should be kept tightly sealed so as to prevent the ingress of moisture; during storage, conditions that generate static electricity, which attracts dust and other contaminants, should also be avoided.

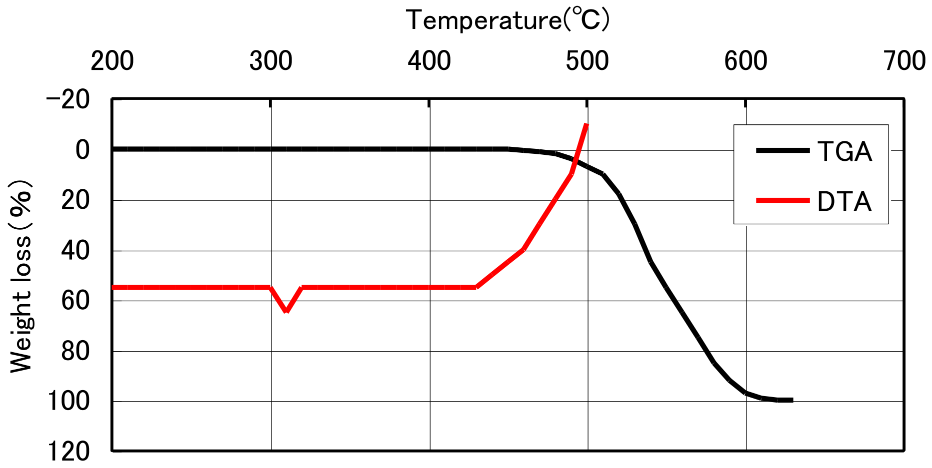
4. Thermal properties

4-1. Thermal decomposition

Figure 1 shows curves for DTA (differential thermal analysis) TGA (thermal gravity analysis). Table 1 shows data for weight loss related to temperature.

Up to around 450°C there is excellent thermal stability without weight loss. Moreover, at 700°C there was not decomposition residue.

Figure 1. DTA (differential thermal analysis) and TGA (thermal gravity analysis)



(Rate of temperature increase 10°C/min, in air)

Table 1. Weight loss temperature

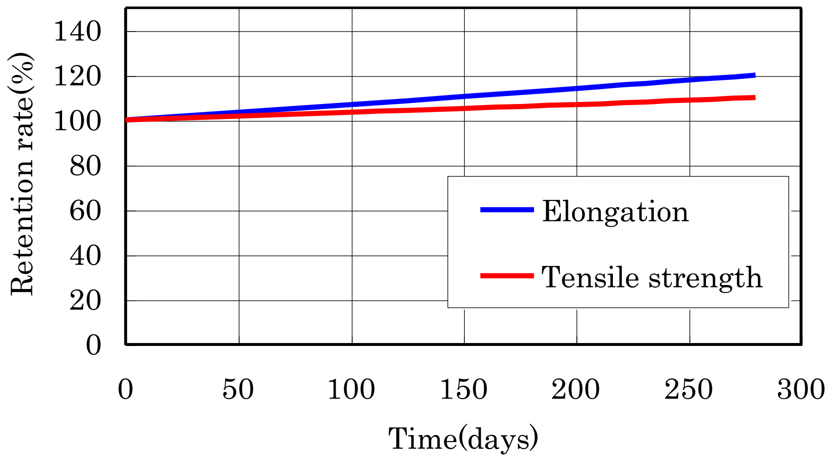
Unit: °C

Grade	P-66P	P-63P	P-62XP
Initial weight loss	450	449	436
10% weight loss	519	518	516
50% weight loss	540	542	539

4-2. Heat aging (ASTM D638)

After being maintained at 280°C for 280 days, the tensile strength and elongation values were greater than the values obtained at the start of the experiment.

Figue2. Retention of tensile strength and elongation.

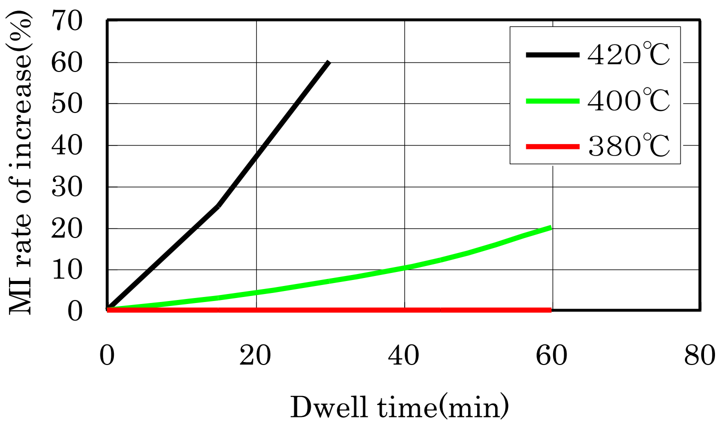


4-3. Thermal stability

Figure 3 shows the effect of temperature and dwell time on MFR. Resin reached the specified temperatures inside the melt indexer; after being held at these temperatures, at the specified times, MFR was evaluated.

After being kept at 380°C for more than 1 h, there is no change in the MFR of the resin.

Figure 3. Effect of temperature and dwell time on MFR (P-63P).



4-4. Linear Thermal Expansion Coefficient (ASTM D 696)

Table 2 shows data for the linear thermal expansion coefficient from –100℃ to +210℃

Tabel-2. Linear thermal expansion coefficient [unit: 10^{-5} /K]

Temperature range [degree C]	P-66P	P-63P	P-62XP
-100 ~ -75	9	9	8
-75 ~ -15	12	11	12
-15 ~ +100	14	14	15
+100 ~ +150	16	16	17
+150 ~ +210	21	21	21

4-5. Heat Distortion Temperature (JIS K7207)

Table 3 shows the heat distortion temperature. The temperatures are those at which test pieces under loading, one under 0.45 MPa and the other under 1.81 MPa, showed bending of 0.254 mm as the temperature was increased at a rate of 2℃/min.

Table-3. Heat distortion temperature [unit: ℃]

Loading	P-66P	P-63P	P-62XP
0.45MPa	91	92	93
1.81MPa	56	57	57

4-6. Vicat Softening Temperature (JIS K7206)

Table 4 shows Vicat softening temperature. The values shown are the temperatures at which a needle, 1 mm in diameter and under a load of 1 kg, placed at the center of a test piece, penetrated 1 mm into the test piece as the temperature was increased at a rate of 50℃/h.

Table-4. Vicat softening temperature [unit: ℃]

P-66P	P-63P	P-62XP
287	281	270

4-7. Flammability

Table 5 shows the oxygen index and combustibility test results

Because it is a perfluoro resin, Fluon PFA does not burn even when the concentration of oxygen reaches more than 95%. Moreover, Fluon PFA passes 94V-0, the most difficult UL 94 combustibility test standard.

Table-5. Oxygen index and Flammability

Grade	P-66P	P-63P	P-62XP
Oxygen Index (ASTM D2863)	>95	>95	>95
Flammability (UL 94V)	94V-0	94V-0	94V-0

5. Mechanical Properties

5-1. Tensile Properties (ASTM D638)

Fig-4、5、6 and 7 show the effect of temperature on tensile strength, elongation, yield strength and Young's modulus (elastic modulus in tension). Table-6 presents data showing the effect of low temperature on tensile strength and elongation.

Figure 4. Effect of temperature on Tensile strength

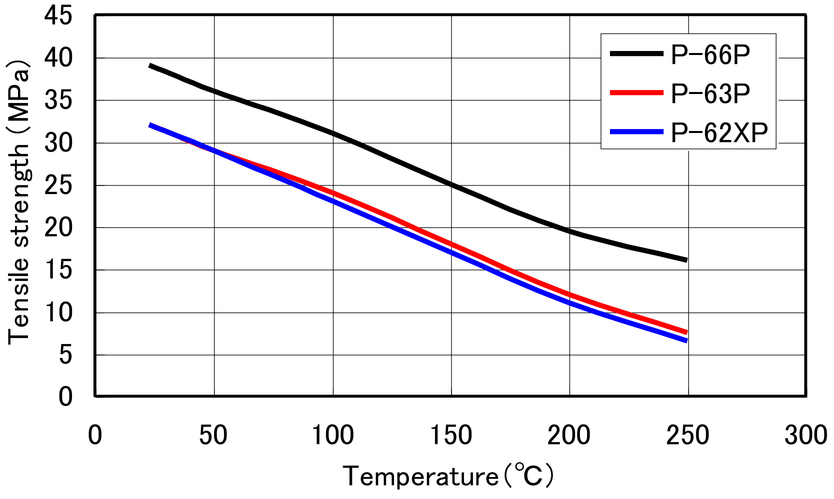


Figure 5. Effect of temperature on tensile elongation

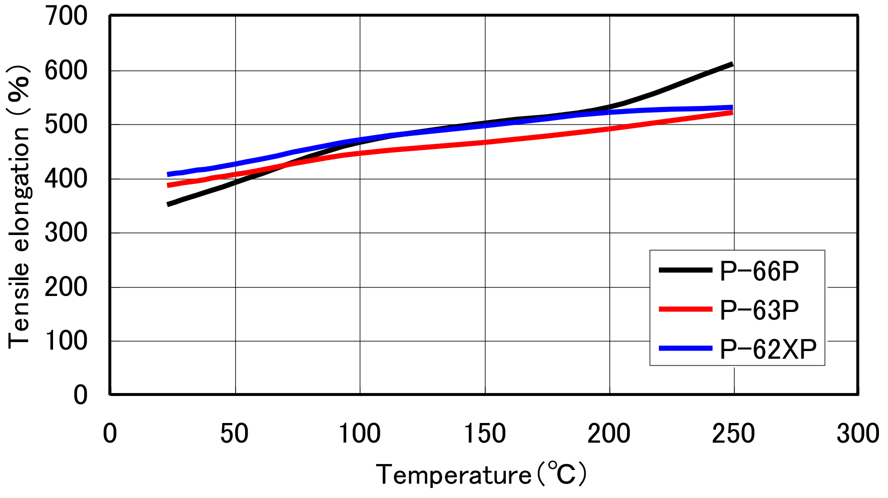


Figure 6. Effect of temperature on yield strength

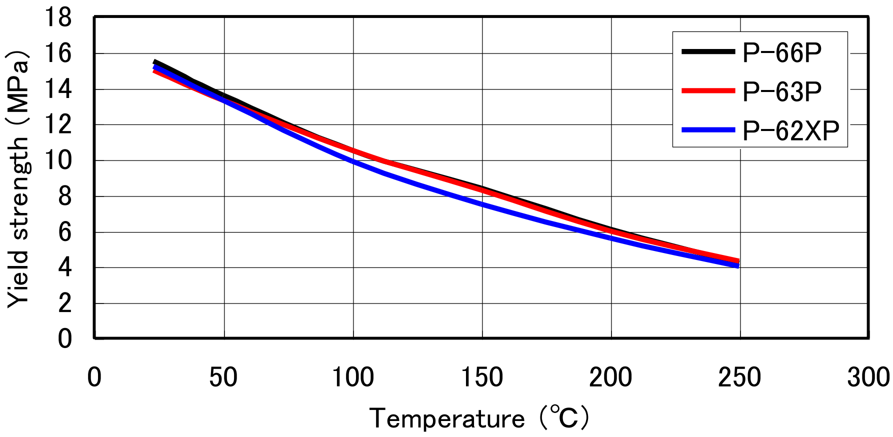


Figure 7. Effect of temperature on Young's Modulus (elastic modulus in tension)

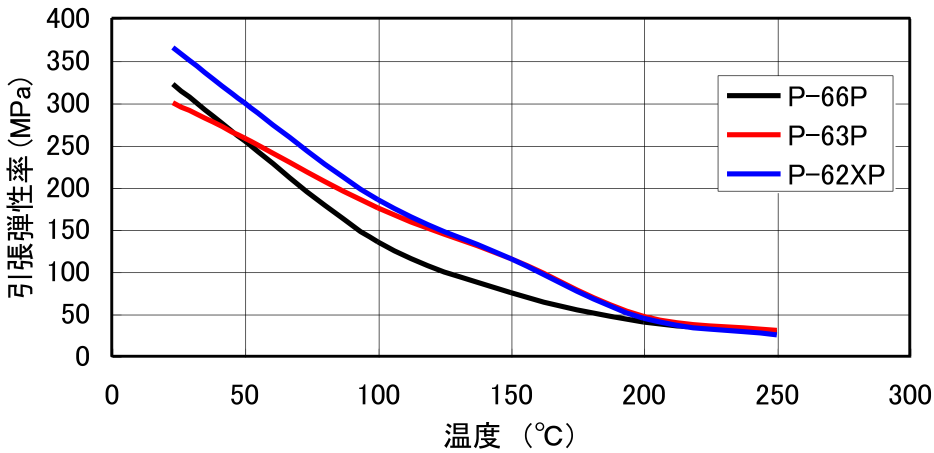


Table-6. Effect of low temperature on tensile strength and elongation.

	P-66P		P-63P		P-62XP	
	Strength MPa	Elongation %	Strength MPa	Elongation %	Strength MPa	Elongation %
-198 ℃	**130**	**1**	**140**	**1**	**140**	**1**
-129 ℃	**100**	**1**	**110**	**1**	**100**	**1**
-79 ℃	**50**	**9**	**50**	**9**	**50**	**7**

5-2. Flexural properties (ASTM D790)

Figure-8 and 9 show the effect of temperature on flexural strength and flexural modulus. Table-7 shows the flexural modulus at low temperature.

Figure 8. Effect of temperature on flexural strength.

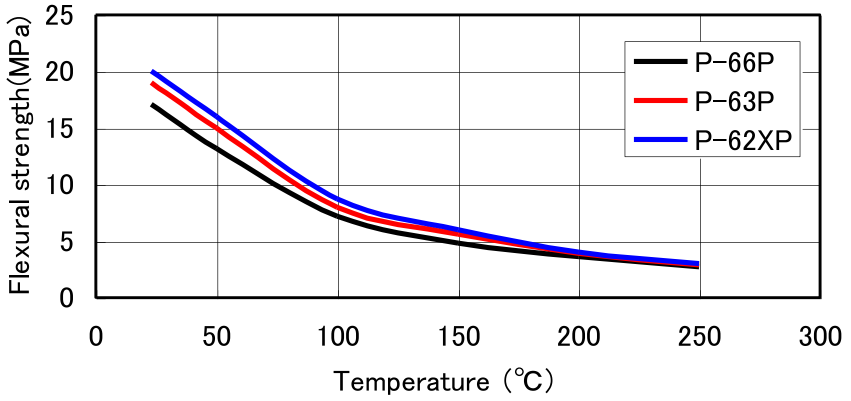


Figure 9. Effect of temperature on flexural modulus.

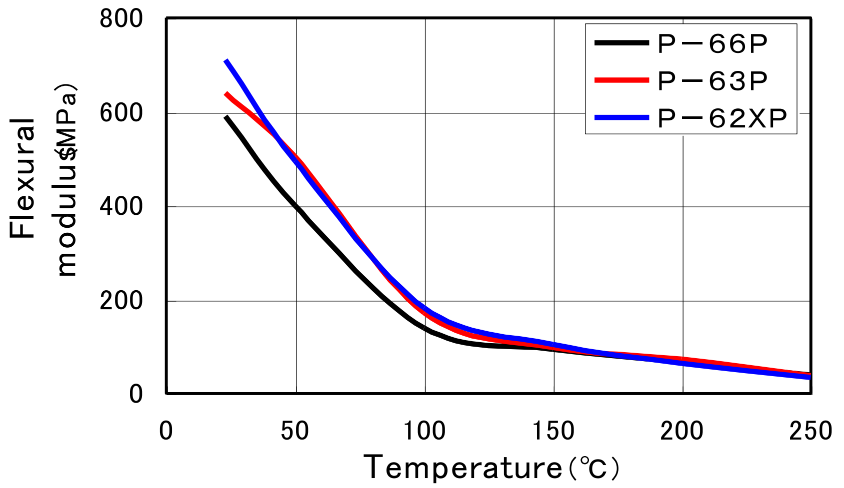


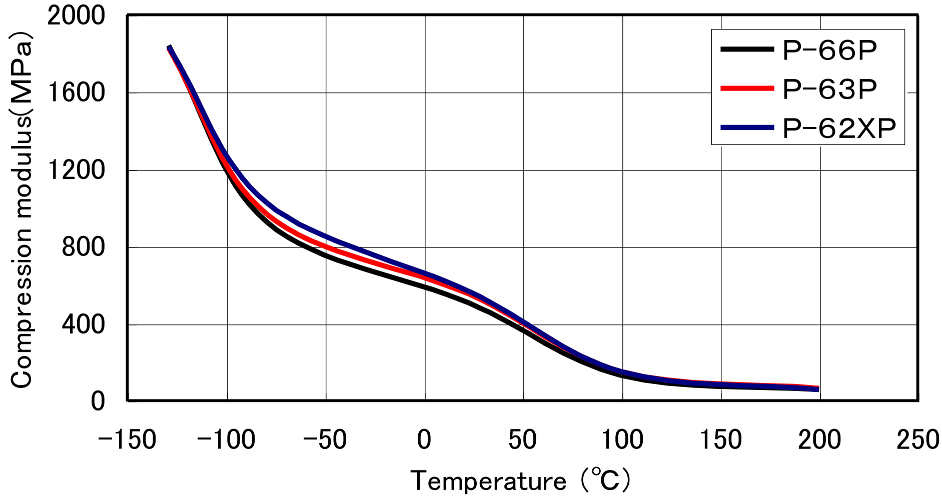
Table-7. Flexural modulus at low temperature [unit: MPa]

Temperature	P-66P	P-63P	P-62XP
-129 ℃	3900	4000	3900
-79 ℃	1500	1600	1500

5-3. Compression Properties (ASTM D695)

Figure 10. shows effect of temperature on the compression modulus .

Figure 10. Effect of temperature on compression modulus



5-4. Creep characteristics

Tensile creep (ASTM D674)

Figure 11 shows the effect of loading on tensile creep and Figure 12 shows tensile creep high temperature.

Figure 11. Effect of loading on tensile creep (P-66P, room temp.).

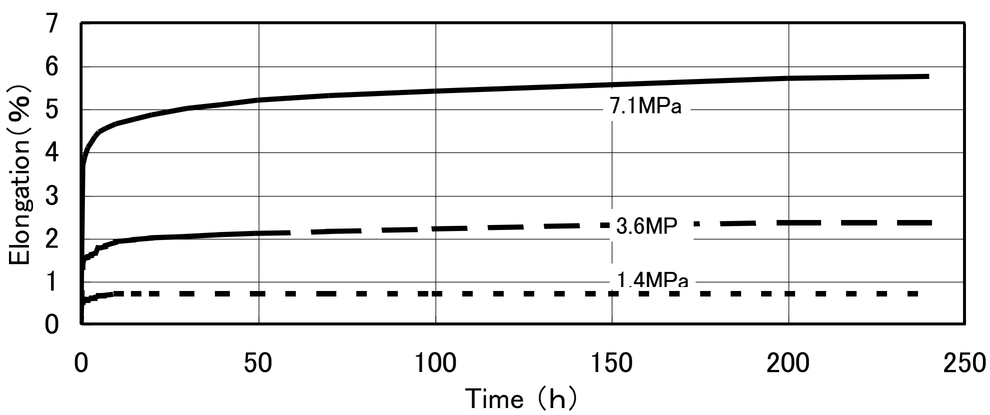
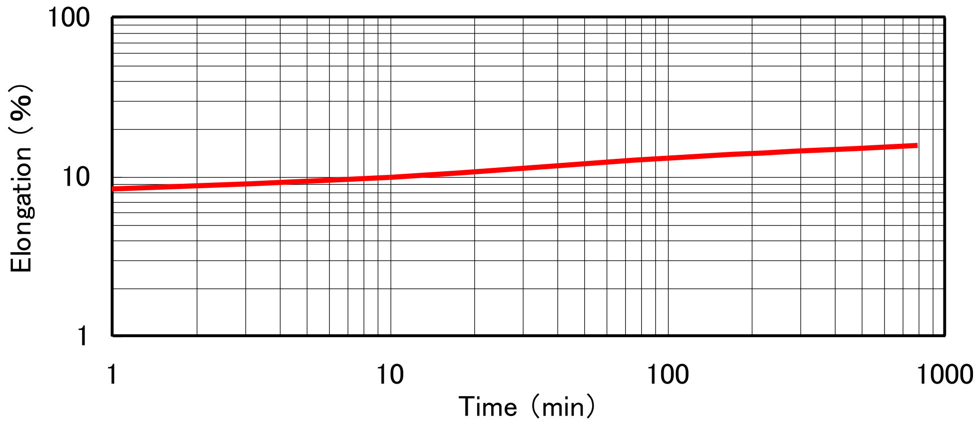


Figure 12. Tensile creep at high temperature　(P-63P 250℃ 2.5MPa)



Compression creep ASTM D621

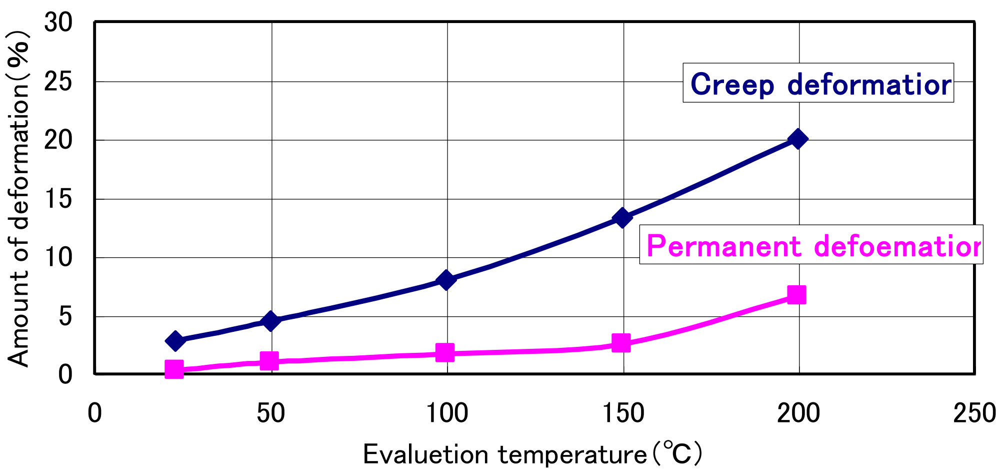
Figure 13 shows the effect of temperature on compression creep and permanent deformation

Figure 13. Effect of temperature on compression creep and permanent deformation.

Test pieces: 12.7mm diameter by 12.7mm length (P-62XP)

Evaluated load: 6.9 MPa, Loading period: 24 h

Figure 13. Effect of temperature on compression creep and permanent deformation.



5-5. Impact strength (ASTM D256)

The notched Izod impact test is a method for evaluating the impact strength of plastic. In this test a notched piece of plastic is subject to impact and the amount of energy absorbed breakage is measured. Fluon PFA does not break at room temperature.

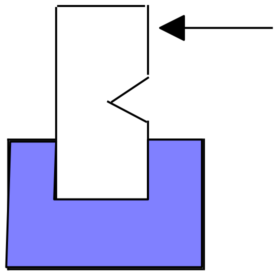


Table 8. Impact strength (notched Izod) Unit: J/m

Temperature	P−66P	P−63P	P−62XP
−40℃	700	680	570
25℃	No breakage	No breakage	No breakage

Test piece : 64 x 12. 7 x 3. 2mm (notched)

5-6. Friction and wear characteristics

Figure 15 represents data for the dynamic friction coefficient and Figure 16 shows wear constant values.

Figure 15. Effect of PV value on dynamic friction coefficient.

Partner material SUS316

Area of contact 2 cm^2

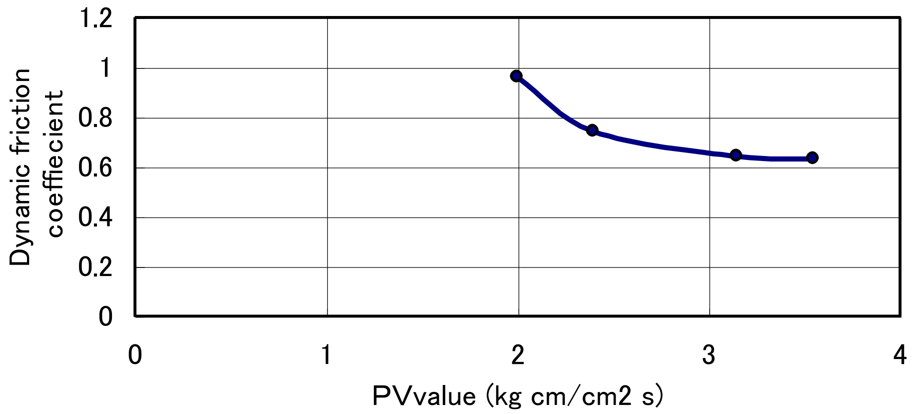
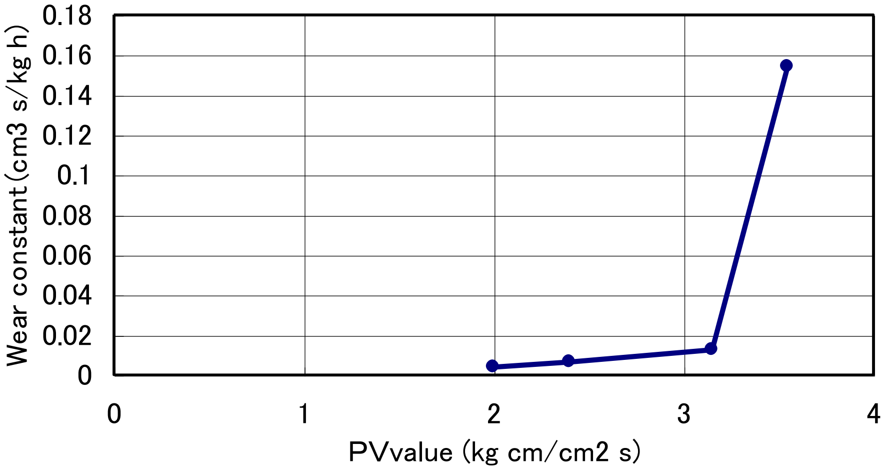


Figure 16. Effect of PV value on wear constant values

Partner material SUS316

Area of contact 2 cm^2



5-7. Flex life (MIT method ASTM D2176)

Using the MIT method, the flex life of PFA was measured as a simple means of evaluating resistance to stress cracking. Test pieces were short straps, 1.25 mm × 130 mm × 0.23 mm, that were bent to ±135° at a rate of 175 times per min until they broke; the number of flexes was recorded. Results show that Fluon PFA has a longer life than similar grades made by other companies.

Table 9. Flex life.

Grade	P-66P	P-63P	P-62XP
Cycles	$50x10^4$	$2.5x10^4$	$1.8x10^4$

6. Electrical properties

6-1. Dielectric constant and dielectric tangent (ASTM D150)

Figures 17 and 18 show the effect of frequency on dielectric constant and dielectric tangent.

Figure 17. Effect of frequency on dielectric constant.

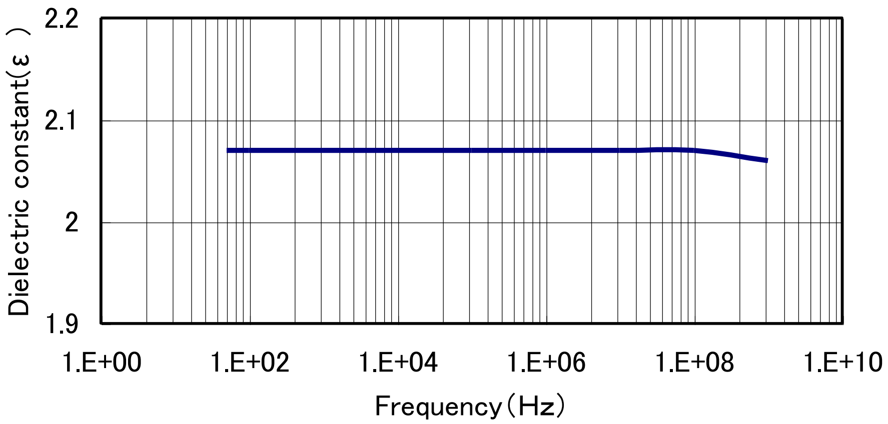
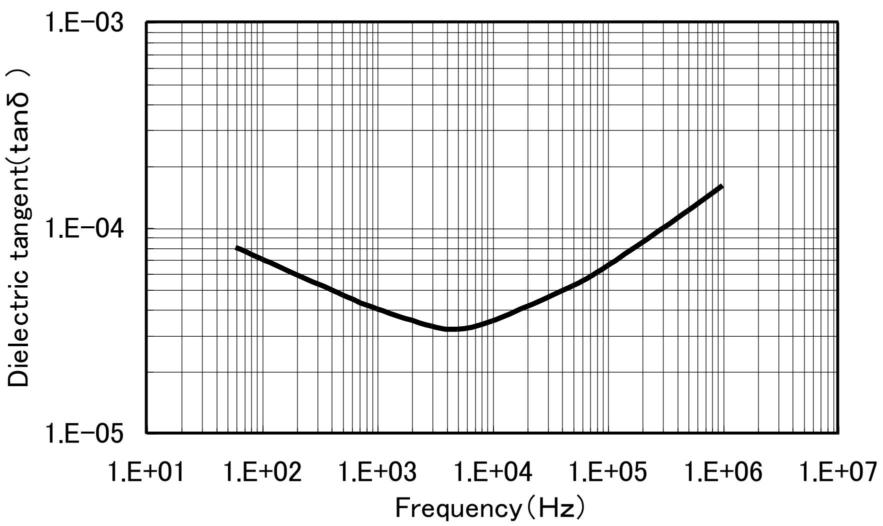


Figure 18. Effect of frequency on dielectric tangent.



6-2. Insulation characteristics

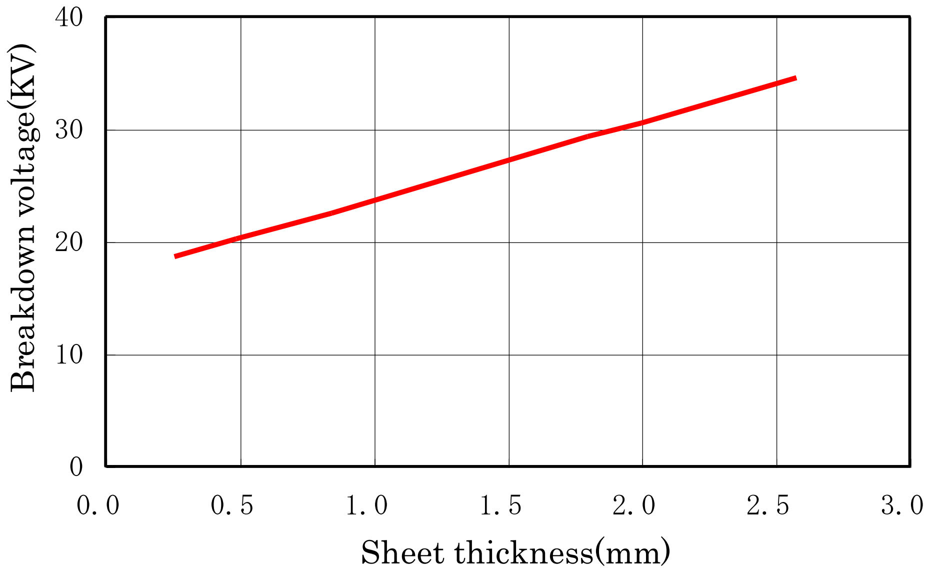
The data in Table 10 shows the effect of temperature on volume resistivity and Figure 19 shows the dependence of insulation breakdown voltage on material thickness.

Table 10. Effect of temperature on volume resistivity ASTM D257

Temperature (℃)	23	50	100
Volume resistivity (Ωcm)	3×10^{17}	5×10^{17}	3×10^{17}

Figure 19 shows the dependence of insulation breakdown voltage on material thickness.

Figure 19. Dependence of insulation breakdown voltage on material thickness.



7. Chemical properties and other qualities

7-1. Chemical resistance

Table 11 shows data for changes in tensile strength, tensile elongation, and weight, before and after immersion in various chemicals. Values after immersion, expressed as a percentages of the values before immersion, show that immersion had little effect on the properties.

Table-11. Chemical resistance

Chemical	Immersion temperature (℃)	Immersion period (days)	Tensile Strength Retention (%)	Tensile Elongation Retention (%)	Weight change (%)
Sulfuric acid/hydrogen peroxide＊	150	28	85	103	0.40
Fuming nitric acid	25	28	88	91	0.61
Conc. Hydrochloric acid	100	28	94	105	0.44
Ethanol	78	7	88	124	0.09
Acetone	56	7	93	119	0.31
Carbon tetrachloride	78	7	81	116	2.49
Chloroform	61	7	97	109	1.49
Toluene	110	7	99	111	0.77
Xylene	138	7	95	104	0.72
Benzene	80	7	100	108	0.56
ｎ－Hexane	64	7	87	100	0.53
Ethylmethylketone	80	7	86	94	0.61
Ethyl acetate	77	7	94	100	0.59
Aniline	185	7	100	97	0.30
Phenol	182	7	84	94	1.33

＊ 96%Sulforic acid／35% hydrogen peroxide＝70/30 wt%　Exchange chemicals is every 8 days.

7-2. Environmental Stress Crack Resistance (ASTM D1693)

After a notch was cut into the middle of one side of a long narrow strip (38 mm x 2.3 mm), each test piece was bent 180[deg] and immersed in one of the solvents for the indicated period. The test pieces were subsequently examined for evidence of cracking.

Table-12. Stress crack resistance

Chemical	Temp.	Days	Number of cracked pieces (cracked/tested)	
Grade			P-66P	P-63P
Non chemical, heat cycle	*	21d	0/3	0/3
Toluene	100℃	7d	0/3	0/3
Nitrobenzene	100℃	7d	0/3	0/3
Acetophenone	100℃	7d	0/3	0/3
Perchloroethylene	100℃	7d	0/3	0/3
Sulfuryl chloride	23℃	7d	0/3	0/3
Carbon tetrachloride	75℃	7d	0/3	0/3

*Rapid cooling once a day from 100°C to room temperature

Fluon PFA has excellent chemical resistance to other inorganic acid and bases and organic solvent.

It should be noted, however, that Fluon PFA shares with PTFE and other fluororesins a propensity to react with alkali metals (metallic sodium) and flourine.

7-3. Radiation resistance

If Fluon PFA is exposed to a large amount of radiation, because it is a perfluororesin, the principal chain in the copolymer structure is liable to breakage, which reduces tensile strength and tensile elongation.

Figure 20. Retention of tensile strength on exposure to radiation.

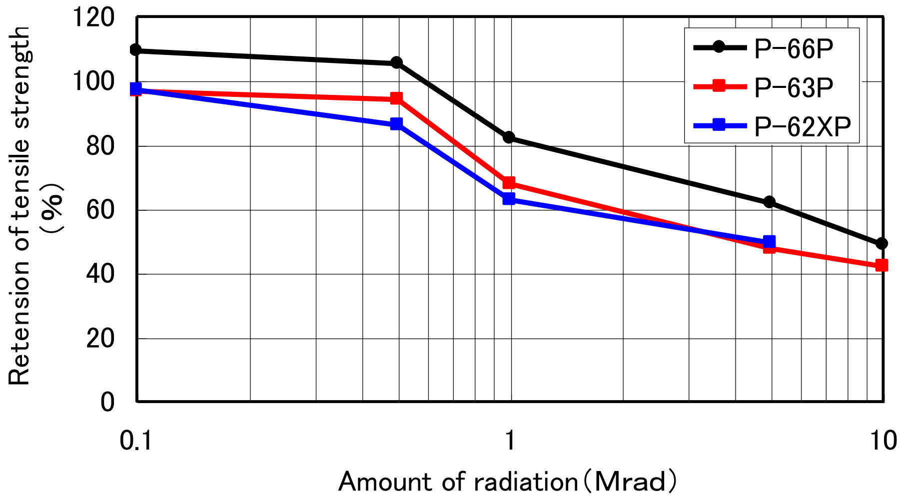
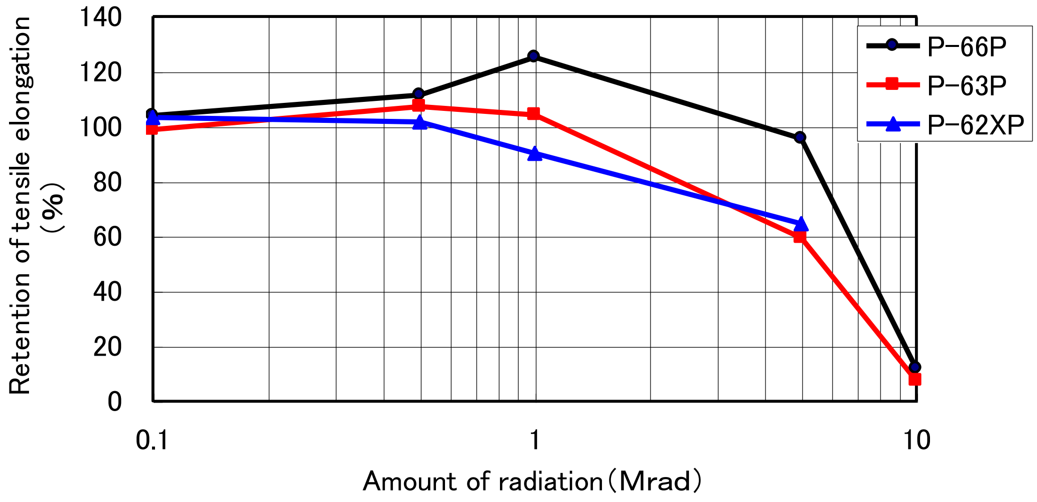


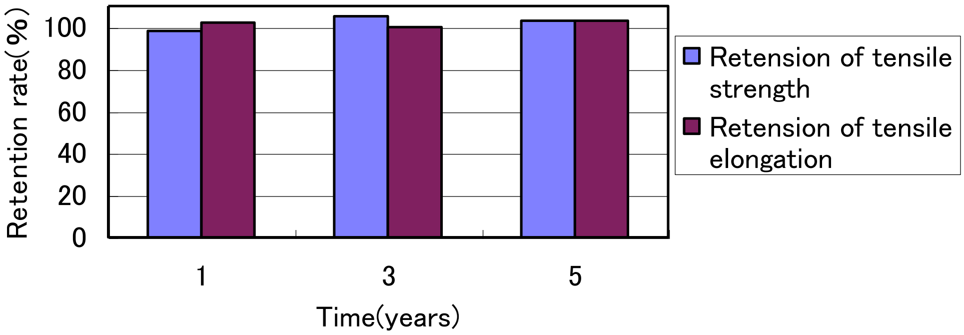
Figure 21. Retention of tensile elongation on exposure to radiation.



7-4. Weatherability

Fluon PFA has stands up to the weather exceptionally well: even after long exposure out of doors, there is no significant reduction in its material properties.

Figure 22. Weatherability



Material : P－63P
Form of material: Film, thickness 50 μm

7-5. Gas permeability (ASTM D1434)

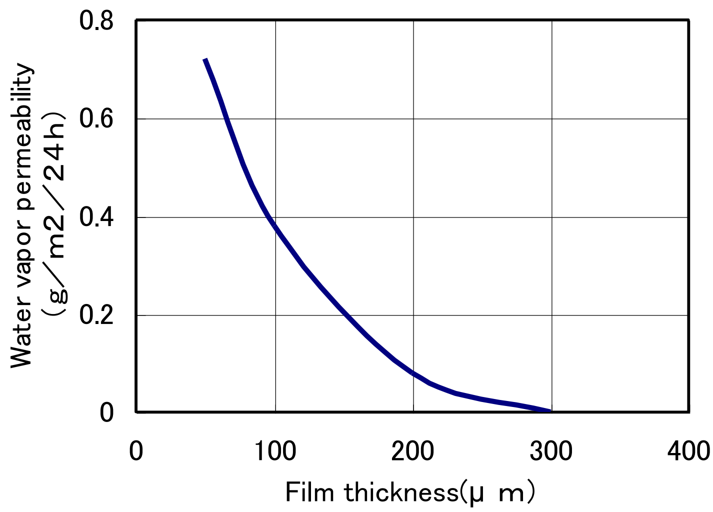
Table 13. Gas permeability

unit $\times 10^{-10} cm^3$ cm/sec cm^2 cmHg

	P－66P	P－63P	P－62XP
Oxygen	4.4	3.6	3.6
Nitrogen	1.5	1.4	1.6

7-6. Water vapor permeability

Figure 23. Water vapor permeability.



7-7. Contact angle

Table 14. Water contact angle and critical surface tension

Grade	Unit	P66P	P63P	P62XP
Water contact angle	Degree	115.4	114.8	115.5
Critical surface tension	dyne/cm	18	17	17

- Critical surface tension

If the contact angles (θ) of a number of alkanes that have differing surface tension are measured on a solid substrate, when cos θ of the vertical axis is obtained against the horizontal axis of the surface tension of alkane and the result is a straight line, cos θ equals 1; in other words, the liquid completely wets the surface; at this point, the surface tension of the liquid is taken to be the critical surface tension of the solid substrate.

7-8. Refractive index ASTM D542

Table 15. Refractive index

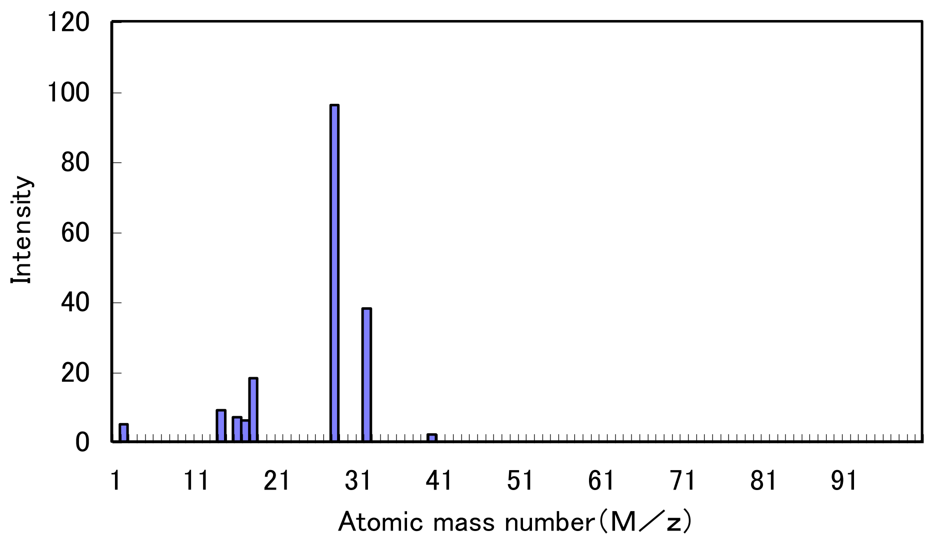
P－66P	P－63P	P－62XP
1. 35	1. 35	1. 35

7-9. Gas emission in high vacuum

Fluon PFA was subjected to a high vacuum and thermal desorption spectroscopy – mass spectroscopy (TDS–MS) was used to detect whether any gases were present. The mass spectroscopy data are presented in Figure 24: each of the peaks detected was of adsorption water and air from the sample; no gases derived from the resin were detected.

Figure 24. Mass spectroscopy detection of gas emission in high

Conditions: Temperature 100°C, pressure 1×10^{-8} torr



Atomic mass number	2	14	16	17	18	28	32	40
Type of molecule	H_2^+	N^+	O^+	OH^+	H_2O^+	N_2^+	O_2^+	Ar^+

7-10. Food safety

Fluon PFA has passed the Chemical Testing Association's test based on criteria listed in the 20th Bulletin (1982) issued by the Japanese Ministry of Health and Welfare.

8. Properties in molten state

Melt viscosity

Figures 25, 26, and 27 show the effect of shear rate on apparent melt viscosity.

Orifice: 2.095mm ϕ ×8mm

Figure 25. Effect of shear rate on apparent melt viscosity P-66P

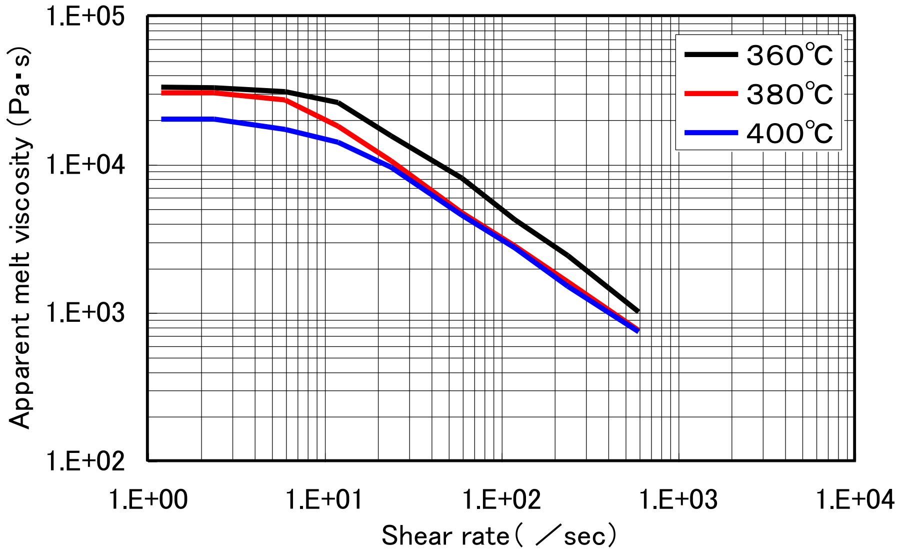


Figure 26. Effect of shear rate on apparent melt viscosity P-63P

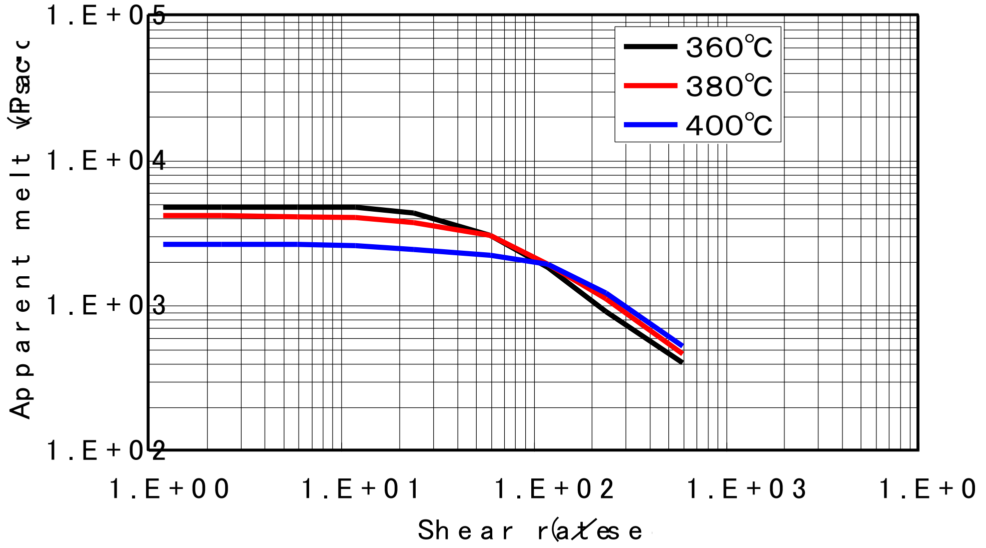
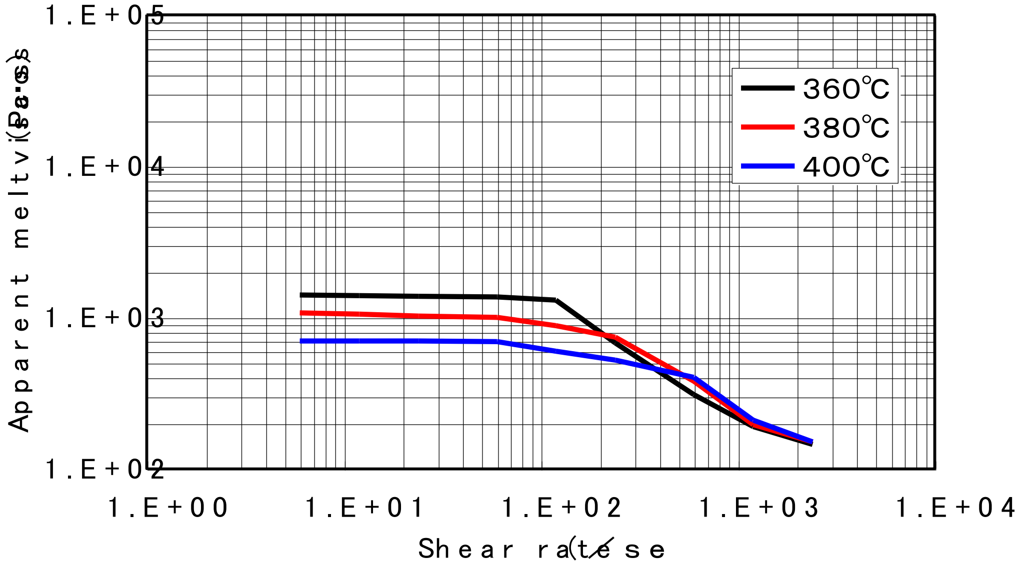


Figure 27. Effect of shear rate on apparent melt viscosity P-62XP



9. Precautions for safe handling of Fluon PFA

To ensure safety, before using Fluon PFA read and understand the MSDS (manufacturing safety data sheet).
Precautions during processing

Although PFA has excellent resistance to heat, it has a high melting temperature (350°–400°C).

In common with other general-purpose resins, even though only slight, PFA does undergoe some heat decomposition.
Normally, in the temperature range from 260°–425°C, the following decomposition gases are detectable:

- Fluorinated 3–5 carbon compounds (low toxicity)
- Slight trace of hydrogen fluoride (detected at 400°C)
- Wax sublimates

Consequently, when processing fluoropolymers, the work areas should be well ventilated and measures implemented to prevent environmental impact by exhaust gases.
The amount of discharge is only slight, so a relatively small amount of equipment is required to deal with the gases.

- Measures in the work area
  - Adequate ventilation
  - Provision of exhaust hoods
- Environmental protection measures:
  - Neutralization (percolation through dilute alkali solution)
  - Use of adsorption agents (sodium bicarbonate, sodium carbonate)

Be aware that tobacco smoke is changed by contact with PFA resin; if such smoke is subsequently inhaled, a harmful noxious gas is formed: smoking should be avoided in the workplace or anywhere in the vicinity of unprocessed PFA.

None of the products referred to in this document are intended for implantation in the human body; neither is it suggested that they should be used for any therapeutic medical application in which they come into contact with body fluids or tissues; this document does not refer to any of these types of products, which require specialized design and manufacture. Asahi Glass has not carried out any testing to examine the suitability and safety of products for medical applications.

10、Material properties of Fluon PFA

	Property	Unit	ASTM standard	P-66P	P-63P	P-62XP
Physical	Melting point	℃	--	305～315	305～315	305～310
	MFR	g/10min	D3307	1～3	7～18	24～36
	Specific gravity	--	D792	2.12～2.17	2.12～2.17	2.12～2.17
Mechanical	Tensile strength 23C	kg/cm^2 (MPa)	D638	400 (39)	330 (32)	330 (32)
	250C	kg/cm^2 (MPa)	D638	160 (16)	80 (8)	75 (7)
	Elongation 23C	%	D638	340	410	410
	250C	%	D638	610	520	530
	Impact strength (Izod)	kg-cm/cm (J/M)	D256A	No break (↑)	No break (↑)	No break (↑)
	Hardness (Dorometer)	--	D1706	D60	D60	D60
	Flexural modulus	$10^3 kg/cm^2$ (GPa)	D790	5.5 (0.54)	6.３ (0.62)	6.５ (0.64)
	ＭＩＴ (Flex life)	Times	D2176	5.0×10^5	2.5×10^4	1.8×10^4
Thermal	Thermal conductivity	10^{-4}cal/cm/sec・℃	C177	6.0	6.0	6.0
	Specific heat	cal/℃・g		0.25	0.25	0.25
	Coefficient of linea thermal expansion	10^5 ℃	D696	14	14	15
	Ball pressure temp.	℃		230	230	--
	Max. service temp. (continuous)	℃		260	260	260
Electrical	Volume resistivity	Ω-cm	D257	＞10^{17}	＞10^{17}	＞10^{17}
	Surface resistivity	Ω	D257	＞10^{17}	＞10^{17}	＞10^{17}
	Dielectric comstant	60Hz	D150	＜2.1	＜2.1	＜2.1
		10^3Hz	D150	＜2.1	＜2.1	＜2.1
		10^6Hz	D150	＜2.1	＜2.1	＜2.1
		10^9Hz	D150	＜2.1	＜2.1	＜2.1
	Dielectric tangent	60Hz	D150	＜0.0003	＜0.0003	＜0.0003
		10^3Hz	D150	＜0.0003	＜0.0003	＜0.0003
		10^6Hz	D150	＜0.0003	＜0.0003	＜0.0003
	Ark resistance	s	D495	＞300	＞300	＞300
Others	Water absorbtion	%	D570	＜0.03	＜0.03	＜0.03
	flammability	--	UL94	V-0	V-0	V-0
	Oxygen index	--	D2863	＞95	＞95	＞95