TECHNICAL NOTE

SUMITOMO CHEMICAL

Ultra-High Heat Resistant Engineering Plastics

SUMIKAEXCEL™ PES

Polyethersulfone

High heat Resistant Amorphous Polymer

Version 04 / Nov. 2023

SUMITOMO CHEMICAL Co., Ltd. Advanced Polymers Division

Proper Use of SUMIKAEXCEL PES

The information contained in this document has been prepared based on materials, information and data currently available and is subject to revision based on new findings.

1. Handling

The following is a list of key points that must be observed when handling SUMIKAEXCEL PES. Before handling SUMIKAEXCEL PES, please be sure to read the Safety Data Sheet (SDS), which has been prepared separately. Please note that it is the responsibility of the user to investigate the safety of any additives used in conjunction with SUMIKAEXCEL PES.

(1) Safety and Health

Ensure to avoid contact with the eyes and skin, as well as the inhalation of gases that are generated when drying and melting SUMIKAEXCEL PES. In addition, be careful not to directly touch the resin while it is still hot. Local ventilation equipment must be installed and proper protective gear (such as protective goggles and protective gloves) must be worn while drying or melting this product.

(2) Flammability

SUMIKAEXCEL PES is a flame-resistant material (classified as UL94 V-0). However, it should be handled and stored in places well away from heat and ignition sources. If the material catches fire, toxic gases may be released. Use water, foam, or fine chemical extinguishers to extinguish any flames.

(3) Disposal

SUMIKAEXCEL PES may be disposed by burial or incineration. Burial of the material should be conducted by certified industrial waste processors or by the local municipal authorities in accordance with the Waste Management and Public Cleansing Act. Incineration should be conducted using a furnace which complies with the laws and regulations of the Air Pollution Control Act. Toxic gases may be released when this product is incinerated.

(4) Storage

Store SUMIKAEXCEL PES at room temperature away from direct sunlight, water, and humidity.

2. Applicable standards

SUMIKAEXCEL PES comes in a variety of grades which comply with standards specified by Underwriters Laboratories Inc., such as UL94 and UL746, and by the U.S. Food and Drug Administration (FDA). Refer to this booklet or contact Sumitomo Chemical for further details. Contact Sumitomo Chemical for information regarding the use of this material in other special applications.

3. Security Trade Control

The products of SUMIKAEXCEL and SUMIPLOY are not on the control list of the Export Trade Control Order of Japan. However, row 16 (catch-all control) in Appended Table 1 of the same Order does apply.

4. Other

All data in this document is for reference only and is not intended as guarantees on product performance. Please be aware of intellectual property rights when using this product.

SUMIKAEXCEL PES Technical Notes Index

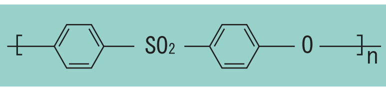
1. Features and Grade Lineup of SUMIKAEXCEL PES

1-1 Features

Introduction

SUMIKAEXCEL PES (Polyethersulfone) is a heat resistant amorphous resin that Sumitomo Chemical manufactures in Japan under license from Imperial Chemical Industries PLC (ICI). The molecular structure is shown in the figure below.

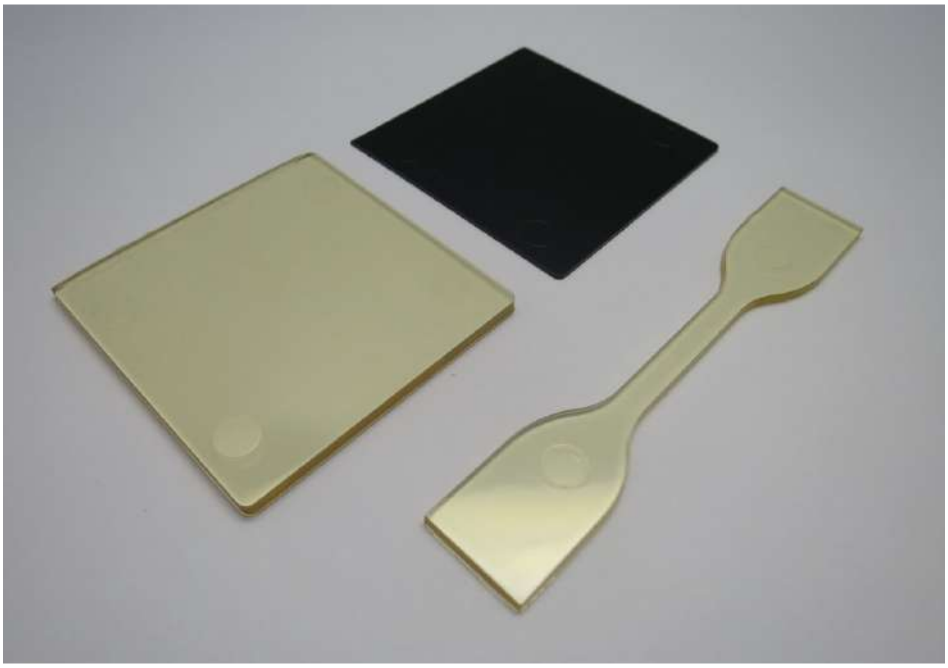
Figure 1-1-1 Chemical Structural Formula of PES



(Glass transition temperature Tg 225°C)

SUMIKAEXCEL PES is an amber-color transparent resin with heat resistance, creep resistance, dimensional stability, flame retardancy, and hot water resistance. It was developed as a molding material for various applications, including electronic components, such as relays and burn-in sockets; IC trays; printer and copier parts; medical equipment parts and dental equipment requiring sterilization; and pagers and films for LCD substrates.
Powder grades are also available that are widely used in applications such as agents for giving toughness to epoxy composite materials for aircraft applications, heat-resistant paints, adhesives, and flat membranes and hollow fiber membranes for medical and food products.

Figure 1-1-2 Photograph of SUMIKAEXCEL PES Moldings



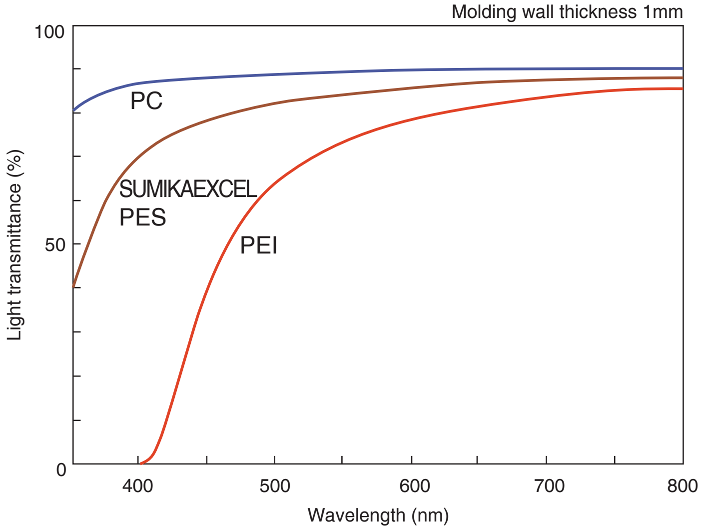
SUMIPLOY is a high-performance, high-heat-resistant polymer alloy compound that incorporates technologies that we have cultivated and accumulated. It is mainly based on super engineering plastics such as SUMIKASUPER LCP, polyethersulfone, and polyetheretherketone.

SUMIPLOY E is a sliding material that is composed mainly of heat-resistant polyethersulfone (PES) and SUMIKASUPER E101, and has the best sliding characteristics (with low and stable friction coefficient in a dry state and with a high limit PV value) among the sliding materials that can be used for injection molding. It does not easily cause scratches to mating materials even on soft metals such as Stainless steel (SUS) or aluminum. SUMIPLOY S is a sliding material based on PES that has good sliding properties while maintaining the mechanical and thermal properties of PES. It is good for applications requiring a certain degree of mechanical strength under relatively mild sliding conditions (low PV value). SUMIPLOY K is a sliding material based on polyetheretherketone (PEEK). It provides good sliding properties while maintaining the original excellent chemical resistance, fatigue resistance, radiation resistance, and heat resistance of PEEK. It is good for use under harsh conditions such as high temperatures and high loads.

Light transmittance

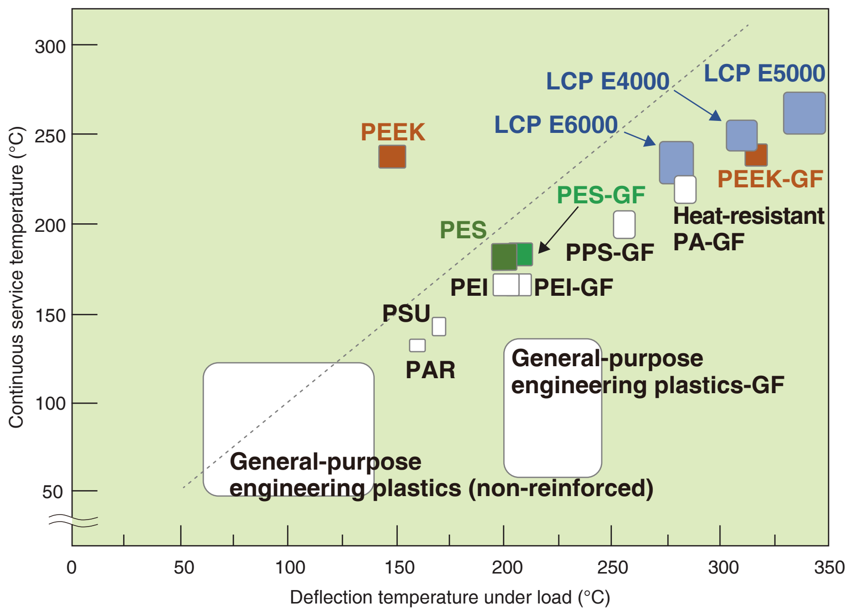
It has an excellent level of light transmittance among heat-resistant engineering plastics.

Figure 1-1-3 Light Transmittance of SUMIKAEXCEL PES



Heat resistance

Figure 1-1-4 Continuous Service Temperature and DTUL (1.82MPa)



Features of SUMIKAEXCEL PES and SUMIPLOY

Table 1-1-1 Features of SUMIKAEXCEL PES and SUMIPLOY

SUMIKAEXCEL	SUMIPLOY
· High heat resistance · Long-term heat resistance (180 to 200°C) · Heat water resistance · High strength and impact resistance · Creep resistance · High dimensional accuracy · Flame retardant · Low smoke, low gas emission	· High heat resistance · High strength · High rigidity · High sliding property

1-2 Grade Lineup

Injection Molding Grades

Standard non-reinforced grades and glass fiber reinforced grades are available, and functional grades such as sliding grades, high dimensional accuracy grades, and carbon fiber reinforced grades are also available. Functional grades are sold under the SUMIPLOY trademark.

Table 1-2-1 Injection Molding Grades for SUMIKAEXCEL PES and SUMIPLOY

Grade		Filler	Features
SUMIKAEXCEL	3600G	Unreinforced	High flow for injection molding
	4100G	Unreinforced	Standard for injection molding and extrusion molding
	4800G	Unreinforced	High molecular weight for injection molding and extrusion molding
	3601GL20	20% Glass fiber reinforced	High flow for injection molding
	3601GL30	30% Glass fiber reinforced	High flow for injection molding
	4101GL20	20% Glass fiber reinforced	Standard for injection molding
	4101GL30	30% Glass fiber reinforced	Standard for injection molding
	ES5340	20% Glass fiber reinforced	Ultra high flow for injection molding
SUMIPLOY	E3010	40% E101 / Fluororesin reinforced	Unreinforced, sliding
	FS2200	10% Fluororesin reinforced	Unreinforced, sliding
	GS5620	40% glass fiber / Fluororesin reinforced	Sliding, high dimensional accuracy
	CS5220	20% Carbon fiber / Fluororesin reinforced	Sliding, high dimensional accuracy
	CS5530	40% Carbon fiber / Inorganic filler reinforced	Ultra-high dimensional accuracy
	CS5600	30% Carbon fiber reinforced	High strength
	CK3400	18% Carbon fiber reinforced	PEEK resin base high speed and high load sliding
	CK3420	30% Carbon fiber / Fluororesin reinforced	PEEK resin base high speed and high load sliding
	CK4600	30% Carbon fiber reinforced	PEEK resin base high strength

Powder Grade

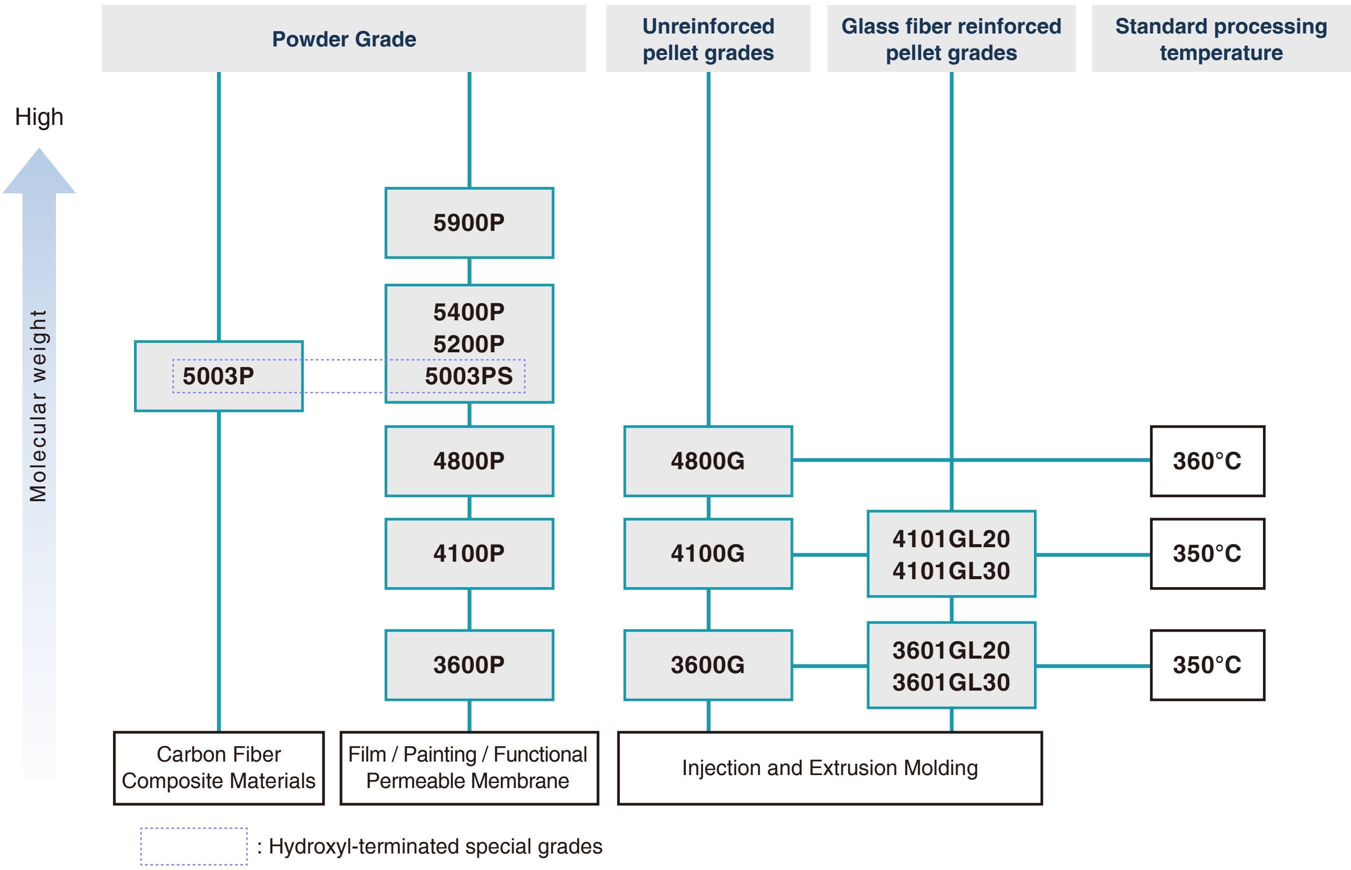
A variety of grades are available as powder grades having different values of RV (reduced viscosity), which is a guideline for molecular weight. The most appropriate grade may be selected to suit the particular application.
The following solvents can be used with PES : N-methylpyrrolidone (NMP), dimethylformamide (DMF) dimethyl acetamid, γ-butyrolactone, and a 50/50 (weight ratio) mixture of dichloromethane and 1,1,2 - trichloroethane.

Table 1-2-2 Powder Grades of SUMIKAEXCEL PES

Grade	Reduced viscosity (RV)*1	Applications						
		Compound	Painting	Functional permeable membrane	Adhesive	Film	Epoxy reinforcing agent	Carbon fiber composite material (Aircraft applications)
3600P	0.36	✓	-	-	-	-	-	-
4100P	0.41	✓	✓	-	✓	✓	-	-
4800P	0.48	✓	✓	✓	✓	-	-	-
5003PS*2	0.50	-	✓	-	✓	-	✓	-
5200P	0.52	-	-	✓	-	-	-	-
5900P	0.59	-	-	✓	-	-	-	-
5003P*2	0.50	-	-	-	-	-	-	✓

*1 Viscosity measured with 1(W/V)% PES dissolved in DMF
*2 Having many terminal hydroxyl groups. For example, for 5003P, it is 0.6 to 1.4 per 100 polymer repeating units.

Figure 1-2-1 Grade Lineup for SUMIKAEXCEL PES



2. Table of Physical Properties

Table 2-1 General Physical Properties of SUMIKAEXCEL PES

General Physical Properties		Test method	Unit	3600G	4100G	4800G	3601GL20	3601GL30	4101GL20	4101GL30	ES5340
				SUMIKAEXCEL PES							
Color				Natural/ Black	Natural/ Black	Natural/ Black	Natural/ Black	Natural/ Black	Natural/ Black	Natural/ Black	Black
Filler				Unreinforced	Unreinforced	Unreinforced	Glass fiber	Glass fiber	Glass fiber	Glass fiber	Glass fiber
Filler contents			wt%	□	□	□	20	30	20	30	20
Physical properties											
Density		ISO 1183	g/cm^3	1.37	1.37	1.37	1.51	1.60	1.51	1.60	1.52
Specific gravity		ASTM D792	□	1.37	1.37	1.37	1.51	1.60	1.51	1.60	1.51
Water absorption rate	24 hrs in water at 23℃	ISO 62	%	1.0	1.0	1.0	0.8	0.7	0.8	0.7	0.5
Mold shrinkage	MD	Internal*1	%	0.60	0.60	0.60	0.30	0.20	0.30	0.20	0.39
	TD		%	0.60	0.60	0.60	0.40	0.40	0.40	0.40	0.60
Mechanical properties											
Tensile strength		ISO 527-1,2	MPa	85	85	85	135	145	135	145	96
		ASTM D638	MPa	84	84	84	124	140	124	140	104
Tensile strain at break		ISO 527-1,2	%	6.5*2	6.5*2	6.5*2	2.4	1.8	2.4	1.8	1.5
Tensile elongation		ASTM D638	%	40-80	40-80	40-80	3.0	3.0	3.0	3.0	4.0
Tensile modulus		ISO 527-1,2	MPa	2,700	2,700	2,700	7,200	9,800	7,200	9,800	8,900
Flexural strength		ISO 178	MPa	130	130	130	190	210	190	210	139
		ASTM D790	MPa	129	129	129	172	190	172	190	138
Flexural modulus		ISO 178	MPa	2,600	2,600	2,600	6,600	9,500	6,600	9,500	7,200
		ASTM D790	MPa	2,600	2,600	2,600	6,000	8,400	6,000	8,400	7,600
Charpy impact strength	Unnotched	ISO 179-1/1eU	kJ/m^2	NB*3	NB*3	NB*3	45	55	45	55	19
	Notched	ISO 179-1/1eA	kJ/m^2	6	7	8	5	6	6	6	4
Izod impact strength	Unnotched	ISO 180/1U	kJ/m^2	NB*3	NB*3	NB*3	30	35	30	35	15
	Notched	ISO 180/1A	kJ/m^2	7	8	8	5	6	6	6	4
	Unnotched	ASTM D256	J/m	NB*3	NB*3	NB*3	431	539	431	539	186
	Notched		J/m	85	85	85	80	81	80	81	□
Rockwell hardness	M scale	ISO 2039-2	□	95	95	95	100	100	100	100	89
Thermal properties											
Deflection temperature under load	1.80MPa	ISO 75	°C	205	205	205	221	221	221	221	211
	0.45MPa		°C	214	214	214	222	223	222	223	223
	1.82MPa	ASTM D648	°C	203	203	203	210	216	210	216	211
	0.45MPa		°C	210	210	210	□	□	□	□	□
Coefficient of linear thermal expansion	MD (50 -150°C)	ISO 11359-1,2	$10^{-5}/K$	5.5	5.5	5.5	2.4	2.0	2.4	2.0	2.0
	TD (50 -150°C)		$10^{-5}/K$	5.5	5.5	5.5	5.8	5.2	5.8	5.2	6.4
MFR	360°C/2.16kg	ISO 1133-1	g/10min	55	25	8	17	14	9	7	26
	400°C/2.16kg		g/10min	□	□	□	□	□	□	□	□
Electrical properties											
Relative permittivity (dry)	100Hz	IEC 62631-2-1	□	3.5	3.5	3.5	3.8	3.9	3.8	3.9	□
	1kHz		□	3.5	3.5	3.5	3.8	3.9	3.8	3.9	□
	1MHz		□	3.4	3.4	3.4	3.7	3.8	3.7	3.8	□
	1GHz	IEC 60250	□	3.4	3.4	3.4	3.7	3.8	3.7	3.8	□
Dielectric dissipation factor (dry)	100Hz	IEC 62631-2-1	□	0.002	0.002	0.002	0.002	0.002	0.002	0.002	□
	1kHz		□	0.002	0.002	0.002	0.002	0.002	0.002	0.002	□
	1MHz		□	0.004	0.004	0.004	0.004	0.003	0.004	0.003	□
	1GHz	IEC 60250	□	0.004	0.004	0.004	0.004	0.003	0.004	0.003	□
Dielectric strength	(1mm)	IEC 60243-1	kV/mm	43	43	43	39	38	39	38	□
Volume resistivity		IEC 60093	Ωm	> 10^{13}	> 10^{13}	> 10^{13}	> 10^{13}	> 10^{13}	> 10^{13}	> 10^{13}	> 10^{13}
Arc resistance		ASTM D495	sec	70	70	70	120-180	120-180	120-180	120-180	□
Tracking resistance		IEC 60112	V	150	150	150	□	□	150	150	□
Flame retardancy											
Flame retardant rank		IEC 60695-11-10	class	V-0	V-0	V-0	V-0	V-0	V-0	V-0	V-0
UL Yellow Card File No.		□	□	E249884	E249884	E249884	E249884	E249884	E249884	E249884	E249884

*1 Mold shrinkage is measured on a 64mm x 64mm x 3mm flat test piece. *2 Tensile yield strain *3 Does not break

Table 2-2 General Physical Properties of SUMIPLOY

General Physical Properties		Test method	Unit	E3010	FS2200	GS5620	CS5220	CS5530	CS5600	CK3400	CK3420	CK4600
				SUMIPLOY								
Color				Natural	Natural	Black	Black	Black	Black	Black	Black	Black
Filler				E101 / Fluororesin	Fluororesin	Glass fiber / Fluororesin	Carbon fiber / Fluororesin	Carbon fiber / Inorganic filler	Carbon fiber	Carbon fiber	Carbon fiber / Fluororesin	Carbon fiber
Filler contents			wt%	40	10	40	20	40	30	18	30	30
Physical properties												
Density		ISO 1183	g/cm³	1.46	1.42	1.66	1.45	1.56	1.47	1.36	1.43	1.44
Specific gravity		ASTM D792	□	1.48	1.42	1.66	1.45	1.55	1.47	1.36	1.42	1.44
Water absorption rate	24 hrs in water at 23℃	ISO 62	%	0.7	0.9	0.7	0.9	0.5	0.8	0.1	0.1	0.1
Mold shrinkage	MD	Internal*1	%	0.92	0.60	0.14	0.18	0.09	0.10	0.18	0.16	0.13
	TD		%	0.97	0.60	0.30	0.35	0.03	0.25	0.48	0.50	0.55
Mechanical properties												
Tensile strength		ISO 527-1,2	MPa	35	72	117	107	135	178	197	176	231
		ASTM D638	MPa	36	77	123	112	133	176	196	173	216
Tensile strain at break		ISO 527-1,2	%	4.0	8.6	1.6	2.3	0.6	1.5	2.2	2.0	1.9
Tensile elongation		ASTM D638	%	7.6	15.0	4.5	6.0	3.4	4.0	6.4	6.3	4.0
Tensile modulus		ISO 527-1,2	MPa	2,490	2,490	9,890	7,670	26,800	20,100	13,900	16,000	21,800
Flexural strength		ISO 178	MPa	71	104	172	155	206	246	305	276	339
		ASTM D790	MPa	64	118	159	147	162	255	290	240	333
Flexural modulus		ISO 178	MPa	2,600	2,200	8,600	5,900	26,500	14,700	13,700	14,100	16,700
		ASTM D790	MPa	2,500	2,500	8,600	6,600	18,100	15,200	12,900	12,100	18,200
Charpy impact strength	Unnotched	ISO 179-1/1eU	kJ/m²	19	148	30	29	14	32	51	43	53
	Notched	ISO 179-1/1eA	kJ/m²	3	6	7	4	5	5	7	5	7
Izod impact strength	Unnotched	ISO 180/1U	kJ/m²	14	99	24	22	14	28	40	36	43
	Notched	ISO 180/1A	kJ/m²	4	6	7	5	6	6	7	6	7
	Unnotched	ASTM D256	J/m	232	980	363	348	140	510	700	506	666
	Notched		J/m	29	78	71	□	□	59	□	69	98
Rockwell hardness	M scale	ISO 2039-2	□	57	85	91	93	89	100	111	104	110
Thermal properties												
Deflection temperature under load	1.80MPa	ISO 75	°C	205	204	216	214	217	219	313	311	329
	0.45MPa		°C	214	213	231	227	224	234	337	327	340
	1.82MPa	ASTM D648	°C	203	203	218	210	216	217	325	324	328
	0.45MPa		°C	□	□	□	□	□	□	□	□	□
Coefficient of linear thermal expansion	MD (50 -150°C)	ISO 11359-1,2	10^{-5}/K	5.7	5.7	1.6	1.4	0.7	0.7	1.0	0.8	0.6
	TD (50 -150°C)		10^{-5}/K	6.0	5.8	5.1	5.5	4.4	5.0	5.4	5.8	5.7
MFR	360°C/2.16kg	ISO 1133-1	g/10min	4	17	7	15	3	11	□	□	□
	400°C/2.16kg		g/10min	□	□	□	□	□	□	7	2	1
Electrical properties												
Relative permittivity (dry)	100Hz	IEC 62631-2-1	□	□	□	□	□	□	□	□	□	□
	1kHz		□	□	□	□	□	□	□	□	□	□
	1MHz		□	□	□	□	□	□	□	□	□	□
	1GHz	IEC 60250	□	□	□	□	□	□	□	□	□	□
Dielectric dissipation factor (dry)	100Hz	IEC 62631-2-1	□	□	□	□	□	□	□	□	□	□
	1kHz		□	□	□	□	□	□	□	□	□	□
	1MHz		□	□	□	□	□	□	□	□	□	□
	1GHz	IEC 60250	□	□	□	□	□	□	□	□	□	□
Dielectric strength (1mm)		IEC 60243-1	kV/mm	□	□	□	□	□	□	□	□	□
Volume resistivity		IEC 60093	Ωm	> 10^{13}	> 10^{13}	> 10^{13}	□	□	□	□	□	□
Arc resistance		ASTM D495	sec	90-100	80	□	□	□	□	□	□	□
Tracking resistance		IEC 60112	V	□	□	□	□	□	□	□	□	□
Flame retardancy												
Flame retardant rank		IEC 60695-11-10	class	V-0	V-0	V-0	□	V-0	V-0	□	□	□
UL Yellow Card File No.		□	□	E249884	E249884	E249884	□	E249884	E249884	□	□	□

*1 Mold shrinkage is measured on a 64mm x 64mm x 3mm flat test piece.

3. Physical properties

3-1 Heat Resistance

The thermal properties required for the design of SUMIKAEXCEL PES are shown in Table 3-1-1.

Table 3-1-1 Thermal Properties of SUMIKAEXCEL PES

Heat resistance	Test method	Unit	Unreinforced	Glass fiber reinforced	
			4100G 4800G	3601GL20 4101GL20	3601GL30 4101GL30
Deflection temperature under load (0.45MPa)	ASTM D648	°C	210	□	□
Deflection temperature under load (1.82MPa)	ASTM D648	°C	203	210	216
Deflection temperature under load (0.45MPa)	ISO 75	°C	214	222	223
Deflection temperature under load (1.80MPa)	ISO 75	°C	205	221	221
Vicat softening point (1kg)	ASTM D1525	°C	226	□	□
Vicat softening point (5kg)	ASTM D1525	°C	222	□	□

Arrhenius Plot

The temperature range where the resin can be used for a long period of time is limited by the thermal stability of the resin. According to the UL-compliant relative temperature index (RTI), the aging test continues until the observation target property value becomes half the initial value. Perform aging tests at several different temperatures and create an Arrhenius plot based on that data. An Arrhenius plot is a graph created by plotting the heat aging time (also called half-life) required for the property value to reach half the initial value against the reciprocal of the aging temperature (K).

Figure 3-1-1 Temperature Dependence of Tensile Strength Half-life of 4800G

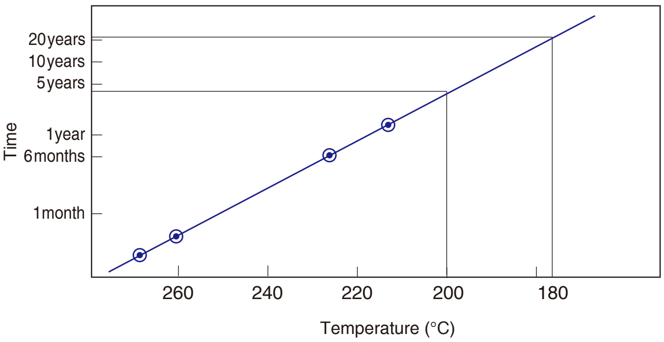
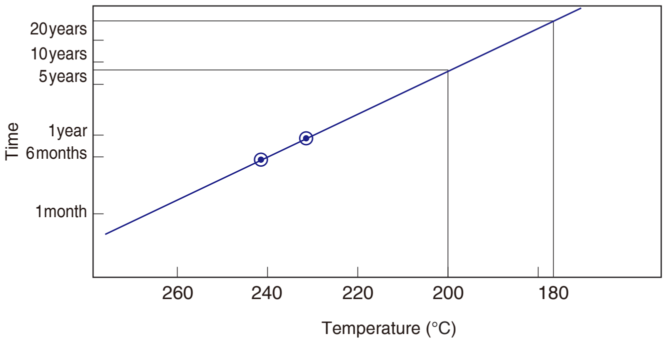


Figure 3-1-2 Temperature Dependence of Tensile Strength Half-life of 4101GL30



Long-Term Heat Resistance

SUMIKAEXCEL PES has excellent long-term heat resistance. The following shows the relative temperature index (RTI) for SUMIKAEXCEL PES. The RTI indicates the temperature at which the impact strength (Imp) and tensile strength (Str) of the electrical properties (Elec) and mechanical properties (Mech) become half their initial values after the material is aged 100,000 hours. Generally, deterioration is more rapid for thin test pieces, so RTI evaluation for UL is performed according to the thickness of the test piece.

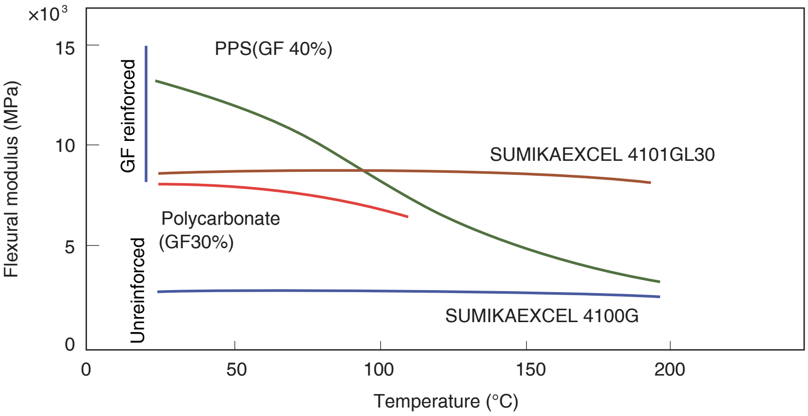
Table 3-1-2 Relative Temperature Index of SUMIKAEXCEL PES (UL746B)

Grade	Thickness (mm)	RTI		
		Elec	Imp	Str
3600G	0.41	-	-	-
	0.75	180	170	180
	1.6	180	170	180
	3.0	180	170	180
4100G	0.41	180	170	180
	0.75	180	170	180
	1.5	180	170	180
	3.0	180	170	180
4800G	0.30	180	170	180
	0.46	180	170	180
	1.5	180	170	180
	3.0	180	170	180
3601GL20	0.43	180	180	180
	3.0	180	180	180
3601GL30	0.43	190	190	190
	3.0	190	190	190
4101GL20	0.43	180	180	180
	1.5	180	180	180
	3.0	180	180	180
4101GL30	0.43	190	190	190
	1.5	190	190	190
	3.0	190	190	190

Temperature Dependence of Flexural Modulus

Figure 3-1-3 shows the temperature dependence of flexural modulus. The flexural modulus shows almost no change from 100 to 200°C. It is far superior to noncrystalline polycarbonate resins and glass fiber reinforced grades of crystalline PPS resins, especially above 100°C, and belongs to the highest class of thermoplastic resins.

Figure 3-1-3 Temperature Dependence of Flexural Modulus of 4100G and 4101GL30

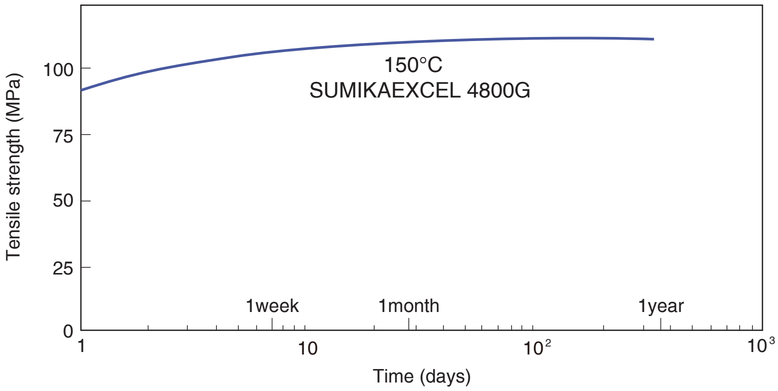


Aging Characteristics (in Air and in Hot Water)

Heat Aging Resistance

PES has excellent heat aging resistance property. Even after aged in air at 150°C, the strength remains stable.

Figure 3-1-4 Heat Aging Resistance of Tensile Strength, in Air at 150°C



Hot Water Resistance

When SUMIKAEXCEL PES is immersed in water (23°C) or hot water (100°C) without loading, there is almost no change in tensile strength. The impact strength of SUMIKAEXCEL PES will initially decrease when exposed to hot water (100°C), but will thereafter remain stable, maintaining a sufficiently high level of impact resistance.

Figure 3-1-5 Hot Water Resistance of Tensile Strength

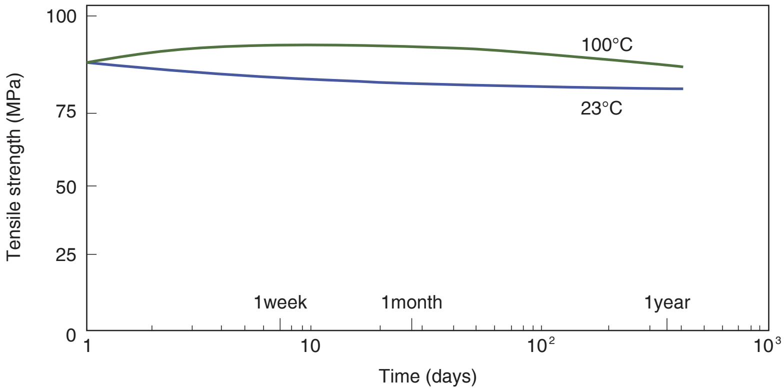
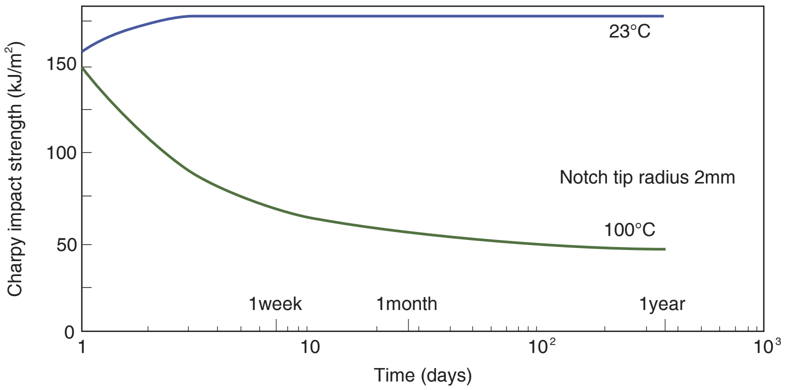


Figure 3-1-6 Hot Water Resistance of Impact Strength



Steam Resistance (Steam Sterilization Resistance)

No changes to impact strength were observed as a result of cyclical tests using a steam pressure of 3.2 atmospheres (143°C) vacuum dehydration (room temperature).
However, when PES is to be used in steam, testing should be performed prior to usage at actual operating temperatures, in accordance with the specified application.

3-2 Mechanical Properties

Short-term deformation

Tensile strength

The stress-strain curve (hereinafter referred to as S-S curve) from the tension test for SUMIKAEXCEL PES is shown. Stress and strain are proportional until the stress reaches a certain level. When designing PES strength, it is important to remember that there are portions where the stress and strain are not proportional.

Figure 3-2-1 S-S Curve of Tensile Strength of 4100G

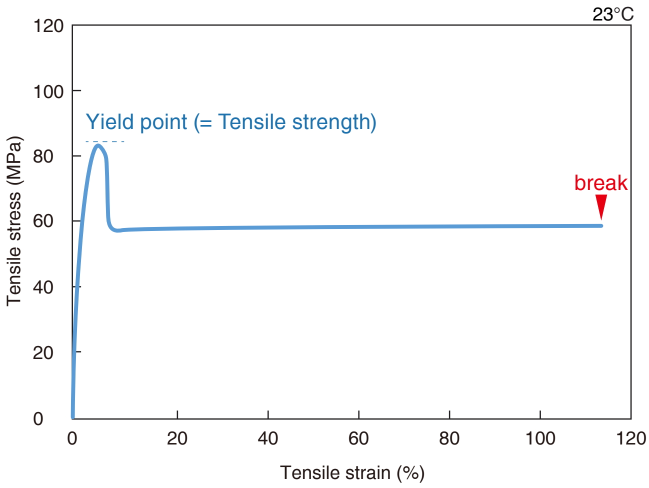
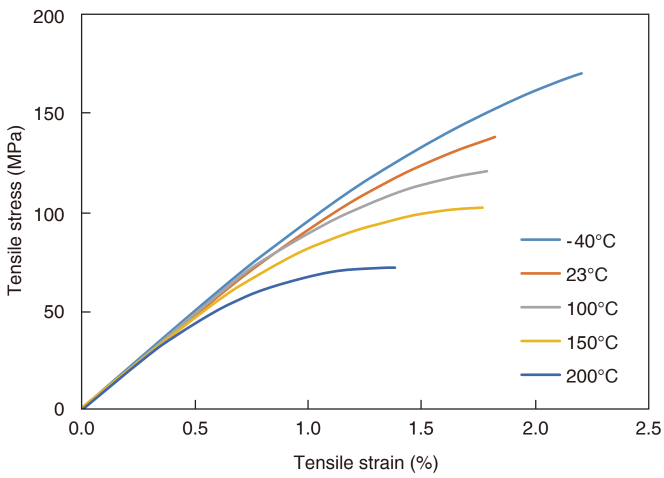


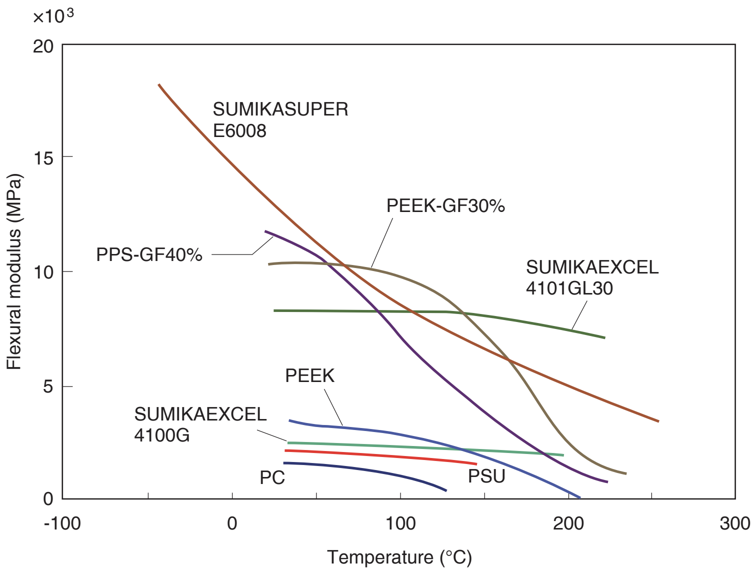
Figure 3-2-2 S-S Curve of Tensile Strength of 4101GL30



Temperature Dependence of Flexural Modulus

The heat deformation temperature is 200 to 220°C, and the continuous operating temperature is certified as 180 to 190°C by the UL temperature index. The modulus of elasticity shows almost no change in the temperature range of -100 to 200°C. It has the highest level among all thermoplastic resins, especially above 100°C.

Figure 3-2-3 Temperature Dependence of Flexural Modulus



Impact strength

SUMIKAEXCEL PES has excellent impact resistance. Izod impact strength is shown in comparison with other heat resistant resins. The unnotched non-reinforced grade does not break. Figure 3-2-6 shows the temperature dependence of the impact strength. SUMIKAEXCEL PES has sufficient impact strength even at temperatures below 0°C such as -100°C.

Figure 3-2-4 Impact Resistance of SUMIKAEXCEL PES

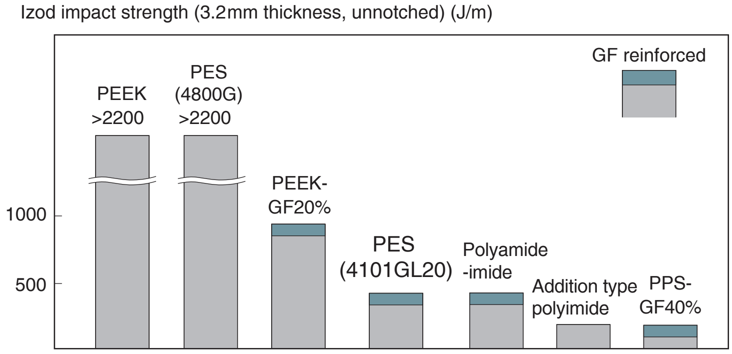


Figure 3-2-5 Notch Sensitivity of Impact Strength at 20°C (4800G)

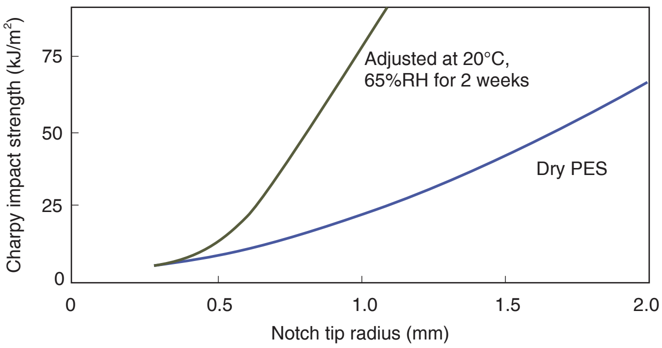
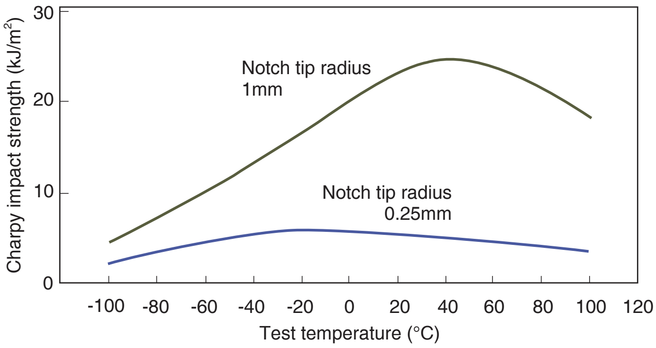


Figure 3-2-6 Temperature Dependence of Impact Strength (4800G)



Weld strength

With injection molding, the strength of welded areas (resin junction) becomes lower than that of the non-welded areas. The strength of the welded areas of the glass fiber reinforced grade decreases according to the amount of glass fiber. Figure 3-2-7 shows a comparison between the strength of non-welded areas and the strength of welded areas, and Table 3-2-1 shows the tensile strength of welded areas with SUMIKAEXCEL PES. SUMIKAEXCEL PES has extremely high weld strength compared to other resins. The non-reinforced grade in particular shows almost no decrease in reinforcement of welded areas and has the same strength as non-welded areas.

Weld tensile strength

Figure 3-2-7 Tensile Strength

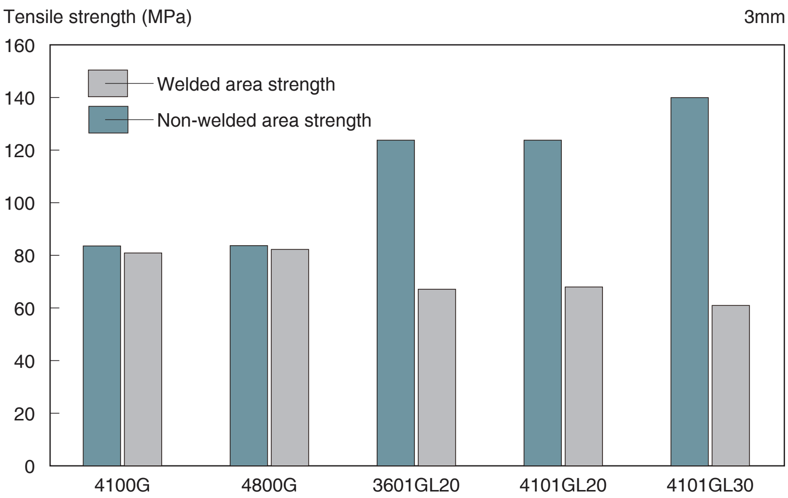


Table 3-2-1 Tensile Strength of Welded Area

(Unit : MPa)

Grade	Non-welded area	Welded area
4100G	84	81
4800G	84	82
3601GL20	124	67
4101GL20	124	68
4101GL30	140	61

Weld flexural strength

Figure 3-2-8 Shape of Moldings for Weld Evaluation

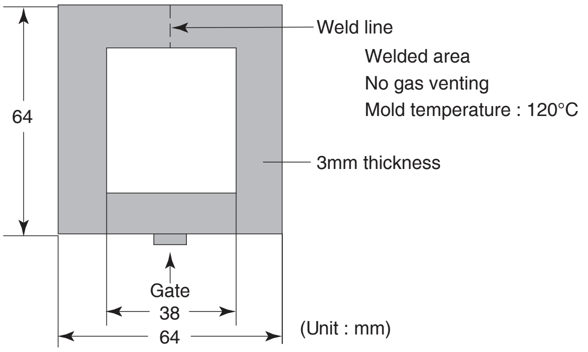


Table 3-2-2 Flexural Strength and Izod Impact Strength of Welded and Non-Welded Areas

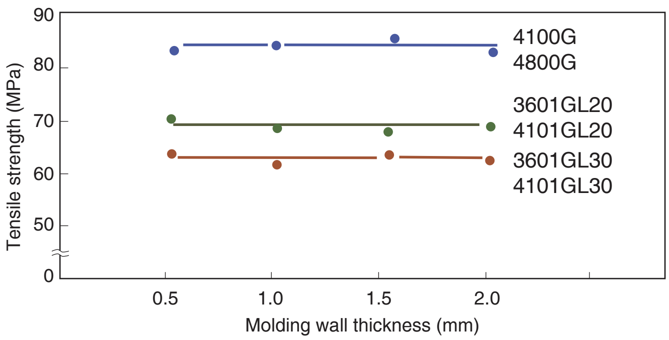
Grade	Flexural strength (MPa)		Izod impact strength (J/m)			
			Unnotched		0.25 notch	
	Non-welded area	Welded area	Non-welded area	Welded area	Non-welded area	Welded area
4100G	140*	140*	> 1960*	2156	68	49
4101GL20	190	110	411	117	68	29
4101GL30	180	110	362	98	68	29
PPS-GF40%	170	70	166	29	49	19

Values with * mark : Do not break

Molding machine : Sumitomo Heavy Industries' Neomat N47/28
Injection pressure : 130MPa
Injection speed : 60%
Cylinder temperature : 340°C (4100G)
350°C (4101GL20, 4101GL30)
Injection time : 10 seconds
Cooling time : 20 seconds

Weld strength of thin-walled moldings

Figure 3-2-9 Wall Thicknesses Dependence of Weld Tensile Strength



Improvement of Weld Strength

If the degradation of weld strength proves to be a problem during actual usage, weld strength can be improved through the methods introduced below.

- Improvement by Annealing

The strength of the welded areas of the glass fiber reinforced grade can be improved by 15 to 20% through annealing treatment at a temperature range of 150 to 180°C. The appropriate annealing conditions are as follows: 150°C x 20 minutes for moldings having a wall thickness of 0.5 to 1.5mm thickness ; and 180°C x 180 minutes for moldings having a wall thickness of 2mm thickness.

Table 3-2-3 Improvement of Weld Tensile Strength in Glass Fiber Reinforced Grades through Annealing

(Unit : MPa)

Grade	Initial	150°C	180°C	
		20min	20min	180min
3601GL20 4101GL20	68	76(113%)	76(113%)	77(114%)
3601GL30 4101GL30	61	75(123%)	75(121%)	75(121%)

Percentage in parentheses indicates the comparison with the initial strength as 100%.

- Improvement Through Increased Mold Temperatures

Greater weld strength can be achieved if the mold temperature is increased during the molding process. Therefore, set the mold temperature to 160 to 180°C and then observe any strength changes.

Long-Term Deformation

Creep properties

When designing parts of the appropriate strength required for actual usage, it is not adequate to rely solely upon the values derived from standard testing (e.g., ASTM) for mechanical strength and flexural modulus.
In order to determine the most appropriate design values, all potential changes that may occur in the dimensions and mechanical strength of moldings must be considered under actual operating conditions, based upon creep properties and temperature-induced changes.
Figure 3-2-10 depicts the tensile creep properties of the non-reinforced grade 4800G at temperatures of both 20°C and 150°C. The non-reinforced grades of PES sustained a creep deformation of only 1% after 3 years, under a load of 20MPa at a temperature of 20°C. At 150°C, the creep deformation after 3 years remained at only 1%, under a load of 10MPa. Figure 3-2-11 shows the flexural creep properties at 150°C for glass fiber reinforced grades (3601GL30 and 4101GL30). SUMIKAEXCEL PES shows excellent creep properties compared to crystalline PPS (40% glass fiber reinforced grade).

Figure 3-2-10 Tensile Creep Properties of Non-Reinforced Grade (4800G)

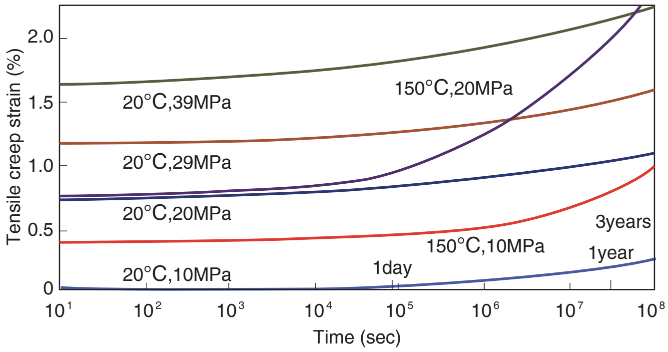


Figure 3-2-11 Flexural Creep Properties of Glass Fiber Reinforced Grades (3601GL30, 4101GL30)

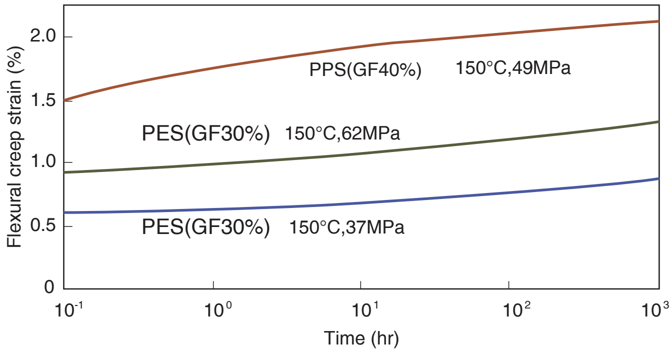


Figure 3-2-12 Tensile Creep Properties of Non-Reinforced Grade (4100G)

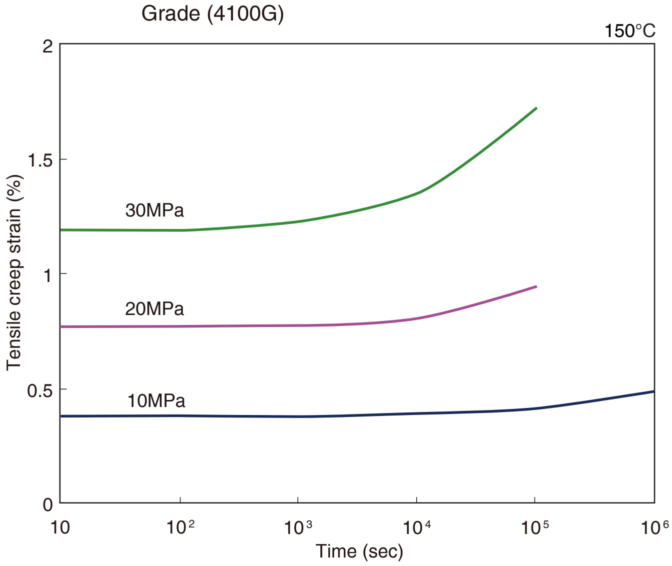


Figure 3-2-13 Tensile Creep Properties of Glass Fiber Reinforced Grade (4101GL30)

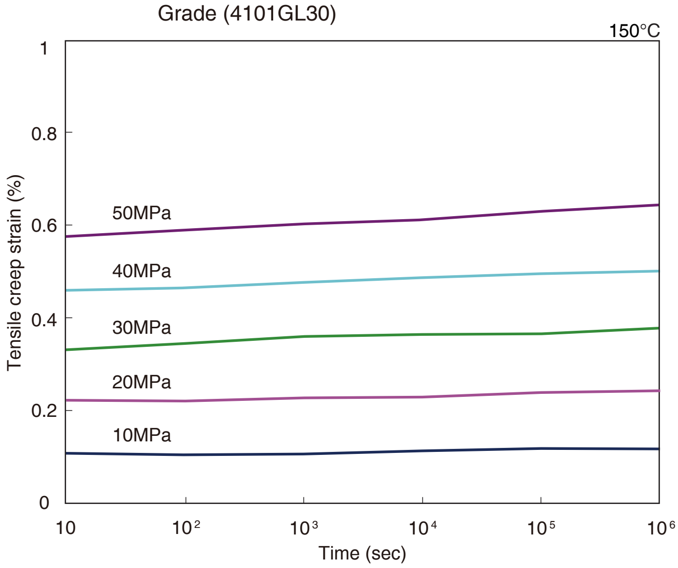
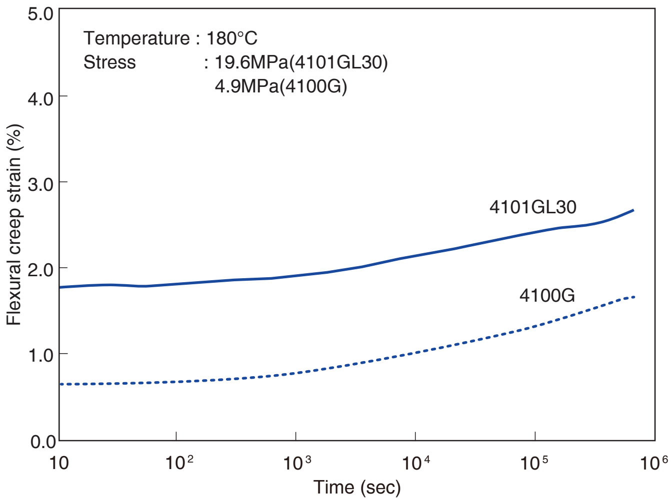


Figure 3-2-14 Flexural Creep Properties



Fatigue Properties

Materials under loads that fluctuate over a long period of time experience fatigue fractures. The stress-life curve from a tensile fatigue test is shown. At 23±1°C with 60±5% RH, fatigue failure does not occur up to about 1.0 × 10^7 times even with a repeated load of 30MPa.

Figure 3-2-15 Stress-Life Curve of SUMIKAEXCEL Non-Reinforced Grades (3600G, 4100G, 4800G)

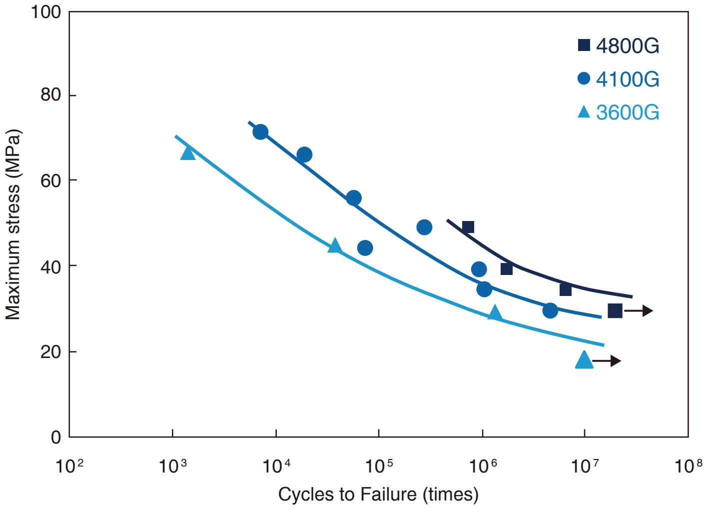
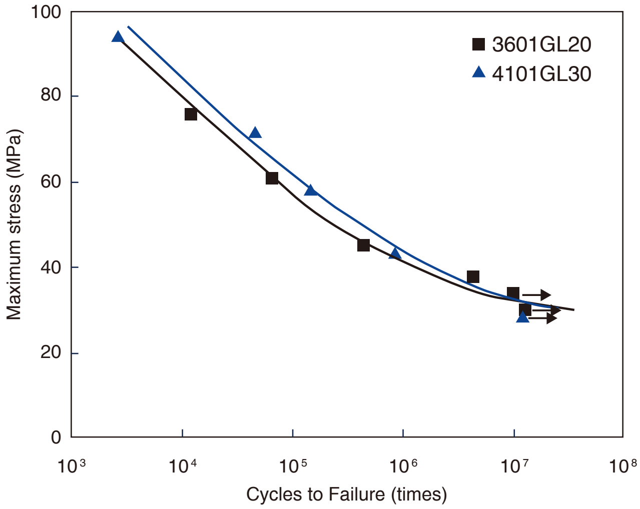


Figure 3-2-16 Stress-Life Curve of SUMIKAEXCEL Glass Reinforced Grades (3601GL20, 4101GL30)



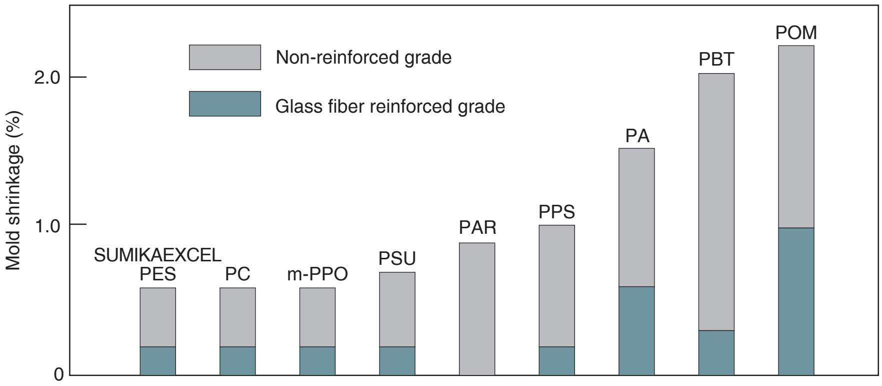
The symbol with a right arrow (→) indicates that the test piece has not been broken at that number of repetitions.

3-3 Dimensional Stabilities

Mold shrinkage

Non-reinforced grades of PES have low mold shrinkage (0.6%) and no anisotropy. However, glass fiber reinforced grades possess anisotropic shrinkage, at 0.2% for MD and 0.4% for TD due to the orientation of GF.

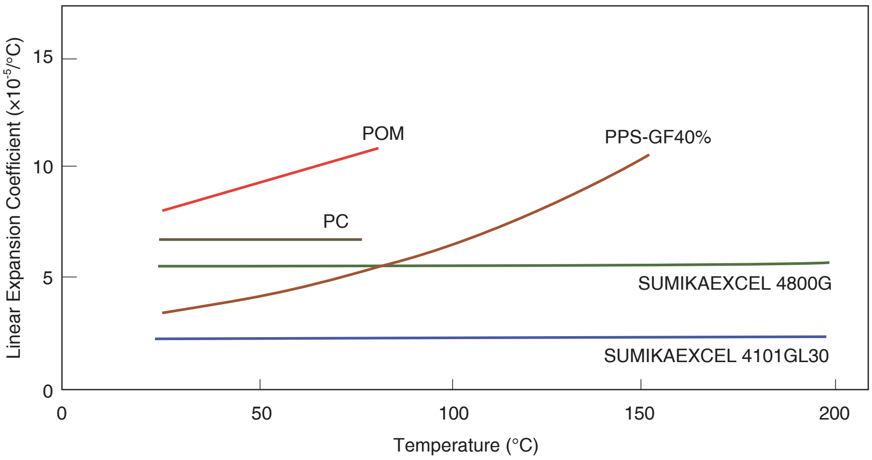
Figure 3-3-1 Comparison of Mold Shrinkage



CLTE (Coefficient of linear thermal expansion)

SUMIKAEXCEL PES has a small CLTE (Coefficient of linear thermal expansion) and a small temperature dependence. Figure 3-3-2 shows the temperature dependence of the CLTE. The CLTE of crystalline PPS-GF40% increases as the temperature rises, but amorphous SUMIKAEXCEL PES shows a constant value up to 200°C regardless of the temperature. Glass fiber reinforced 4101GL30 has a low CLTE of 2.0×10^{-5} (/°C) similar to that of aluminum, making it an ideal material for precision molding.

Figure 3-3-2 Comparison of the CLTE of SUMIKAEXCEL PES with That of Other Resins



PVT characteristics

The specific volume of thermoplastic resin, including SUMIKAEXCEL PES, changes according to the pressure regardless of whether it is in a solid or melted state. The compressibility of this resin is expressed as the relationship (PVT characteristics) between Pressure, Specific Volume and Temperature. PPS is a crystalline resin, so there is large amount of shrinkage due to crystallization. However, PES is an amorphous resin, so the amount of shrinkage is small, and it is excellent for dimensional accuracy and warpage.

Figure 3-3-3 PVT Characteristics of PPS-GF30%

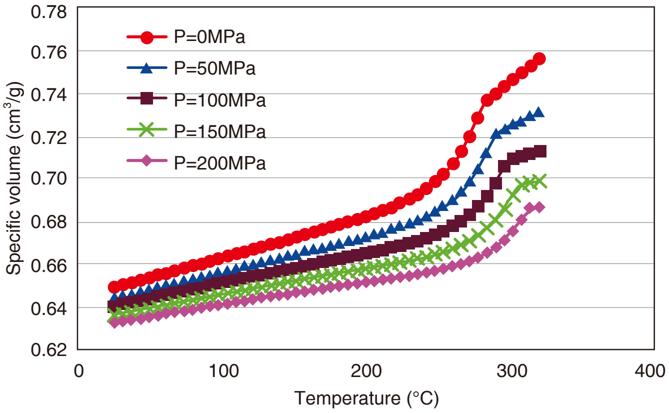
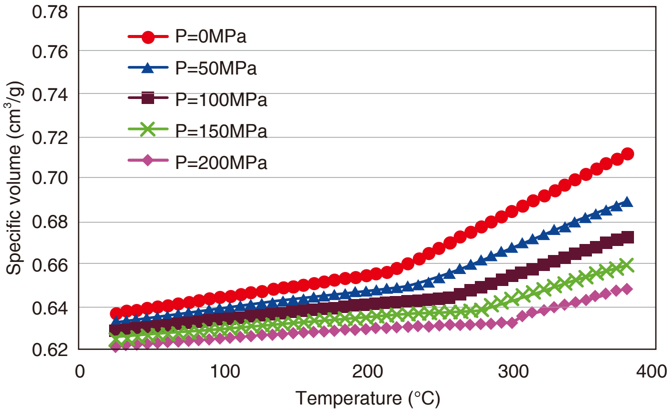


Figure 3-3-4 PVT Characteristics of 4101GL30



Dimensional Change due to Water Absorption

Although SUMIKAEXCEL PES has a small moisture absorption property, the dimensional change due to moisture absorption of parts immediately after molding is small, at 0.15% at saturation (1.1%).

Figure 3-3-5 Dependence of Dimensional Change on Moisture and Water Absorption

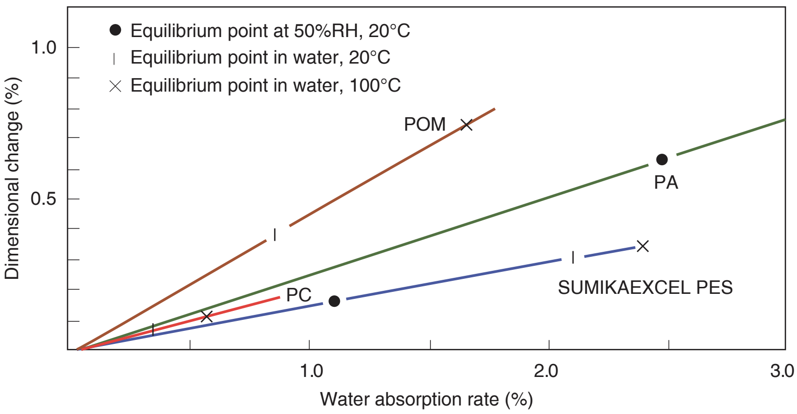
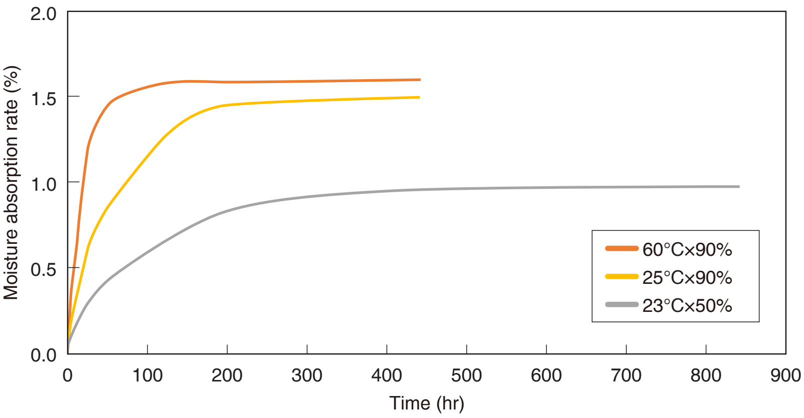


Figure 3-3-6 Moisture Absorption Curve of SUMIKAEXCEL PES



3-4 Flame Retardancy

Limiting Oxygen Index and Smoke Emission

Figure 3-4-1 shows the Limiting Oxygen Index for comparing flame retardancy with other resins. SUMIKAEXCEL PES is known to have low smoke emission and is even used for parts inside aircrafts. Figure 3-4-2 shows the smoke emission test results by The National Institute of Standards and Technology (NIST) compared with other resins.

Figure 3-4-1 Limiting Oxygen Index (ASTM D2863)

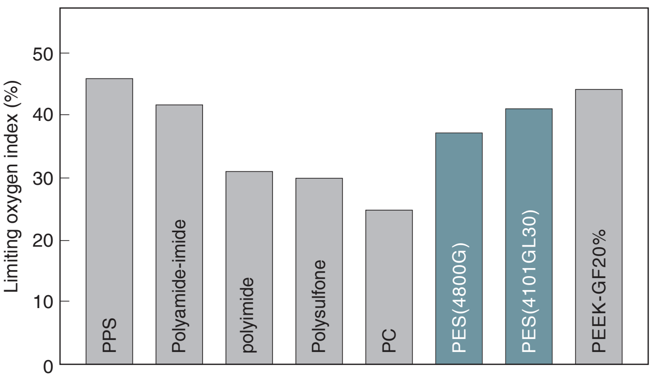
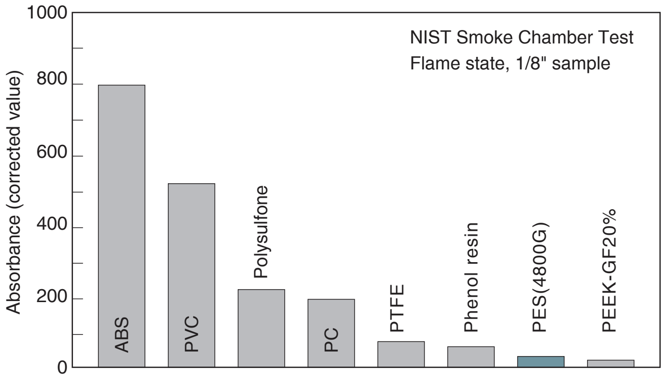


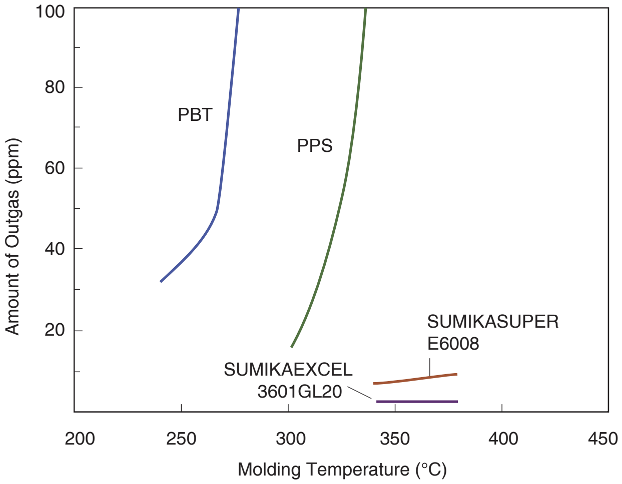
Figure 3-4-2 Amount of Smoke Emission



Outgas

SUMIKAEXCEL PES generates very little corrosive gas during the molding process, and also causes very little outgassing from the moldings.

Figure 3-4-3 Molding Temperature and Outgas from Moldings



(Dumbbell test pieces molded at each temperature were heated at 120°C for 20 hours, and the outgas was analyzed using head space gas chromatograph.)

UL Standard

The UL 94 flammability standard, established by Underwriters Laboratories Inc. is a system for classifying plastic materials based on their flammability resistance. The UL file number for SUMIKAEXCEL PES is registered as E249884.

Color : Color (ALL : All colors, NC : Natural color, BK : Black color, RD : Red color, WT : White color)

Flame Class : Flammability Class

Relative Thermal Index (RTI) : Temperature index

Hot Wire Ignition (HWI) : Hot wire ignition resistance

High Ampere Arc Resistance (HAI) : High current arc ignition resistance

High Voltage Arc Tracking Rate (HVTR) : High voltage arc tracking rate

D495 : Arc resistance test

Comparative Tracking Index (CTI) : comparative tracking index

PLC : HWI, HAI, HVTR, D495, CTI are indicated by the grade of Performance Level Categories (PLC).

Table 3-4-1 UL Registration Status of SUMIKAEXCEL PES and SUMIPLOY

Grade	Color	Thickness (mm)	Flame Class	HWI	HAI	CTI	HVTR	D495	RTI		
									Elec	Imp	Str
3600G	NC	0.41	V-0	4	1	4	2	7	-	-	-
	BK	0.75	V-0	3	1	-	-	-	180	170	180
	WT	1.6	V-0	3	1	-	-	-	180	170	180
	NC	3.0	V-0	2	0	-	-	-	180	170	180
4100G	ALL	0.41	V-0	3	4	3	1	6	180	170	180
		0.75	V-0	3	4	-	-	-	180	170	180
		1.5	V-0	2	2	-	-	-	180	170	180
		3.0	V-0	1	2	-	-	-	180	170	180
4800G	ALL	0.30	V-1	-	-	3	1	6	180	170	180
		0.46	V-0	3	4	-	-	-	180	170	180
		1.5	V-0	2	2	-	-	-	180	170	180
		3.0	V-0,5VA	1	2	-	-	-	180	170	180
3601GL20	NC,BK	0.43	V-0	-	-	4	3	5	180	180	180
		3.0	V-0	0	4	-	-	-	180	180	180
3601GL30	NC,BK	0.43	V-0	-	-	4	2	5	190	190	190
		3.0	V-0	1	4	-	-	-	190	190	190
4101GL20	NC,BK	0.43	V-0	-	-	4	3	5	180	180	180
		1.5	V-0	1	4	-	-	-	180	180	180
		3.0	V-0	0	4	-	-	-	180	180	180
4101GL30	NC,BK	0.43	V-0	-	-	4	3	5	190	190	190
		1.5	V-0	1	4	-	-	-	190	190	190
		3.0	V-0	0	4	-	-	-	190	190	190
ES5340	BK	0.52	V-0	-	-	-	-	-	50	50	50
	NC	0.81	V-0	-	-	-	-	-	50	50	50
	NC,BK	3.0	V-0	-	-	-	-	-	50	50	50
E3010	NC	0.53	V-0	-	-	-	-	-	130	130	130
FS2200	NC,BK	0.43	V-0	-	-	-	-	-	50	50	50
CS5530	NC	1.5	V-0	-	-	-	-	-	50	50	50
		3.0	V-0	-	-	-	-	-	50	50	50
CS5600	NC,BK	0.53	V-0	-	-	-	-	-	50	50	50
GS5620	ALL	0.75	V-0	-	-	-	-	-	50	50	50

3-5 Chemical Stabilities

- PES is not susceptible to hydrolysis.
- Please note that PES may be affected by strong acids.
- SUMIKAEXCEL PES has outstanding chemical resistance among most amorphous polymers. However, precautions must be taken according to the actual usage conditions. Some organic chemicals such as ketones and esters may cause stress cracking. In addition, please note that PES does dissolve in highly polar solvents such as dimethylsulfoxide (DMSO), aromatic amines, nitrobenzene, and some chlorinated hydrocarbons (e.g., dichloromethane, chloroform).
- PES possesses excellent resistance to aliphatic hydrocarbons, alcohols, some types of chlorinated hydrocarbons, certain aromatic chemical agents, oil and grease. Furthermore, depending upon conditions of actual usage, PES is not usually affected by most bleaches and disinfectants.
- However, chemical effects should be evaluated based on actual conditions prior to usage.

Annealing

Residual stress can be relieved in moldings through annealing, which is good for improving chemical resistance. This is easy to confirm by immersing it in toluene or methyl ethyl ketone (MEK).

Hot Water Resistance

SUMIKAEXCEL PES is not susceptible to hydrolysis, thus enabling its usage in hot water and steam having a high temperature of 160°C. However, attentions must be given to potential changes in its properties that may occur due to the absorption of water.

Table 3-5-1 Resistance in Hot Water and under Load (Hot Water 90°C)

		Stress (MPa)				
		13	20	26	33	40
SUMIKAEXCEL PES	4100G	R56.5	R20.2	R15.3	R12.5	-
	4800G	989.6	R65.5	R18.7	-	-
	4101GL30(GF30%)	-	-	987.3	732.5	R25.5
PPS(GF40%)		-	-	R130	R87	-

R56.5: Ruptured after 56.5 hours [R = ruptured].
In 4100G, cracking occurred in 56.5 hours under 13MPa load.
In 4101GL30, no problem up to 987.3 hours under 26MPa load.
(Does not mean that cracking occurs after 987.3 hours)

Table 3-5-2 Hot Water Resistance at 140°C (4100G)

Period (weeks)	Tensile strength (MPa)	Rate of change (%)	Charpy impact strength (kJ/m^2)	Rate of change (%)
Control	81	100	39	100
2	88	108	18	46
7	93	114	14	35
14	92	113	14	34
29	81	100	14	37
42	84	104	15	39

- Steam Sterilization at 140°C
  The tensile strength of PES does not change at all, even after steam sterilization has been performed at 140°C for 24 hours. A 1% increase in weight occurred during this time.
  * 4800G, with high molecular weight, possesses greater resistance to severe hot water conditions than 4100G.

Chemical Resistance

PES is resistant to oils such as gasoline and engine oil, grease, and cleaning solvents such as chlorothene and fluorocarbon. However, it is affected by polar solvents such as acetone and chloroform, so care should be taken when using them. On the other hand, it has the best stress cracking resistance of all amorphous polymers. It is also resistant to alkalis and acids even under high temperatures.

Table 3-5-3 Chemical Resistance and Stress Cracking Resistance

	Immersion test	Stress cracking resistance test	
	4800G	4800G	Polysulfone
Ammonia	A	-	-
50% Caustic soda	A	-	-
Concentrated hydrochloric acid	A	-	-
10% Nitric acid	A	-	-
Concentrated nitric acid	C	-	-
Hydrogen peroxide solution	A	-	-
Benzene	A	a	c
Xylene	B	a	c
Acetone	C	c	c
Methyl ethyl ketone	C	c	c
Heptane	A	a	a
Cyclohexane	A	a	a
Glycerin	A	a	a
Ethylene glycol	A	a	a
Carbon tetrachloride (CCl4)	A	a	a
Gasoline	A	a	b
Ethyl acetate	C	b	c

A : No effect
B : Some effect
C : Unfit for use
a : Can be used, except under large loads
b : Can only be used when the load is small
c : Unfit for use

Table 3-5-4 Change in Weight and Tensile Strength When Immersed in Inorganic Chemicals

Chemical name	Grade	Temperature (°C)	Weight change		Tensile strength change (%)					Remarks
			Immersion time	Weight change	Immersion time (days)					
			(days)	(%)	14	30	90	180	360	
Water	4100G	Room temperature	1	0.43	-	-17.7	-16.6	-21.1	-	-
Water	4100G	50	-	-	-	-13.5	-13.1	-17.7	-	-
Water	4100G	100	-	-	7.0	7.4	9.8	9.2	9.5	-
10% Hydrochloric acid	4100G	Room temperature	180	1.95	-15.6	-14.9	-17.8	-21.1	-	-
Concentrated hydrochloric acid	4100G	Room temperature	180	2.19	-	-6.3	-12.2	-21.1	-	-
15% Hydrochloric acid	4100G	90	-	-	-	-	-40.0	-49.0	-53.0	Significant crazing occurs
10% Sulfuric acid	4100G	Room temperature	180	1.82	-	-13.2	-17.7	-23.4	-	-
50% Sulfuric acid	4100G	60	14	-0.39	6.3	-	-	-	-	-
50% Sulfuric acid	4101GL30	60	14	-0.20	-	-	-	-	-	-
Concentrated sulfuric acid	4100G	Room temperature	-	-	-	-	-	-	-	Dissolves
25% Sulfuric acid	4100G	90	-	-	-	-	2.0	3.0	7.0	-
40% Sulfuric acid 40% Phosphoric acid	4100G	60	14	-0.55	-	-	-	-	-	-
40% Sulfuric acid 40% Phosphoric acid	4101GL30	60	14	-0.37	-	-	-	-	-	-
10% Sulfuric acid	4100G	Room temperature	180	2.27	-	-	-	-	-	-
Concentrated nitric acid	4100G	Room temperature	-	-	-	-	-	-	-	Dissolves
5% Nitric acid	4100G	90	-	-	-	-	0.0	-29.0	-24.0	Slight crazing occurs
10% Caustic soda	4100G	Room temperature	180	1.79	-	-13.9	-18.2	-22.3	-	-
Sodium saturated causticum	4100G	Room temperature	180	0.82	-	-4.8	-11.0	-14.2	-	-
5% Caustic soda	4100G	90	-	-	-	-	3.0	2.0	6.1	-
Saturated potassium chloride	4100G	Room temperature	120	1.46	-	-	-	-	-	-
Saturated sodium hypochlorite	4100G	Room temperature	180	1.42	-	-9.8	-15.8	-19.6	-	-
25% Saturated sodium hypochlorite	4100G	90	-	-	-	-10.0	-9.0	-6.0	-	-
10% Ammonium hydroxide	4100G	Room temperature	120	1.63	-	-	-	-	-	-
Hydrogen peroxide solution	4100G	Room temperature	120	2.52	-	-9.8	-	-	-	-
Chlorinated bromine water (PH4)	4100G	90	30	0.33	-	-1.0	-	-	-	-
5% Alum	4100G	90	-	-	-	-	-8.0	-11.0	-12.0	Slight crazing occurs
Sulfurous acid gas	4100G	Room temperature	180	8.49	-	-15.0	-	-34.0	-	-
Nitrogen dioxide	4100G	Room temperature	180	1.19	-	-4.5	-	-4.5	-	-
Sulfur hexafluoride	4100G	Room temperature	30	-0.11	-	2.4	-	-	-	-
Chlorine (Cl)	4100G	Room temperature	28	0.47	-	-62.8	-	-	-	Cracking occurs

Organic Chemical Resistance

Stress Cracking Resistance

The condition of a tensile impact test piece (1.6mm thick) after immersion in each chemical for up to 20 minutes under a constant load is shown using the legend.

Table 3-5-5 Stress Cracking Resistance 1

	Stress 10MPa					
	Polyethersulfone			Polysulfone	Polycarbonate	Modified PPO
	4100G	4800G	4101GL30	Unreinforced	Unreinforced	Unreinforced
Acetone	R1S	R4S	20	R2S	R1S	20
Methyl ethyl ketone	R1S	R2S	20	R1S	20	R18
Cyclohexanone	R1S	R19S	20	20	20	D
Benzene	C20	20	20	R1S	R4	D
Toluene	20	20	20	R1S	R11	D
Xylene	20	20	20	R4S	R15	D
Trichloroethylene	C20	C20	20	D	20	D
1.1.1 - Trichloroethane (Chlorothene)	20	20	20	R8S	R3	D
Carbon tetrachloride (CCl_4)	20	20	20	SLC20	R6S	D
1.2 - Dichloroethane	R1S	R1S	20	D	D	D
Perchloroethylene	20	20	20	C20	R1S	D
Chloroform	R1S	R1S	20	D	D	D
Trichlorotrifluoroethane	20	20	20	20	20	D
Methanol	20	20	20	20	20	20
Ethanol	20	20	20	20	20	20
N-butanol	20	20	20	20	20	20
Ethylene glycol	20	20	20	20	20	20
2-ethoxyethanol	C20	SLC20	20	C20	R17	20
Propane - 1.2 - diol	20	20	20	20	20	20
Heptane	20	20	20	20	20	20
Ethyl acetate	R315	C20	20	R3S	20	20
Diethyl ether	C20	SLC20	20	C20	R1	20
Carbon dioxide	20	20	20	R8S	R1S	D
Gasoline	20	20	20	20	C20	20
Light oil	20	20	20	20	20	20

(Legend) 20 ....After 20 minutes of immersion, no changes at all were observed in the test piece.
C20 ....After 20 minutes of immersion, crazing occurred on the test piece.
SLC20 ....After 20 minutes of immersion, slight crazing occurred on the test piece.
R8 ....After 8 minutes of immersion, the test piece ruptured.
R2S ....After 2 seconds of immersion, the test piece ruptured.
D ....The test piece dissolved.

Table 3-5-5 Stress Cracking Resistance 2

	Stress 19MPa					
	Polyethersulfone			Polysulfone	Polycarbonate	Modified PPO
	4100G	4800G	4101GL30	Unreinforced	Unreinforced	Unreinforced
Acetone	R1S	R3S	20	R2S	R1S	20
Methyl ethyl ketone	R1S	R1S	20	R1S	R5	R20S
Cyclohexanone	R1S	R5S	20	D	D	D
Benzene	R2	C20	20	R1S	R3	D
Toluene	R6	C20	20	R1S	R3	D
Xylene	20	20	20	R2S	R11	D
Trichloroethylene	R6	R11	20	D	R17	D
1.1.1 - Trichloroethane (Chlorothene)	20	20	20	R3S	R1	D
Carbon tetrachloride (CCl_4)	20	20	20	R3	R3S	D
1.2 - Dichloroethane	R1S	R1S	20	D	D	D
Perchloroethylene	20	20	20	R8	R1S	D
Chloroform	R1S	R1S	20	D	D	D
Trichlorotrifluoroethane	20	20	20	20	20	D
Methanol	20	20	20	20	20	20
Ethanol	20	20	20	20	20	20
N-butanol	20	20	20	C20	C20	20
Ethylene glycol	20	20	20	20	20	20
2-ethoxyethanol	C20	C20	20	C20	R10	20
Propane - 1.2 - diol	20	20	20	20	20	20
Heptane	20	20	20	20	SLC20	R19
Ethyl acetate	R17S	R7	20	R1S	R4	20
Diethyl ether	C20	C20	20	R7	R1	R15
Carbon dioxide	20	20	20	R5S	R1S	D
Gasoline	20	20	20	C20	R3	R1
Light oil	20	20	20	20	20	20

(Legend) 20 ....After 20 minutes of immersion, no changes at all were observed in the test piece.
C20 ....After 20 minutes of immersion, crazing occurred on the test piece.
SLC20 ....After 20 minutes of immersion, slight crazing occurred on the test piece.
R8 ....After 8 minutes of immersion, the test piece ruptured.
R2S ....After 2 seconds of immersion, the test piece ruptured.
D ....The test piece dissolved.

Solubility

PES is a polar polymer that dissolves in polar solvents. PES solubility is important for paint and coating applications and for adhesion of solvents. Solvents for PES are as follows: dimethylsulfoxide, N,N-dimethylformamide, N-methylpyrrolidone, and dimethylacetamide.

Changes in Weight and Tensile Strength

Table 3-5-6 indicates the weight changes that occur when PES is immersed in various organic chemicals. Although the weight of PES will change over a range of -0.5% to 2% when immersed in non-solvent chemicals, depending on the temperature and time of immersion, the dimensions themselves remain unchanged. When immersed in weak solvents, PES generally softens and swells, with its weight changing significantly.

Table 3-5-6 Changes in Weight and Tensile Strength When Immersed in Organic Chemicals (4100G)

Chemical name	Grade	Temperature (°C)	Weight change		Change in tensile strength					Remarks
			Immersion time (days)	Weight change (%)	Immersion time (days)					
					7	30	90	180	360	
25% Acetic acid	4100G	90	-	-	-	-	-3.00	-27.00	-42.00	Crazing occurs after 360 days
Glacial acetic acid		Room temperature	30	0.31	-	-	-	-	-	-
5% Phenol		Room temperature	90	6.66	-29.70	-35.70	-45.80	-	-	-
Hydrazine anhydride		Room temperature	14	3.50	-	-	-	-	-	Softens
Benzene		Room temperature	180	1.48	-3.20	-3.10	-8.60	-13.50	-	-
Xylene		Room temperature	7	0.49	-	-	-	-	-	-
Heptane		Room temperature	180	0.21	-0.80	-1.00	-5.80	-10.00	-	-
Cyclohexane		Room temperature	120	0.12	-	-	-	-	-	-
Methanol		Room temperature	14	2.09	-	-	-	-	-	-
Ethanol		Room temperature	180	1,46	-2.20	-5.00	-13.60	-18.70	-	-
Ethylene glycol		Room temperature	120	0.53	-	-	-	-	-	-
Propylene glycol		100	14	-0.36	-	-	-	-	-	-
Glycerin		150	14	0.06	-	-	-	-	-	-
White spirit		130	7	-0.51	+21.90	-	-	-	-	Slight cracking
Ethyl acetate		Room temperature	60	10.70	-	-	-	-	-	Softens
Amyl acetate		Room temperature	120	-0.08	-	-	-	-	-	-
Diethyl ether		Room temperature	120	2.91	-	-	-	-	-	-
Carbon tetrachloride (CCl4)		Room temperature	180	0.44	-0.40	-0.30	-6.40	-11.30	-	-
1.1.1-Trichloroethane (Chlorothene)		Room temperature	120	1.01	-10.20	-19.20	-32.80	-51.60	-	-
Genklene		Room temperature	120	1.13	-	-	-	-	-	-
Perchloroethylene		Room temperature	120	0.78	-	-	-	-	-	-
North Sea Gas		Room temperature	180	0.01	-	-0.34	-	0.20	-	-
Ethylene oxide		Room temperature	190	7.59	-	-14.00	-	-39.10	-	Cracking occurs at a stress of 140kg/cm²
Propylene gas		Room temperature	180	0.21	-	-	-	-0.11	-	-

Cleaning solvents

When coating or bonding with PES, it is often necessary to remove grease, oils, and parting agents from the surface of moldings. For this purpose, the usage of certain cleaning solvents, such as acetone and methyl ethyl ketone, should be avoided. Table 3-5-7 indicates the effects of cleaning solvents on 4100G.

Table 3-5-7 Effect of Cleaning Solvents (4100G)

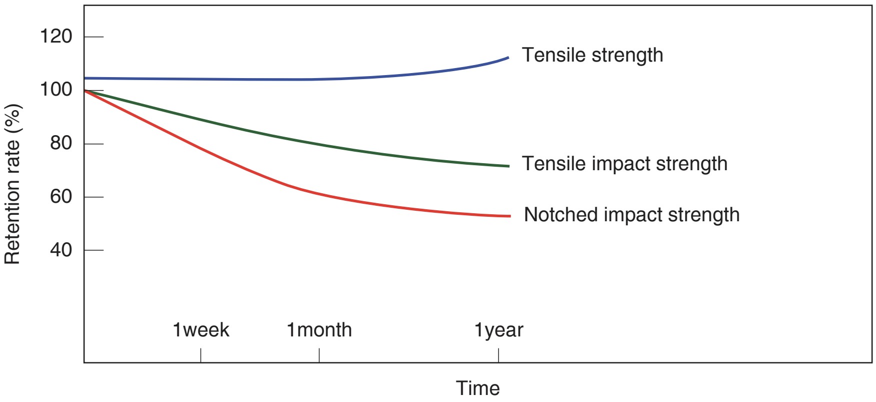
Cleaning solvent (under reflux)	Time (minutes)	Hardness (initial value=98)	Weight increase (%)
Arklone P	2 10 30	98 98 98	0 0 0
Arklone L	2 10 30	98 98 98	0 0 0
Genklene	2 10 30	98 98 98	0 0 0
Trinklone A	2 10 30	98 98 98	0 1 1
Trinklone N	2 10 30	98 Surface cracking occurs Surface cracking occurs	1 1 2
Perchloroethylene	2 10 30	98 98 98	0 0 0
Methylene chloride	2 10 30	98 Dissolves Dissolves	3

Oil , Gasoline, and Transmission Fluid Resistance

Table 3-5-8 Weight Changes in Oils or Gasoline (4100G)

Environment	Immersion time (days)	Temperature (°C)	Weight change (%)
Linseed oil	180	Room temperature	0.63
Deep Frying Oil	2	180	-0.10
Silicone oil (ICI 190)	180	Room temperature	0.37
Veedol ATF 3433 (Transmission oil)	365	130	0.38
Castrol ATF	90	160	-0.55
Shell Diala trans oil	180	Room temperature	0.30
Castrol ATF Solvent flushing Oil	90	Room temperature	0.50
Duckhamz 20/50 oil	90	160	2.84
Gunk	90	Room temperature	0.55
98-octane gasoline	180	Room temperature	0.60
3 Star petrol	90	Room temperature	0.20
ASTMII Oil	7	Room temperature	0

Figure 3-5-1 Change in Mechanical Properties in Transmission Oil (4100G)



(Immersion conditions)
Transmission oil VEEDOL ATF
Temperature: 130°C

Table 3-5-9 Stress Cracking Resistance in Gasoline (Room Temperature)

Grade	Environment	Stress (MPa)			
		9	19	28	37
4100G	Diesel gasoline	20	20	20	20
4100G	97-octane gasoline	20	20	SLC20	C20
4100G	100-octane gasoline	20	R270h	C20	R19
4100G	Paraffin	2110h	2110h	2110h	2110h
4101GL30	97-octane gasoline	20	20	20	20
4101GL30	100-octane gasoline	360h	360h	20	20

R : Crack
C : Crazing
SLC : Slight crazing
h : Hour, minutes if there is no particular unit
(Legend) 20 : No problem for 20 minutes
R270h : Cracks occurred at 270 hours
2110h : No problem until 2,110 hours

Table 3-5-9 Stress Cracking Resistance in Oil (Vactralite Oil) (100°C)

Grade	Notch radius (mm)	Stress (MPa)					
		5	10	20	25	30	40
4100G	0.01	2000h	R150h	-	-	-	-
4100G	0.25	2300h	R110h	-	-	-	-
4100G	0.50	-	1450h	R330h	-	-	-
4100G	1.00	-	2000h	2000h	-	3000h	R790h
4100G	2.50*	-	-	2300h	-	2000h	R700h
4101GL20	0.50	-	-	-	1632h	R460h	R160h

*Mold notch
(Items without an asterisk (*) are machine notched.)
(Legend) 20 : No problem for 20 minutes
R270h : Cracks occurred at 270 hours
2110h : No problem until 2,110 hours

Table 3-5-11 Stress Cracking Resistance in Turbine Oil (160°C)

Grade	Oil	Notch radius (mm)	Stress (MPa)			
			10	20	30	40
4800G	Aeroshell 555	2.5	3000h	R1h	-	-
4101GL20	Aeroshell 555	0.5*	250h	R3h	-	-
4101GL30	Aeroshell 555	2.5	-	3700h	-	-
4800G	Esso Turbo 2380	2.5	3200h	-	-	-
4101GL30	Esso Turbo 2380	2.5	-	-	1650h	R2h
4800G	Esso Turbo 2389	2.5	1400h	R20h	-	-

*Mold notch
(Items without an asterisk (*) are machine notched.)
(Legend) 20 : No problem for 20 minutes
R270h : Cracks occurred at 270 hours
2110h : No problem until 2,110 hours

Table 3-5-12 Effects of Oil Immersion on Mechanical Properties (4800G)

Oil type		Temperature (°C)	Immersion time (weeks)					
			2	4	6	16	32	52
Mineral oil		100	+	+	+	+	+	+
		120	+	+	+	+	0	0
		140	+	0	0	0	0	
Synthetic hydrocarbon oil		100	+	+	+	+	0	0
		120	+	+	+	+	0	0
		140	0	0	0	0	-	
Silicone oil	Dimethyl	120	+	+	+	+	0	0
		160	+	0	0	0	0	0
	Methylphenyl	120	+	+	+	+	+	+
		140	+	+	+	0	0	
		160	+	0	0	0	0	0
		180	+	0	-	-	-	-
	Chlorophenyl	160	0	0	0	0	0	0
		180	-	-	-	-	-	-
		200	-	-	-	-	-	-
Ester oil	Diester	120	+	+	+	+	0	0
	Polyester	120	+	+	0	0	-	-
		160	0	0	-	-	-	-
		180	0	-	-	-	-	-
Polyglycol oil		100	+	+	+	+	+	+
		120	+	+	+	0	0	0
		140	0	0	0	0	0	
Fluorinated alkylether oil		180	0	0	0	-	-	-
		200	-	-	-	-	-	-
Water-soluble oil emulsion		80	0	0	0	0	-	-
Mineral base oil + Thickener								
(a) Calcium soap		80	+	+	0	0	0	0
(b) Lithium soap		120	+	0	0	-	-	-
(c) Lithium lead soap		120	0	0	0	0	-	-
(d) Calcium complex soap		120	+	+	+	+	+	-
(e) Sodium synthetic soap		120	0	0	0	-	-	-
(f) Polyurea		120	0	0	0	0	-	-
Diester + Lithium soap		120	+	+	+	+	0	0
Silicone base oil								
Dimethyl+Denatured amide		120	+	0	0	0	0	0
Methylphenyl + Lithium soap		120	+	+	+	+	0	0
		140	+	+	+	+		
		160	+	+	0	0		

(Legend)
+ Resistance Excellent Retention 75% or greater
0 Good 50% or greater
- Fail Less than 50%

Table 3-5-13 Stress Cracking Resistance under Constant Strain in Turbine Oils (4800G)

Oil	Temperature			
	Room temperature	150°C	160°C	
	Deformation			
	3%	2%	1%	0%
Aeroshell 500	0.05	R5	0.15	15
Aeroshell 555	5	R5	15*	15
Aeroshell 750	5	R5	15	-
Castrol 580	5	R5	15	-
Esso Turbo 25	5	R5	25	-
Esso Turbo 274	5	R5	R25**	15
Esso Turbo 2380	5	R5	R25**	15
Esso Turbo 2389	5	R5	-	-

20 : No problem for 20 minutes
(Legend)
* Surface cracking occurred parallel to the resin flow direction.
** Cracking did not occur during a 25-minute exposure.

Bleach and Liquid Disinfectant Resistance

PES is not affected by most bleaches and liquid disinfectants, unless they are in highly concentrated form. After being immersed in liquid disinfectant, molded PES products must be rinsed water. If further sterilization is required, steam or dry heat can be applied.

Table 3-5-14 Effects of Bleaches and Liquid Disinfectants (4100G)

Solution	Weight change (%)	Tensile strength change (%)
10% Lissapol N	1.46	-11.6
2% Ivisol	1.35	-14.6
0.5% Gevisol	1.40	-14.8
2% Instrusan	1.42	-15.6
1% Bentenol	1.30	-13.6
1% Soilay 901-SD	1.36	-14.7
Household bleach	1.27	-

Conditions : Immersed for a period of 1 month at room temperature

3-6 Electrical Properties

PES is a heat resistant material that possesses electrical insulating properties. It maintains an outstanding Relative permittivity and dielectric dissipation factor, as well as superb electrical resistance, up until temperatures exceeding 200°C.

Relative permittivity

The dielectric constant of SUMIKAEXCEL PES is constant from 60Hz to 1GHz, and is only slightly higher when molded products absorb water.

Figure 3-6-1 Temperature Dependence of Relative permittivity

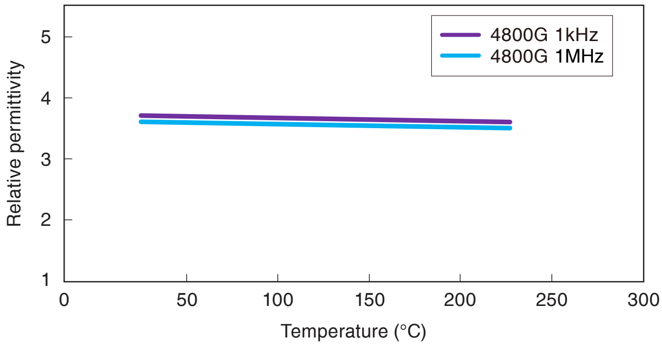
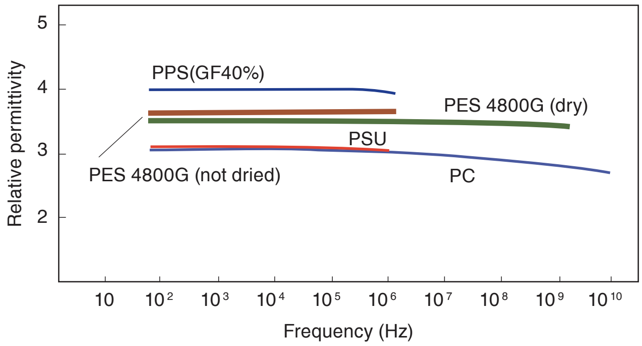


Figure 3-6-2 Frequency Dependence of Relative permittivity



Dielectric dissipation factor

The dielectric dissipation factor of SUMIKAEXCEL PES is stable at a low value of about 0.001 at the 20 to 150°C temperature range. The frequency dependence of the dielectric dissipation factor is about 0.003 even at 10GHz.

Figure 3-6-3 Temperature Dependence of Dielectric Dissipation Factor (60Hz)

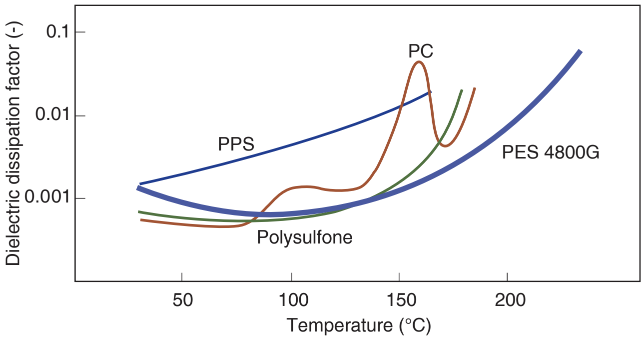
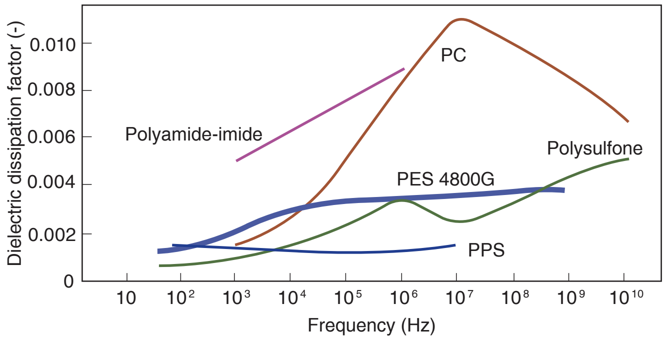


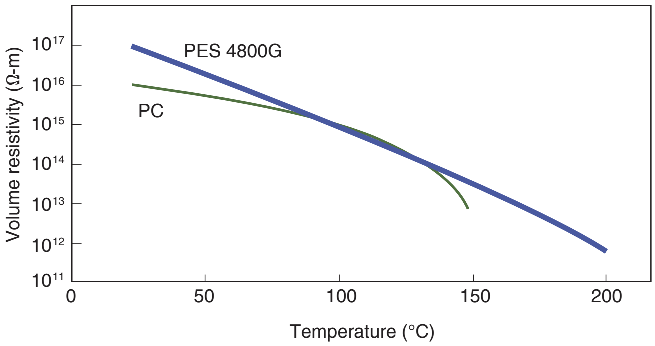
Figure 3-6-4 Frequency Dependence of Dielectric Dissipation Factor



Volume Resistivity

PES possesses a high volume resistivity of 10^{11} Ω-m, even at 200°C.

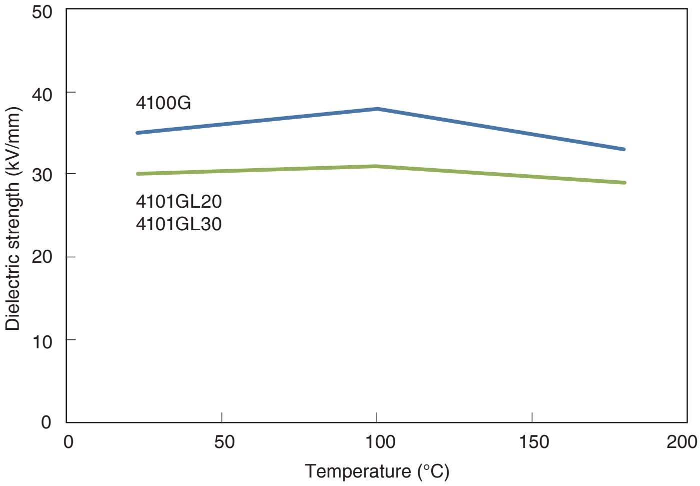
Figure 3-6-5 Temperature Dependence of Volume Resistivity (Polarization Time : 1000 sec.)



Insulation Properties

SUMIKAEXCEL PES has good insulation properties, and insulation remains almost the same even when the temperature increases.

Figure 3-6-6 Temperature Dependence of Dielectric Strength of SUMIKAEXCEL PES



Test conditions
Test method : IEC 60243-1 reference
Test piece thickness : 1.6mm

3-7 Sliding Properties

Test Method

There are various evaluation test methods for sliding characteristics. The appropriate method depends on the application and situation. Devices for evaluating the basic sliding characteristics of resin include a Suzuki wear tester, Pin-on-Disk wear tester, and thrust wear tester (Amsler, etc.).

Limiting PV Value

The limiting PV value (Load pressure x Velocity) represents the limit at which the sliding surface of the material becomes deformed or melts due to frictional heat generation. Therefore, when conditions exceed the limiting PV value, both friction and wear will increase significantly, making it unusable. The limiting PV value increases as the resin heat resistance increases. It is necessary to use it at about 50 to 60% or lower than the limiting PV value.

Frictional Properties

Frictional properties are indicated by the static friction coefficient (μ_S) and dynamic friction coefficient (μ_D). Fluororesin-based sliding materials are said to have the smallest friction coefficient.
The frictional resistance at startup is represented by μ_S. It is important that the μ_S be small and stable for applications where it repeatedly changes from static to movement. The μ_S immediately after molding and μ_S after initial wear are different.

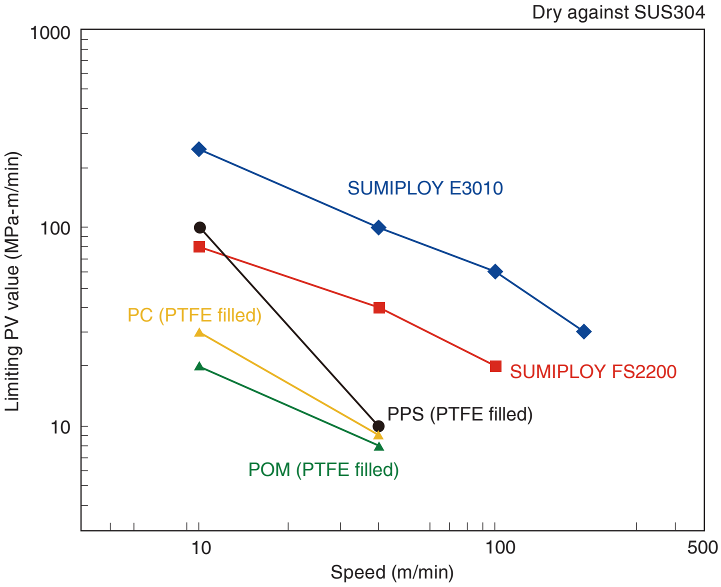
Sliding Characteristics of Non-Reinforced Sliding Grades

Non-reinforced sliding grades that do not contain reinforcing fibers include SUMIPLOY E3010 and SUMIPLOY FS2200. These have a feature making it extremely difficult to damage the mating material in a dry state even when the mating material is a soft metal such as SUS or aluminum.

Limiting PV value

Figure 3-7-1 shows the velocity dependence of the limit PV values for E3010 and FS2200 compared with other engineering plastic sliding grades. This indicates that it has a limit PV value that is considerably higher than the compared sliding materials.

Figure 3-7-1 Velocity Dependence of Limiting PV Values for Non-Reinforced Sliding Grades



Frictional Properties

E3010 shows the smallest static friction coefficient in the dry state among sliding materials for injection molding. E3010 maintains its initial static friction coefficient even after wear and is stable over a long period of time.

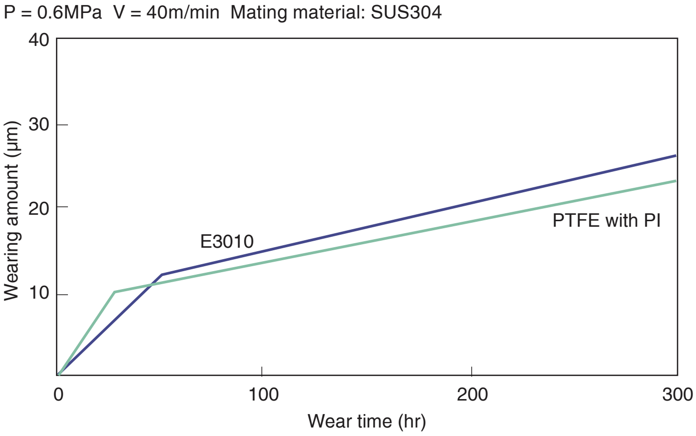
Wear Properties

Table 3-7-1 shows the friction and wear properties of SUMIPLOY sliding grades in comparison with the sliding grades of other general-purpose engineering plastics. It shows stable wear resistance for low to high PV values. Figure 3-7-2 shows the relationship between the amount of wear and time for E3010 when P = 0.6MPa and V = 40m/min. The initial wear is smaller than that of fluororesins containing filler. It is also equivalent to fluororesins containing polyimide.

Table 3-7-1 Friction and Wear Properties of Non-Reinforced Sliding Grades (Thrust Type Testing Machine)

Measuring conditions			Sample	Dynamic friction coefficient μ_D	Cumulative friction amount ΔW(μ)	Wear coefficient K(mm/km-MPa)	Wear of mating material (mg)
Pressure P (MPa)	Speed V (m/min)	Mating material					
1	10	SUS304	E3010	0.16	3.5	1.2×10^{-6}	Transfer
			FS2200	0.12-0.30	11	3.8×10^{-6}	0.27
			PTFE-filled PC	0.12-0.31	95	33.3×10^{-6}	0.13
			PTFE-filled POM	0.13	8.7	3.0×10^{-6}	0.10
0.6	40	SUS304	E3010	0.18	11	1.6×10^{-6}	0.01
			FS2200	0.14-0.21	133	19.2×10^{-6}	0.16
			CF/PTFE filled PPS	0.40	132	19.2×10^{-6}	13.6
			PTFE-filled PC	Above the limiting PV value (melting within a few minutes)			
			PTFE-filled POM				
0.1	100	SKH-2	E3010	0.24	5.7	2.0×10^{-6}	0.16
			FS2200	0.29	85	29.5×10^{-6}	0.14
			CF/PTFE filled PPS	0.81	90	31.3×10^{-6}	10.5
0.2	100	SKH-2	E3010	0.22	5.4	0.9×10^{-6}	0.24
			CF/PTFE filled PPS	0.53	168	29.2×10^{-6}	4.30

Figure 3-7-2 Friction and Wear Properties of Non-Reinforced Sliding Grades



Sliding Characteristics of Fiber-Reinforced Sliding Grades

SUMIPLOY CS5220, CS5530, and CK3420 are reinforced grades with carbon fiber, inorganic filler, etc. These have excellent dimensional stability, mechanical strength and rigidity, a small coefficient of thermal expansion, and can even be used under harsh conditions with a high PV value. Although the friction coefficient is relatively large and has slight fluctuation, it can be used for various applications by using a mating metal material with high hardness, by applying a hardening treatment to the surface of the material, or by using it together with lubricating oil. However, keep in mind that these may damage soft metals such as SUS and aluminum.

Limit PV Values for SUMIPLOY Fiber-Reinforced Grades

Table 3-7-2 shows the limiting PV values for SUMIPLOY CK3420, a fiber-reinforced grade.

Table 3-7-2 Limiting PV Values of Fiber-Reinforced Sliding Grades

Unit : MPa-m/min

	CK3420
V = 40m/min	160
V = 100m/min	100

Mating material : SKH-2, room temperature-DRY

Friction and Wear Properties of SUMIPLOY fiber-Reinforced Grades

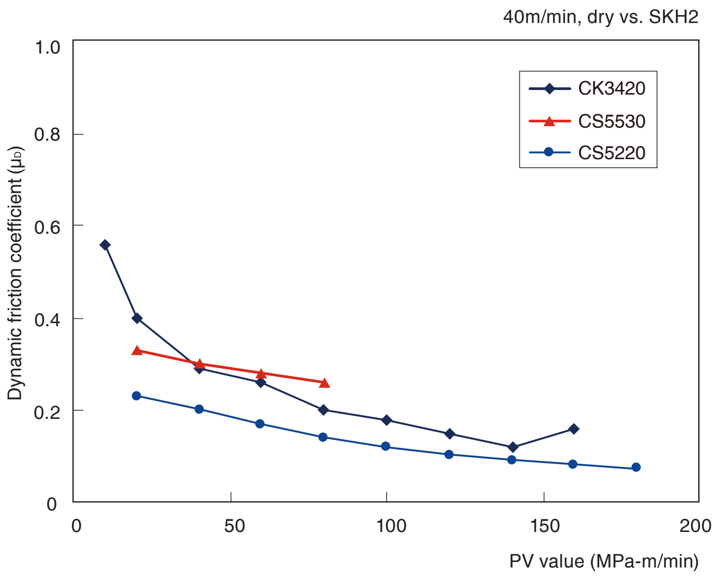
The following shows the PV value dependence of the dynamic friction coefficient μ_D when the velocity is V = 40 m/min, 100 m/min. Each grade shows a small value of 0.1 to 0.2 when the PV value is high (high load), but the friction coefficient is large when the PV value is low (low load). Therefore, it is a good sliding material for high loads and high speeds.
The wear resistance of these fiber reinforced grades is not good compared to non-reinforced sliding grades. Table 3-7-3 shows examples of friction and wear properties.

Table 3-7-3 Friction and Wear Properties of Fiber-Reinforced Sliding Grades

Sliding conditions	Item	CK3420
P = 0.6MPa V = 40m/min Room temperature-DRY	Friction coefficient	0.81
	Wear coefficient (mm/km/MPa)	45×10^{-6}
	Change in mating material weight (mg)*	+1.9
P = 0.2MPa V = 100m/min Room temperature-DRY	Friction coefficient	1.00
	Wear coefficient (mm/km/MPa)	36×10^{-6}
	Change in mating material weight (mg)*	+0.2

Mating material : SKH-2, sliding time : 48hr
* : + denotes transfer.

Figure 3-7-3 Relationship between Dynamic Friction Coefficient and PV

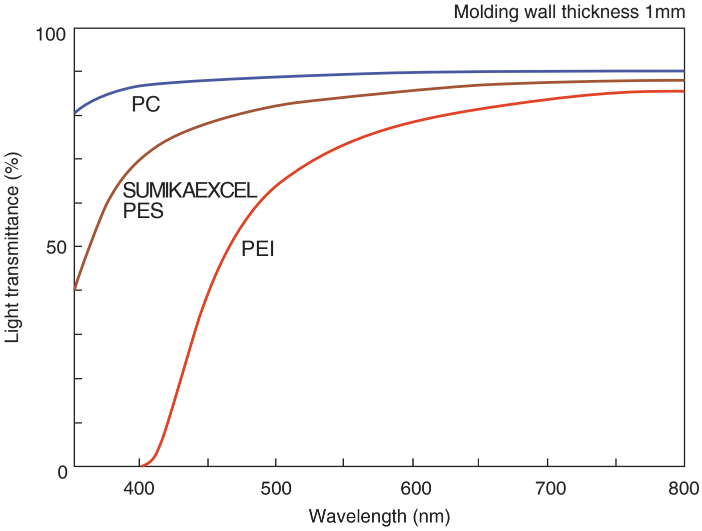


3-8 Other Properties

Light transmittance

SUMIKAEXCEL PES is a transparent resin with a slight yellow color that has a low haze value and an excellent light transmission rate among heat-resistant engineering plastics.

Figure 3-8-1 Light Transmittance of SUMIKAEXCEL PES



Refractive index

This shows the refractive index for SUMIKAEXCEL PES. Since PES has a high refractive index, it is excellent for applications such as lenses.

Table 3-8-1 Refractive Indices of SUMIKAEXCEL PES

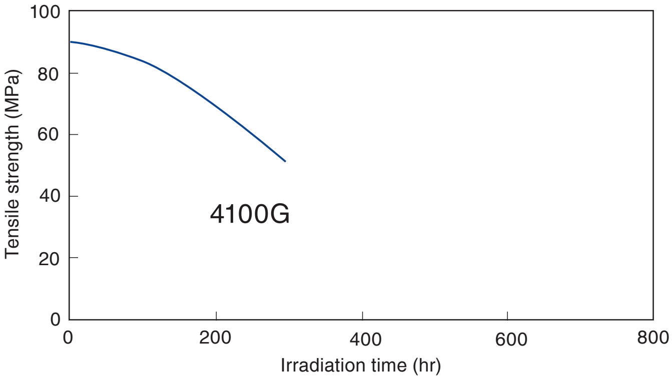
Wavelength (nm)	Refractive index
544 (Green)	1.6677
589 (Orange)	1.6525
633 (Red)	1.6428
670 (Red)	1.6366

Grade : SUMIKAEXCEL 4100G
Measurement temperature : 23°C

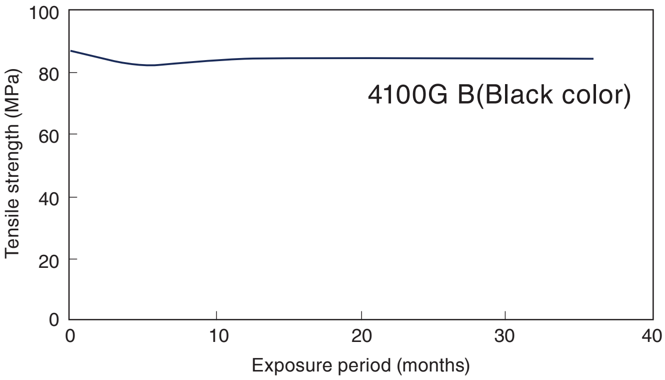
Weather Resistance

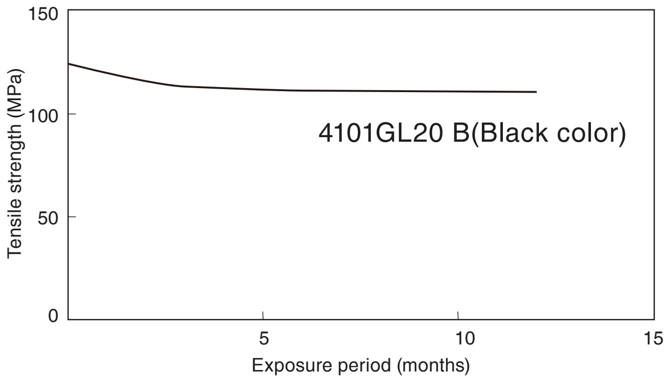
As with other sulfone resins, SUMIKAEXCEL PES does not have good weather resistance. Ultraviolet rays cause the surface of the polymer to deteriorate. It may be possible to use outdoors in black to reduce loss of strength.

Figure 3-8-2 Weather Resistance of SUMIKAEXCEL PES



Weather Resistance Test Conditions
Test equipment : UV carbon arc type weather meter
Black panel temperature : 63±3°C
Water spray : 120-minute cycle
(108 minutes irradiation only ⇒ 12 minutes irradiation + spray)





CAE Analysis

CAE (Computer-Aided Engineering) analysis can be used to evaluate (simulate) product design issues using a computer. The table below shows some of the technical data required for CAE. The following data was measured for flow analysis. Please contact us to obtain the detailed technical data required for CAE analysis.

Table 3-8-2 Characteristics of SUMIKAEXCEL PES

	Test method	Unit	Unreinforced	Glass fiber reinforced	
			3600G 4100G 4800G	3601GL20 4101GL20	3601GL30 4101GL30
Specific heat	ASTM E1269	J/(kg·K)	963	847	788
Thermal conductivity	ISO 22007-2	W/(m·K)	0.16	0.28	0.24
Young's modulus (MD)	ASTM D638	MPa	2,650	6,600	8,900
Young's modulus (TD)	ASTM D638	MPa	2,650	4,300	5,000
Poisson's ratio (MD)	ASTM D638	-	0.40	0.40	0.41
Poisson's ratio (TD)	ASTM D638	-	0.40	0.47	0.49
Linear expansion coefficient (MD)	ISO 11359-2	10^{-5}/K	4.9	2.4	2.1
Linear expansion coefficient (TD)	ISO 11359-2	10^{-5}/K	4.9	4.7	4.5

4. Injection Molding

4-1 Injection Molding Conditions

Molding Conditions

The standard molding conditions for SUMIKAEXCEL PES and SUMIPLOY are shown below.

Table 4-1-1 Standard Molding Conditions for SUMIKAEXCEL PES

Grade		3600G 4100G		4800G		3601GL20 / 3601GL30 4101GL20 / 4101GL30 ES5340	
		Recommended	Range	Recommended	Range	Recommended	Range
Drying temperature (°C)		160-180		160-180		160-180	
Drying time (hr)		5-24		5-24		5-24	
Cylinder temperature (°C)	Rear	320	300-340	320	320-340	320	300-340
	Center	340	320-370	340	330-370	340	320-370
	Front	350	330-380	360	340-390	350	330-380
	Nozzle	350	330-380	360	340-390	350	330-380
Suitable resin temperature (°C)		350	350-360	360	350-370	350	350-360
Tool (Mold) temperature (°C)		140-180	120-180	140-180	120-180	140-180	120-180
Injection pressure (MPa)		100-200	100-200	100-200	100-200	100-200	100-200
Injection speed		Low speed	Low to medium speeds	Low speed	Low to medium speeds	Low speed	Low to medium speeds
Screw rotation (rpm)		50-100	50-100	50-100	50-100	50-100	50-100
Back pressure (MPa)		5-10	5-10	5-10	5-20	5-10	5-10
Holding pressure (MPa)		50-100	50-100	50-100	50-150	50-100	50-100

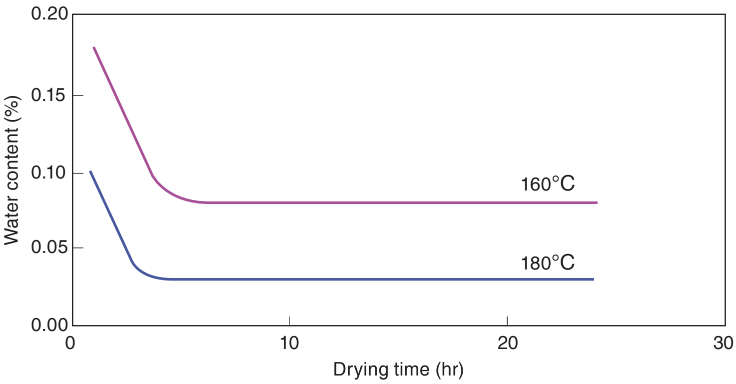
Table 4-1-2 Standard Molding Conditions for SUMIPLOY

Grade		GS5620 CS5220 / CS5530 / CS5600		E3010 FS2200		CK3400 / CK3420 CK4600	
		Recommended	Range	Recommended	Range	Recommended	Range
Drying temperature (°C)		160	160-180	160	160-180	160	160-180
Drying time (hr)		8	5-24	8	5-24	5	5-24
Cylinder temperature (°C)	Rear	320	320-340	320	300-340	380	360-400
	Center	340	330-370	340	320-370	390	370-410
	Front	360	340-390	350	330-380	390	380-420
	Nozzle	360	340-390	350	330-380	400	380-420
Suitable resin temperature (°C)		360	340-390	350	350-360	400	380-420
Tool (Mold) temperature (°C)		140-180	120-180	140-180	120-180	180	120-180
Injection pressure (MPa)		100-200	100-200	100-200	100-200	100-200	100-200
Injection speed		Low speed	Low to medium speeds	Low speed	Low to medium speeds	Low speed	Low to medium speeds
Screw rotation (rpm)		50-100	50-100	50-100	50-100	50-100	50-100
Back pressure (MPa)		5-10	5-10	5-10	5-10	5-10	5-10
Holding pressure (MPa)		100-200	50-200	50-100	50-150	100-200	50-200

Pre-drying

As SUMIKAEXCEL PES is susceptible to water absorption, it must be dried thoroughly prior to usage. PES resin should be dried at temperatures ranging from 160 to 180°C for 5 to 24 hours, using a hot air circulation oven or a dehumidifying dryer. When drying using oven trays, PES resin should be spread on the trays to a thickness of 50mm or less. In particular, for molding large sized moldings, it is recommended that PES resin is dried at a temperature of 180°C.
In addition, the use of a dehumidifying dryer is recommended for non-reinforced grades and for large sized moldings. If a hopper dryer is used, it is important to ensure that it has both adequate resin capacity and large heat capacity. If pre-drying is sufficient, then silver streaking or flashing may appear on the surface of the molding. If this kind of phenomena occurs, then further drying of the resin is necessary.
As SUMIKAEXCEL PES is not susceptible to hydrolysis, it will not deteriorate during the drying process, if dried in accordance with the abovementioned conditions.

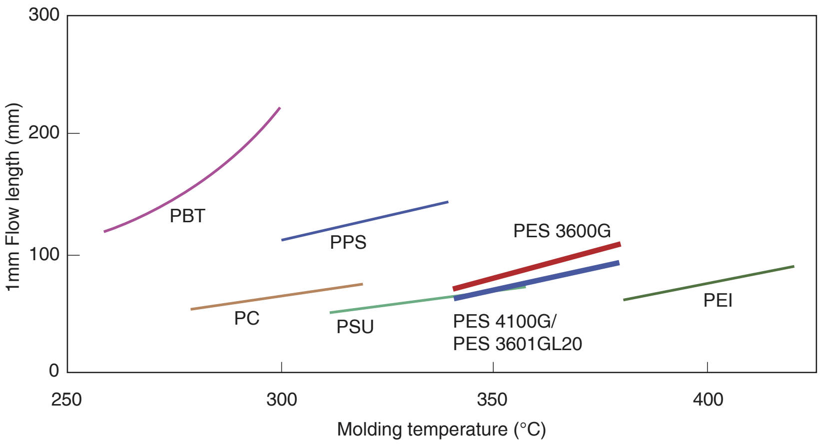
Figure 4-1-1 Drying Curve of 4100G



Resin Temperature

A resin temperature of 330 to 380°C is recommended. As SUMIKAEXCEL PES possesses high melt viscosity, the resin temperature tends to increase to a value higher than the cylinder temperature setting due to shear heat generation, and this may result in a temperature difference of more than 40°C. The resin temperature must be carefully monitored while molding operations are performed.

Figure 4-1-2 Flow length of PES (1mm)



Resin Residence Time

The length of time that it stays in the cylinder has a major impact on injection molding product quality. The residence time should be no longer than 10 minutes. The longer the residence time, the greater the possibility of thermal deterioration resulting in discoloration, black streaks, or black spots on molded parts.

Mold Temperature

The mold temperature should be set in a manner such that the surface temperature will be between 120 to 180°C. Also, ensure that the surface of the mold has a uniform temperature distribution.
If the mold temperature is excessively low, moldings may warp or crack (rupture) due to residual stresses. Residual stresses may also cause glass fibers to be visible on the surface of moldings for glass fiber grades. Moldings having low residual stresses can be obtained by using a high mold temperature. However, if the tool temperature is excessively high, deformation may occur during mold release.
With respect to the methods used for mold heating, both heaters and oil temperature control are recommended. However, for the following molds, oil temperature control should be implemented in order to ensure the most uniform mold temperature distribution: molds that have complex shapes; deep molds; and molds that have slide cores.
In particular, when molding large sized products and when using non-reinforced grades, additional precautions must be taken to ensure that proper mold temperatures are maintained.

Injection Pressure and Holding Pressure

In general, the injection molding of SUMIKAEXCEL PES requires high injection pressure of 100 to 200MPa. Over 150MPa of injection pressure is required for the molding of thin-walled products, for the molding with glass fiber reinforced grades, and for the molding of products with large flow length.
It is recommended that the holding pressure is set to 1/2 to 1/3 of the injection peak pressure, and it should be set as low as possible at the level that does not cause sink marks. The lower the holding pressures, the less residual stress there will be on the molded products.
The higher the peak pressure and holding pressure, the more difficult it is to release from the mold. Therefore, adjust the V-P switching position so that the peak pressure does not increase too much.

Injection speed

In general, SUMIKAEXCEL PES should be molded at low to medium injection speeds. However, the optimum injection speed will vary depending on the shape of the products.
As SUMIKAEXCEL PES has high melt viscosity, an excessively high injection speed will result in burning and silver streaking, due to the heat generated by shear and adiabatic air compression. However, high injection speeds are required for the molding of both thin-walled products (1mmt or less) and products with large flow length. In general, lower injection speeds result in products that have less residual stress.

Screw Rotation Speed and Back Pressure

It is recommended that screw rotation speed is between 50 to 100rpm in order to prevent increases in resin temperature due to shear heat generation.
The appropriate back pressure allows for consistent melting of resin. The recommended back pressure is 5 to 10MPa. When molding PES grades that have high molecular weights, ensure that a greater back pressure is applied. However, if back pressure is too high, problems such as resin overheating and overloading may occur.

Temporary Suspension of Molding

Whenever the molding process is suspended for a short period of time, set the cylinder temperature to 250 to 260°C, in order to prevent thermal deterioration of the resin. If the resin temperature decreases to less than 250°C, the screw surfaces and internal walls of the cylinder may be damaged and foreign objects may be caused after the molding process has resumed. When the molding process is to be suspended for a long period of time, reduce the cylinder temperature only after the inside of the cylinder has been purged with purging materials.

Purging Method

Recommended purging materials are as follows : polyethylene that has a high molecular weight of approximately MFR 0.05 ; polycarbonate ; or more preferably, the same materials containing glass fiber.

- As SUMIKAEXCEL PES requires high processing temperatures, smoke, gas emission, and resin blown-off may occur during the purging process.
- Ensure that none of the purging material is left within the cylinder.

Table 4-1-3 Recommended Purging Procedure (When Switching to SUMIKAEXCEL PES)

Item		Recommended Conditions/Procedures
Setup	Back pressure	High (Ensure that the screw retracts slowly.)
	Screw rotation speed	Set the same rotation speed as for when molding the prior resin.
Purging	1. Prior resin discharge	Discharge as much of the prior resin from the hopper and cylinder as possible.
	2. Purging material input	Input purging material while maintaining the prior resin molding temperature, and perform sufficient purging. When using a glass fiber reinforced purging material replace it with a non-reinforced purging material before replacing it with PES so that no glass fibers remain.
	3. Temperature change	Change to the PES molding temperature while continuing to input purging material.
	4. Purging material discharge and PES input	Discharge the purging material thoroughly after reaching the moldingtemperature of PES, and then input the PES.
	5. Molding	After purging with PES, it is possible to perform molding once the cylinder temperature becomes stable.

Checking of Residual Stress

SUMIKAEXCEL PES molded products may suffer from defects such as cracking or breakage during mold release, due to the effects of residual stress.
The following method can be used to check the residual stress of SUMIKAEXCEL PES molded products. This method can also be used for determining optimum molding conditions.

● Test method

1. Allow the molded products to cool to room temperature
2. Immerse the molded products in xylene for 90 seconds
3. Clean it them in cold water
4. Check the molded products carefully for cracks.
5. If there are no cracks, perform the same test in toluene. Thereafter, perform the test in the same manner, changing the solvent to ethyl acetate, then methyl ethyl ketone, in that order.
6. The kind of solvent that caused the cracks can be used to estimate the magnitude of the residual stress in the molded product. (see "Table 4-1-4")

Table 4-1-4 Residual Stress Checking Method for SUMIKAEXCEL PES (4100G)

Solvent	Residual strain	Residual stress
Cracks occurred in xylene	1.3-1.5% or more	30-40MPa or more
Cracks occurred in toluene	1.0% or more	27MPa or more
Cracks occurred in ethyl acetate	0.50% or more	14MPa or more
Cracks occurred in methyl ethyl ketone	0.35% or more	10MPa or more

4-2 Moldability

Flowability

Flowability of SUMIKAEXCEL PES improves greatly as the cylinder temperature, injection pressure, and wall thickness of molded products increase. However, mold temperature does not have a major impact. If mold release failure, glass fiber floating or weld cracking occurs, it is recommended to increase the mold temperature to 160°C or higher.

Apparent Melt Viscosity

The apparent melt viscosity of SUMIKAEXCEL PES is as follows.

Figure 4-2-1 Temperature Dependence of Apparent Melt Viscosity

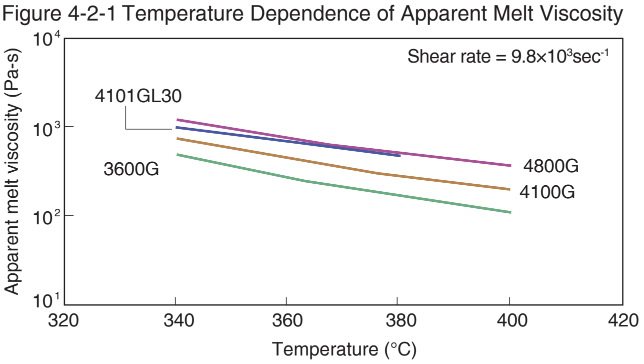
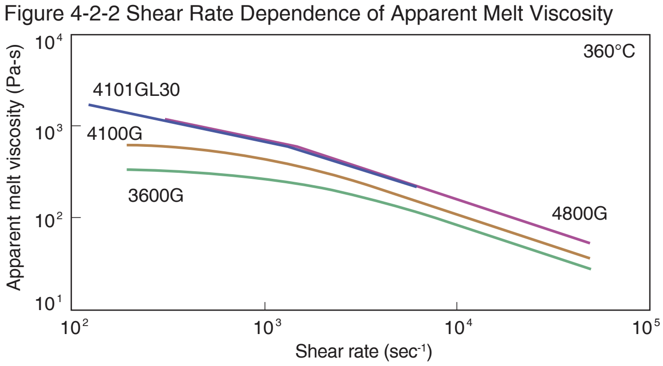


Figure 4-2-2 Shear Rate Dependence of Apparent Melt Viscosity



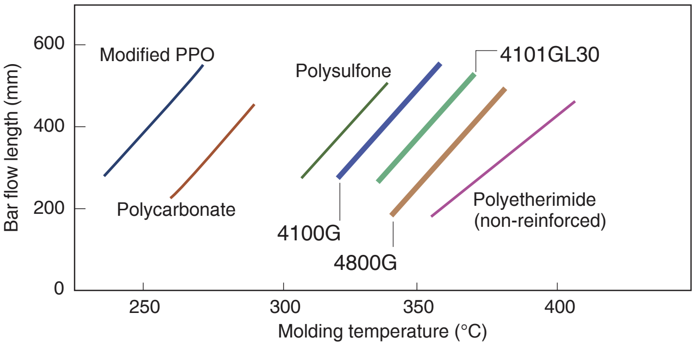
Molding of Relatively Thick-Walled Products

This section focuses on the flow characteristics at a wall thickness of 3mm.

Effect of Cylinder Temperature

When the cylinder temperature increases, the melt viscosity of the resin decreases and the flowability improves. The bar flow length improves by 30 to 60% when it is set 20°C higher.

Figure 4-2-3 Temperature Dependence of Bar Flow Length

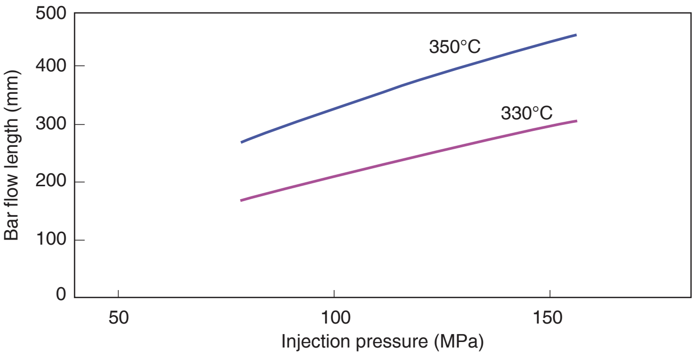


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : medium
Mold : 3mm x 8mmw
Mold temperature : 120°C

Effect of Injection Pressure

The bar flow length improves by 10 to 20% when the injection pressure is set 20 MPa higher. High-pressure molding is generally recommended, but carefully check for mold release defects and residual stress due to overpacking. Select appropriate conditions by setting the secondary pressure.

Figure 4-2-4 Dependence of Bar Flow Length on Injection Pressure (4100G)

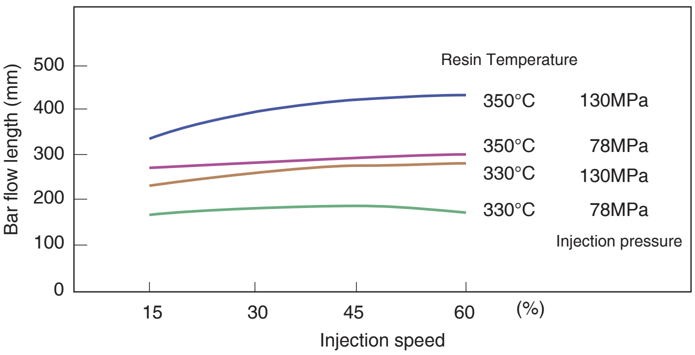


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection speed : medium to high
Resin temperature : 330°C, 350°C
Mold : 3mm x 8mmw
Mold temperature : 120°C

Effect of Injection Speed

Injection speed does not have a significant effect on the bar flow length.

Figure 4-2-5 Dependence of Bar Flow Length on Injection Speed (4100G)

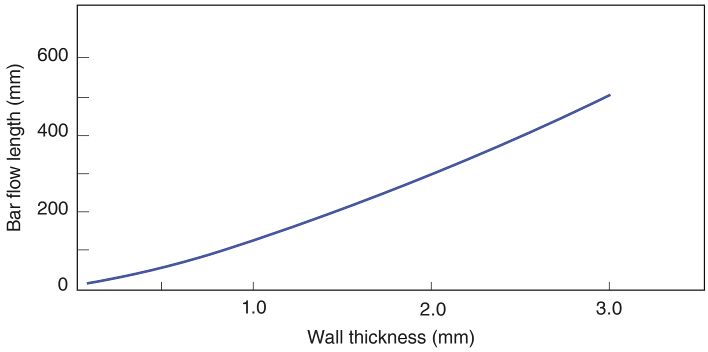


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Mold : 3mm x 8mmw
Mold temperature : 120°C

Effect of Product Wall Thickness

Flow length increases sharply with wall thickness. When the wall thickness is 1.5mm or higher, flowability can be improved 40 to 70% by increasing the wall thickness by 0.5mm.

Figure 4-2-6 Effect of Wall Thickness on Bar Flow Length (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 60%
Resin temperature : 360°C
Mold : 8mmw bar flow
Mold temperature : 120°C

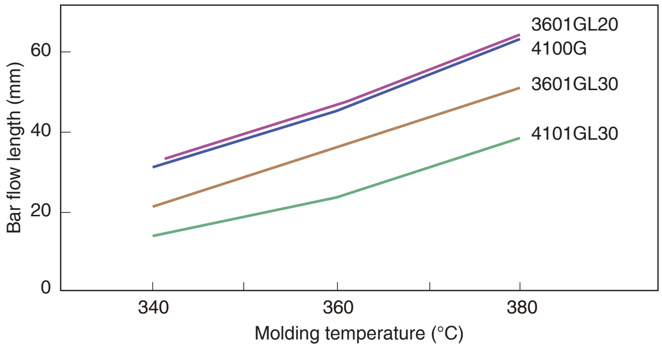
Molding of Thin-Walled Products

This section describes the flow characteristics at wall thickness of 0.1 to 0.7mm.

Effect of Cylinder Temperature

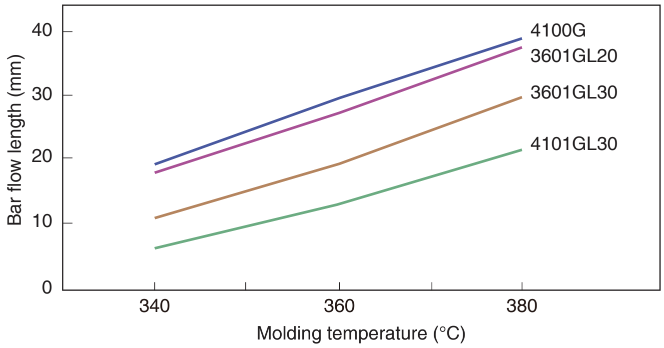
Flowability improves as the cylinder temperature increases, but this effect decreases when the wall thickness is 0.3mm or less. Considering the effects of thermal degradation, a temperature of up to about 380°C is suitable.

Figure 4-2-7 Cylinder Temperature Dependence (Thickness: 0.7mm)



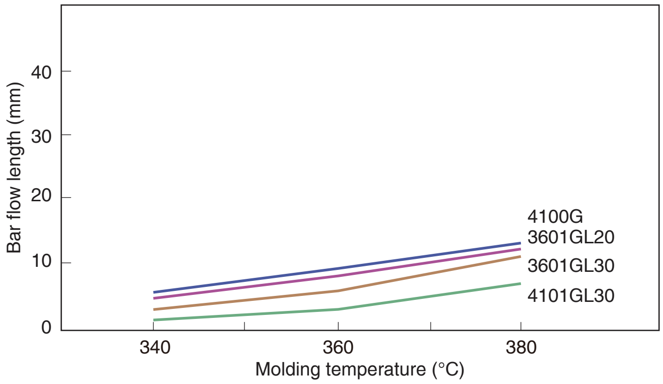
Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Mold : 0.7mmx8mmw
Mold temperature : 140°C

Figure 4-2-8 Cylinder Temperature Dependence (Thickness: 0.5mm)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Mold : 0.5mmx8mmw
Mold temperature : 140°C

Figure 4-2-9 Cylinder Temperature Dependence (Thickness: 0.3mm)

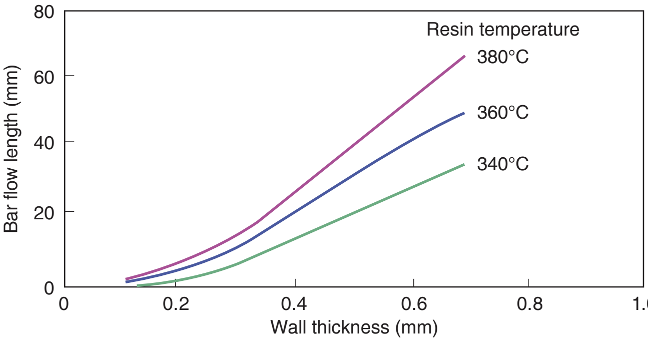


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Mold : 0.3mmx8mmw
Mold temperature : 140°C

Effect of Product Wall Thickness

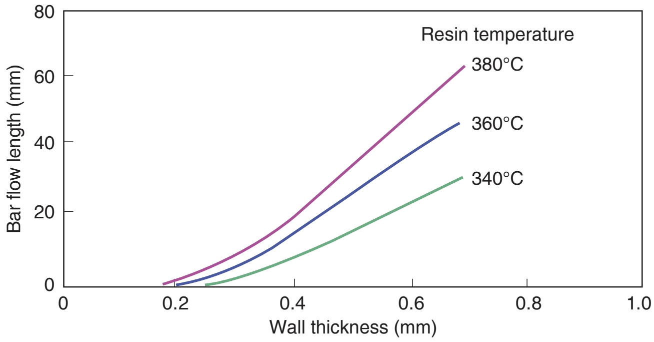
The flowability depends on the wall thickness, so please pay attention to this when designing your product.

Figure 4-2-10 Wall Thickness Dependence (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Bar flow width : 8mm
Mold temperature : 140°C

Figure 4-2-11 Wall Thickness Dependence (3601GL20)

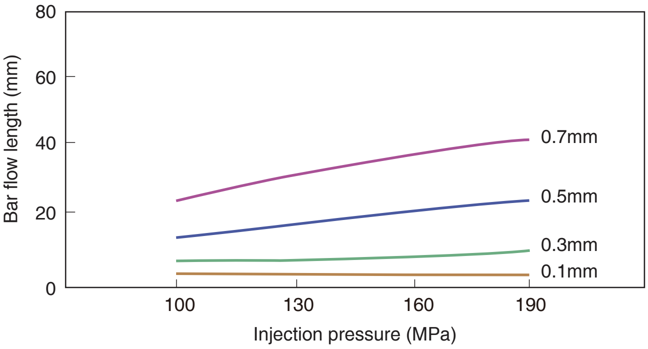


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Bar flow width : 8mm
Mold temperature : 140°C

Effect of Injection Pressure

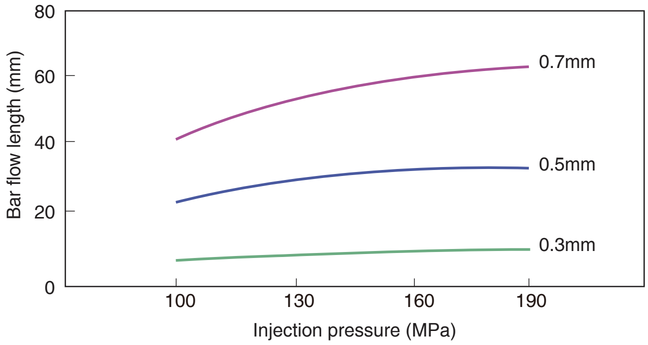
Thin-wall flowability tends to be greatly affected by injection pressure. Injection pressure of at least 100MPa is recommended. However, it is required to determine the proper injection pressure by taking product appearance and residual stress into consideration.

Figure 4-2-12 Injection Pressure Dependence (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection speed : 75%
Resin temperature : 340°C
Bar flow width : 8mm
Mold temperature : 140°C

Figure 4-2-13 Injection Pressure Dependence (3601GL20)

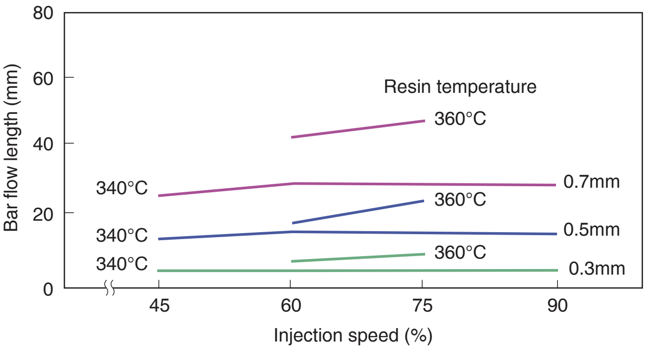


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection speed : 75%
Resin temperature : 340°C
Bar flow width : 8mm
Mold temperature : 140°C

Effect of Injection Speed

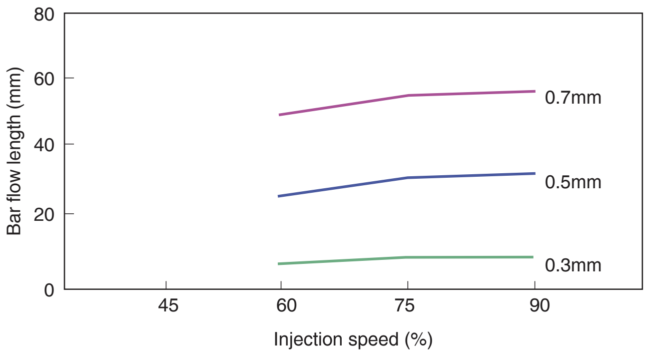
Thin-wall flowability is not affected by injection speed so much. If the injection speed is too high, it may cause defects such as burns.

Figure 4-2-14 Injection Speed Dependence (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Bar flow width : 8mm
Mold temperature : 140°C

Figure 4-2-15 Injection Speed Dependence (3601GL20)

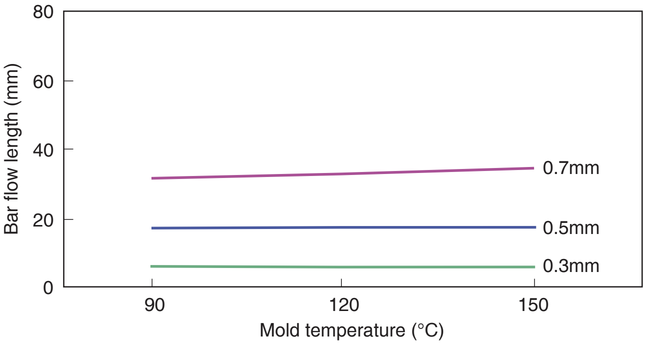


Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Resin temperature : 360°C
Bar flow width : 8mm
Mold temperature : 140°C

Effect of Mold Temperature

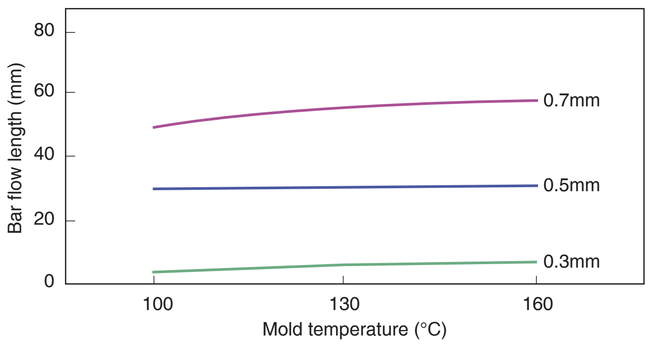
Thin-wall flowability is not affected by mold temperature so much. However, it is recommended to raise the mold temperature to at least 160°C if problems such as sticking in the mold, poor surface appearance, or low weld strength occur.

Figure 4-2-16 Mold Temperature Dependence (4100G)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Resin temperature : 340°C
Bar flow width : 8mm

Figure 4-2-17 Mold Temperature Dependence (3601GL20)



Molding machine : Neomat N47/28 (Sumitomo Heavy Industries, Ltd.)
Injection pressure : 130MPa
Injection speed : 75%
Resin temperature : 340°C
Bar flow width : 8mm

4-3 Injection Molding Machine and Mold Design

Selection of Injection Molding Machine

SUMIKAEXCEL PES can be molded using standard in-line type injection molding machines and plunger (preplasticating) type injection molding machines.

Screw and Cylinder

- Since the filler reinforced grades of SUMIKAEXCEL PES are filled with glass fiber, etc., it is recommended to use wear-resistant materials for screws and cylinders.
- A standard full flight type screw is good for SUMIKAEXCEL PES. Sub-flight screws and high mixing screws are not recommended because the residence time in the cylinder may become longer, or the resin temperature may rise above 400°C due to shear heating.

- A typical screw design suitable for SUMIKAEXCEL PES is as follows.
  - L/D (screw length [L]/screw diameter [D]) : approx. 20
  - Compression ratio : around 2 to 2.2
  - Ratio of each zone :
    Feed zone : around 55%
    Compression zone : around 25%
    Metering zone : around 20%
- Screw heads for in-line type injection molding machines are recommended to be equipped with backflow prevention mechanism.

Nozzle

- For the material of the nozzle, the same as those in "Screw and Cylinder" can be used.
- Use of the open type nozzle is suitable. Shut-off nozzles are not preferable because they have a lot of dead space and resin tends to retain in it.
- For the nozzle heater, it is recommended to use an independent temperature controller with PID control.

Injection Unit and Its Control System

- Due to the high melt viscosity of SUMIKAEXCEL PES, it is recommended that injection molding machines with a maximum injection pressure of 200MPa or higher be used.
- Screw rotation torque during metering tends to be large also due to high melt viscosity, so it is recommended that injection molding machines with high power plasticizing units be used.

Injection Capacity

- It is recommended to select a molding machine whose shot size is about 1/3 to 3/4 of its maximum injection capacity. If the shot size is too small, the residence time of resin in the high temperature cylinder will be longer, and various molding defects are more likely to occur.

Mold Design

As PES has high melt viscosity and low mold shrinkage, the following factors must be taken into account when designing molds.

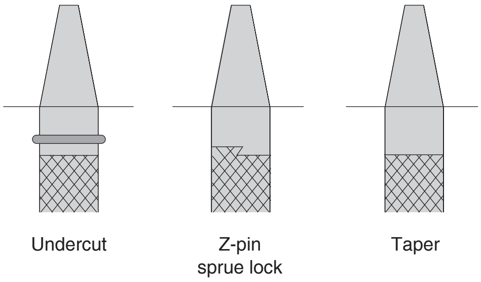
Mold Materials

- Molds used for making prototypes and for small production lots can be composed of carbon alloy steel for machine structural use (S55C). However, these molds should be hardened by quenching if they are to incorporate sliding core parts.
- When mass production and high dimensional precision are required, it is recommended that steels having greater rigidity be used, such as chrome molybdenum steels (SCM435 and SCM440) or alloy tool steels (SKD11 and SKD61).
- Before using a material other than the above, carefully consider whether there are any problems. (Cu alloys, etc., are not recommended as mold materials.)

Sprue

- The length of the sprue should be designed as short as possible, and it is recommended that the taper angle be enlarged (up to 5°).
- A sprue lock should be installed in order to secure better sprue release, as shown in Figure 4-3-1.

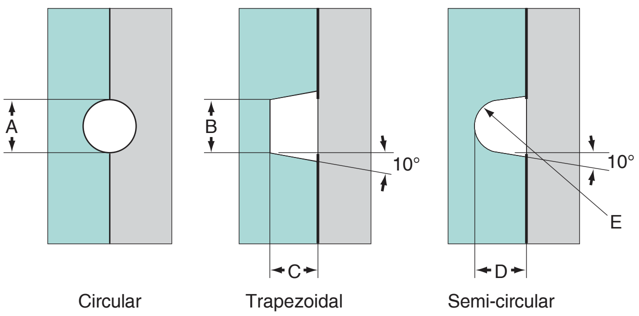
Figure 4-3-1 Sprue Diagram



Runner

- Runners are preferred as thick and short as possible. The thickness and length should be determined with consideration of resin flowability.
- Runners should have a circular or trapezoidal cross-sectional shape.
- Considering the gate balance is also important.

Figure 4-3-2 Runner Cross-Sectional Diagram



Examples of Runner Cross-sectional Sizes (mm)

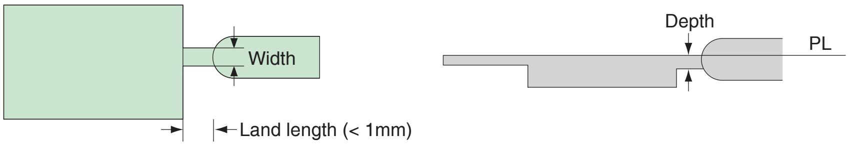
A	B	C	D	E
>4	>3	>3	>4	D/2

Gate system

Side gate

- For rectangular gates, it is most efficient to use deep lands with short lengths. The appropriate land length is 1mm or less, and the land gate depth should be about 70% of the wall thickness of the molded products.

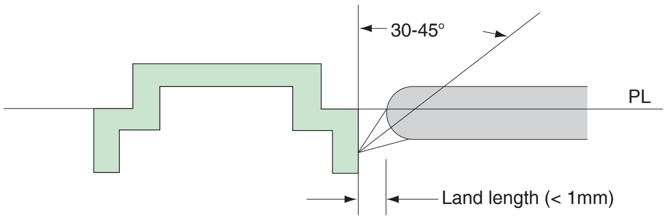
Figure 4-3-3 Side Gate Diagram



Pinpoint/Submarine Gate

- The gate diameter should be between 0.8 to 1.2mm, with land lengths of 1mm or less. If flow length are long, it is preferable to have multi gates rather than to enlarg the gate diameter.

Figure 4-3-4 Pinpoint/Submarine Gate Diagram

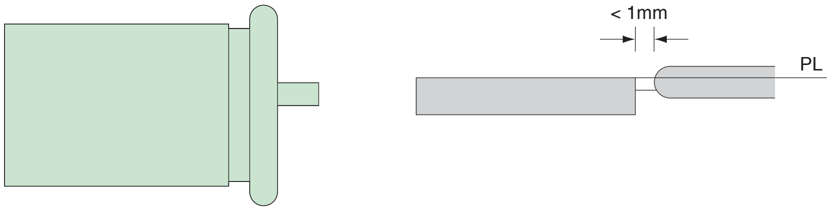


(Example of submarine gate)

Film gate

- The preferred gate depth should be equivalent to "the wall thickness of the moldeding products x 0.5". The land length should be 1mm or less.

Figure 4-3-5 Film Gate Diagram



Draft Angle

- As PES has low mold shrinkage, draft angle should be in the range of at least 1° (1/60) to 2° (1/30). For deeper cavities, a larger draft angle would be recommended.
- As thin-walled products tend to be overfilled, a larger draft angle is recommended.
- Larger draft angles are also recommended for glass fiber reinforced grades.
- If adequate draft angles cannot be utilized due to the shape of the molded products, it may be necessary to install slide cores or devise some good ejection methods.

Air Venting (Gas Drainage)

- The recommended depth for air vents ranges from 0.01 to 0.05mm. SUMIKAEXCEL PES has high melt viscosity, so flash defects will not easily occur even when 0.05mm air vents have been installed.
- Air vents must be installed for the molding of thin-walled products.

4-4 Use of Recycled PES

When mixing recycled PES (re-pelletized or regrind) with virgin pellets, it is necessary to adjust the mixing ratio according to the grade and application. Table 4-4-1 shows the recommended mixing ratios of recycled PES for each grade.

Table 4-4-1 Recommended Mixing Ratios of Recycled PES

Grade	Ratio of recycled PES (%)
4100G / 4800G	30 or less
3601GL20 / 4101GL20	20 or less
3601GL30 / 4101GL30	10 or less

Non-reinforced grades may darken the color of the molded products and become brittle if too much recycled PES are used. For glass fiber reinforced grades, the amount of recycled PES that can be added is limited to smaller quantities because the glass fibers shorten during re-pelletizing or regrinding, which result in a loss of mechanical strength. Table 4-4-2 shows the impacts on mechanical properties when recycled PES is used for SUMIKAEXCEL PES.

Table 4-4-2 Impacts of Using Recycled PES against SUMIKAEXCEL PES on Tensile Properties

Grade		4100G / 4800G				3601GL20 / 4101GL20	
Ratio of recycled PES (%)		30		100		30	100
Property		Tensile strength (MPa)	Mode of break	Tensile strength (MPa)	Mode of break	Tensile strength (MPa)	Tensile strength (MPa)
Number of recycling times	Virgin	86	Ductile	86	Ductile	126	126
	1	87	Ductile	87	Ductile	126	121
	2	89	Ductile	87	Ductile	125	116
	3	88	Ductile	87	Ductile	126	109
	4	88	Ductile	88	Ductile	124	102
	5	89	Ductile	87	Ductile	122	98

5. Secondary Operations

5-1 Adhesives

Commercially available general adhesives (such as epoxy, acrylic, phenol, polyurethane, polyester, and vinyl resin) can be used with SUMIKAEXCEL PES. For recommendations on how to use a particular adhesive, contact the adhesive manufacturer.

Table 5-1-1 Adhesives for SUMIKAEXCEL PES

Type		Name	Manufacturer
Epoxy-based	2-component type	Eccobond 104, 144B	Henkel
	1-component type	Sumimac ECR9000 Series	Sumitomo Bakelite
		Technodyne AH-3063R	Taoka Chemical
Rubber-based		Hamatite PL605-50	Sika Hamatite

Table 5-1-2 Adhesive Strength of Each Adhesive

(Unit : MPa)

Adhesive	Cure conditions	4100G	4101GL30
Eccobond 104	180°C×1hr	5.4	8.8
EccoBond 144B	150°C×1hr	2.0	3.5
Sumimac ECR9000 Series	100°C×1hr	4.6	6.7
Hamatite PL605-50	250-300°C×5min	13.0	-

5-2 Welding

As SUMIKAEXCEL PES is an amorphous resin, a welding is relatively easy to perform if both pieces to be bonded are made of SUMIKAEXCEL PES. Table 5-2-1 shows typical welding methods and features that can be used for welding SUMIKAEXCEL PES. Since features depend on the welding method, it is necessary to consider the size and shape of a product, the characteristics required for the product, and economic efficiency (equipment price, cycle, etc.) when selecting it.

Table 5-2-1 Welding of SUMIKAEXCEL PES

Welding method		Hot plate welding	Ultrasonic welding	Vibration welding	Laser welding	IR welding	CVT (IR+Vibration welding)
Weldability	Welding strength	E*	E	E*	E	G	E
	Appearance of welded area	P	G	G	E	E	E
	Weldable resin	Thermoplastic resin	Thermoplastic resin	Thermoplastic resin	Light transmitting resin Light absorbing resin	Thermoplastic resin	Thermoplastic resin
	Welding time	10-30sec	0.1-5sec	2-10sec	2-15sec	10-30sec	5-30sec
	Weldable size	Heater size-dependent	Business card size	Pallet size	About A3 size	Instrument panel size	Instrument panel size
Design	Product shape restrictions	Limitation on heater shape	Basically flat	Some 3D shape	Highly flexible	Superior to vibration welding	Highly flexible
	Welding area design	Dedicated design	Dedicated design	Dedicated design	Dedicated design	Dedicated design	Dedicated design

* There is a case that it doesn't weld because the softening temperature of PES is high.
E : Excellent, G : Good, P : Possible

5-3 Ultrasonic Welding

As SUMIKAEXCEL PES is an amorphous resin, an ultrasonic welding is relatively easy to perform if both pieces to be bonded are made of SUMIKAEXCEL PES. Three welding combinations are possible:

1. Both pieces are non-reinforced grades
2. A non-reinforced grade is to be bonded to a fiber reinforced grade
3. Both pieces are fiber-reinforced grades

Case 1 is the easiest to accomplish and results in the greatest weld strength. However, cases 2 and 3 have adequate weld strengths and have better weld characteristics than crystalline resins (e.g., PPS).
The conditions for ultrasonic welding will vary depending on the output of the welding horn, the product shape, welding area, and grade. The standard conditions are as follows:

Table 5-3-1 Standard Conditions for Ultrasonic Welding

Pressure (MPa)	30-60
Amplitude (μm)	50-80
Welding time (sec)	0.1-2.0

Measurements of shear strength after ultrasonic welding are shown below. The test method and test pieces used are as follows:

Ultrasonic welder
SONOPET- 1200B (Seidensha Electronic Industry Co., Ltd.)
Nominal output : 1200W
Oscillation frequency : 19.5kHz
Applied pressure : 18N
Amplitude : 34μm

Figure 5-3-1 Test Piece for Shear Strength Measurement of Welded Area

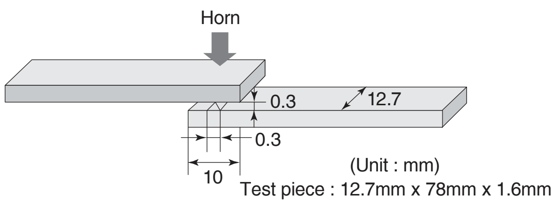


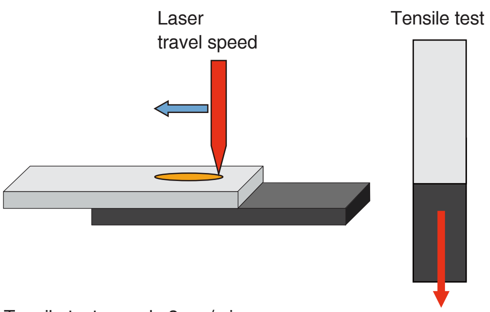
Table 5-3-2 Maximum Load at Fracture of Welded Area (Tensile Shear Test)
(Unit : N)

	Oscillation time (sec)		
	0.1	0.2	0.3
3600G	680	700	Rupture outside the welded area
3601GL20	660	850	Rupture outside the welded area
3601GL30	740	830	Rupture outside the welded area

5-4 Laser Welding

Laser welding is a method where laser light is used to generate heat at the interface with the welding target. When laser welding is used for resin, "light-transmitting resins (thickness 0.5mm)" and "light-absorbing resins (thickness 0.8mm)" are combined. Laser welding is possible with SUMIKAEXCEL PES since it has excellent light transmittance.

Figure 5-4-1 Test Conditions for Laser Welding



Tensile test speed : 2mm/min
Welding strength (MPa) = Maximum strength (N) / Area (mm^2)

Table 5-4-1 Laser Welding Strength

Grade		Laser condition (□0.6)		Welding strength (MPa)
Light transmitting resin (0.5mm think)	Light-absorbing resin (0.8mm thick)	Output (W)	Travel speed (mm/s)	
4100G	4100G B	3	10	30
			15	33
			20	34
3601GL20	3601GL20 B	3	10	38
			15	37
			20	37

6. PES Applications

6-1 Electrical and Electronic Components

SUMIKAEXCEL PES has been used in a variety of electrical and electronic components due to its features such as low outgassing, dimensional stability, creep resistance and resistance to cleaning solvents:

Typical Applications in Electrical and Electronic Components

- Relay base
- Switch base
- Fuse case
- Printed circuit board
- Coil bobbin
- Burn-in socket
- Cases and covers for various sensors
- Movable plate (block of electrodes)
- Connector
- IC Tray

, etc.

Burn-In Socket

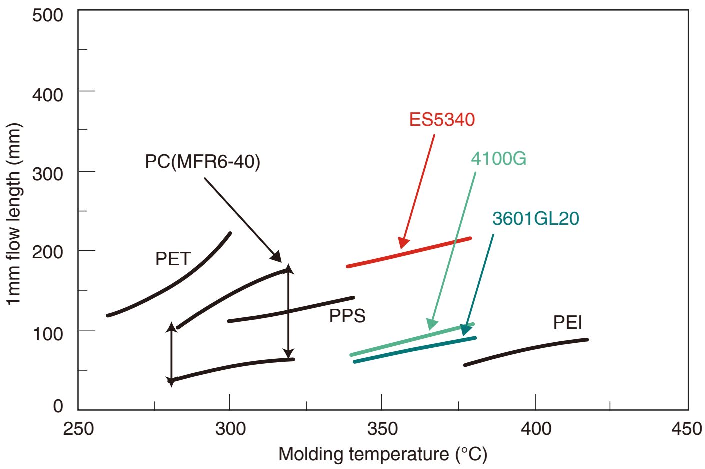
These are sockets used for burn-in tests (tests that accelerate deterioration of electronic device samples by applying temperature and voltage loads to reduce initial defects), and test samples include semiconductors and memory modules. These take advantage of the excellent heat resistance, dimensional accuracy, and dimensional stability of SUMIKAEXCEL PES.

- SUMIKAEXCEL ES5340
  SUMIKAEXCEL ES5340 is an ultra-high flow grade that has improved flowability over 3601GL20.
- SUMIPLOY GS5620
  SUMIPLOY GS5620 is a low-wear, high-strength grade with improved sliding performance.

Table 6-1-1 Grades of SUMIKAEXCEL PES for Burn-in Sockets

Grade		Features
SUMIKAEXCEL	3601GL20	20% Glass fiber reinforced, high flow
	3601GL30	30% Glass fiber reinforced, high flow
	4101GL20	20% Glass fiber reinforced, standard
	4101GL30	30% Glass fiber reinforced, standard
	ES5340	20% Glass fiber reinforced, ultra-high flow
SUMIPLOY	GS5620	30% Glass fiber reinforced, wear-resistant

Figure 6-1-1 Flow Length of 1mm Thickness of SUMIKAEXCEL ES5340



The required performance for burn-in socket materials depends on the application. Please contact us when selecting a grade.

6-2 Automotive and Machinery Parts

Non-reinforced grades are good for parts that require surface smoothness and transparency, and fiber reinforced grades are good for parts requiring higher strength and rigidity. The SUMIPLOY series can be used for parts that require good sliding properties. PES has excellent rigidity over a wide temperature range (-100 to 180°C), dimensional stability, creep resistance at high temperatures, and chemical resistance to gasoline and engine oil. The SUMIPLOY series have also excellent sliding characteristics Typical applications in automotive and machinery parts are as follows.

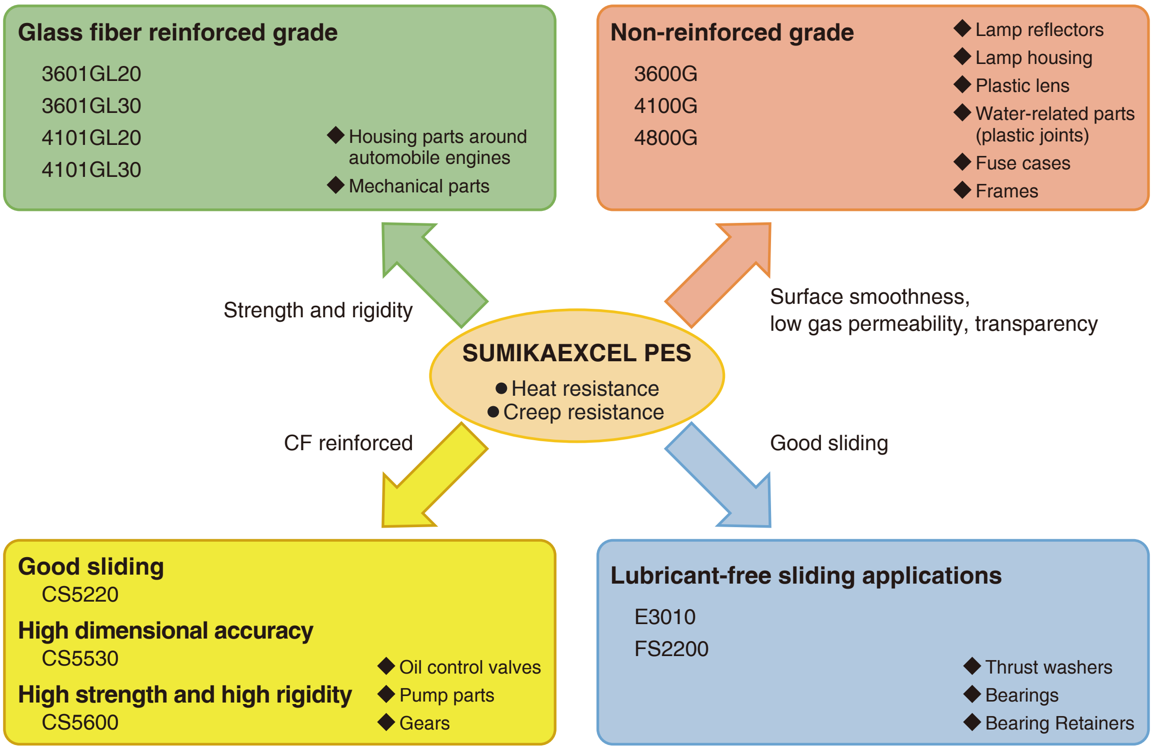
- Automotive lamp components (reflectors, lens holders, etc.)
- Fuse case
- Oil pumps
- Bushings for brake shafts
- Thrust washers
- Sprues for oil control valves
- Gears

, etc.

Application Examples of SUMIKAEXCEL PES in Automotive Parts

SUMIKAEXCEL PES has good heat resistance and excellent dimensional stability, so it can be used for the parts in engine rooms and lamp components. Figure 6-2-1 shows application examples in automotive parts.

Figure 6-2-1 Application Examples of various grades of SUMIKAEXCEL PES in automotive parts



Automotive Lamp Components

SUMIKAEXCEL 4100G has been used for automotive lamp components such as reflectors because of its low outgassing at high temperatures, in addition to its excellent heat resistance and dimensional stability.

Figure 6-2-2 Lamp Reflector

Oil Control Valve

SUMIPLOY CS5530 has the nature of extremely high dimensional stability, and its injection molded products can achieve dimensional accuracy almost equal to that of machined aluminum alloy products. Taking advantage of this property, SUMIPLOY CS5530 is applied to sprues of oil control valves.

Figure 6-2-3 Sprue of Oil Control Valves

6-3 Other Injection Molding Applications

OA/AV Device Components

Taking advantage of its dimensional stability, excellent creep properties, and good sliding properties, PES can be applied in the following applications.

- Various oil-less bearings, guides and gears for copiers and printers
- Optical pickup components , etc.

Applications Exposed to Hot Water (Cooking Utensils, Medical Equipment Applications, etc.)

Taking advantage of its hot water resistance, steam resistance (160°C), dimensional stability, and creep resistance, PES can be applied in the following applications.

- Valve joints for hot water and steam
- Insulating materials for corrosion-resistant electrodes
- Temperature sensor cells
- Hot water pump parts
- Ultrafiltration system parts , etc.

Plastic Substrate for LCD (including Extrusion Processing)

PES films made by injection molding or extrusion processing have excellent transparency (89% total light transmittance), heat resistance, and dimensional stability, and those with ITO (indium tin oxide) thin layer formed by vapor deposition are used as LCD substrates for the following electronic devices.

- Card type calculators
- Pagers
- Electronic organizers , etc.

6-4 Food Contact Applications

SUMIKAEXCEL PES has good heat resistance of about 200°C and has excellent impact resistance and steam resistance, so it is good for steam cookers and for cookwares and tablewares for foods containing fats and oils. Some grades of SUMIKAEXCEL PES comply with the regulations for food contact materials in various countries.

Features

● High heat resistance and cold tolerance

· Cooking is possible at a wide temperature range of -40°C to 200°C.
· Capable of being used in freezers and also of cooking oily foodstuffs.
· Resistant to rapid temperature changes, such as quick freezing and microwave oven heating from frozen.
· Microwave ovens can be used.
· Steam cooking is applicable.

● Thermal conductivity

· With moderate thermal conductivity, heat is transferred to the ingredients evenly during cooking.
· When removed from the heat source, it cools relatively rapidly that allows for quick and safe handling.

● High durability

· Excellent durability allows for long-term use.
· Washing with common detergents and bleaches is possible.
· Use under conditions where metals would corrode is possible.
· Applications where the product is repeatedly exposed to hot water or steam are also possible.

● Safety

· Some grades of SUMIKAEXCEL PES comply with the regulations for food contact materials in the United States, Europe, and Japan.
· Even when heated to high temperatures, there is almost no gas emission or leaching of components.
· Resistant to impact and not easily broken.

● Lightweight

· Lightweight and easy to carry and handle.

● Design

· The original color is light amber, and it is transparent with calm tones.
· Various shapes and designs can be applied due to its good processability. Also, various processing methods can be selected.
· Coloration is possible.

Figure 6-4-1 Examples of PES Injection Molded products in Food Contact Applications

Tableware

Tray (for in-flight meals)

6-5 Application of SUMIPLOY

SUMIPLOY E is a sliding material that is composed mainly of heat-resistant polyethersulfone (PES) and SUMIKASUPER E101, and has the best sliding characteristics among the sliding materials that can be used for injection molding. It does not easily cause scratches to other materials even on soft metals such as SUS or aluminum.
SUMIPLOY S is a sliding material based on PES that has good sliding properties while maintaining the mechanical and thermal properties of PES. Because of its low coefficient of friction and low wear, it is good for applications requiring a certain degree of mechanical strength under relatively mild sliding conditions.
SUMIPLOY K is a sliding material based on polyetheretherketone (PEEK). It provides good sliding properties while maintaining the original excellent chemical resistance, fatigue resistance, radiation resistance, and heat resistance of PEEK. It is good for use under harsh conditions such as high temperatures and high loads.

Grade Selection

Be sure to select multiple types from the table based on the characteristics and conditions required for the intended use, and the general properties and friction and wear property data for each grade. Next, carry out an evaluation test using the actual machine to select the best grade.

Table 6-5-1 Features of SUMIPLOY Grades

Grade			Features
Non-reinforced grade (suitable for soft materials such as aluminum)	SUMIPLOY S series	FS2200	· Has heat resistance of 180°C. · The coefficient of friction and the coefficient of wear are low and stable even in the dry state.
	SUMIPLOY E series	E3010	· No damage to the mating material. · The coefficient of wear is low even in the dry state. · Has a high limiting PV.
Fiber reinforced grades	SUMIPLOY S series	CS5220	· Excellent in dimensional accuracy. · Shows a high limiting PV.
		CS5530	· Very excellent in dimensional accuracy.
		GS5620	· Excellent in dimensional accuracy.
Fiber reinforced grade (suitable for high speed and high load)	SUMIPLOY K series	CK3420	· Low molding shrinkage, low coefficient of linear thermal expansion, and excellent dimensional accuracy. · Shows high limiting PV in the low to high speed range.

Table 6-5-2 Grade Selection Guide for SUMIPLOY

Required characteristics / conditions of use		Non-reinforced sliding grades		Reinforced sliding grade
		E3010	FS2200	CK3420
The mating material is a soft metal (aluminum, SUS, etc.)		E	G	N
The mating material is a metal with high surface hardness		G	G	E
Stable low coefficient of friction and wear-resistant life	For low speed and low load	E	E	N
	For medium speed and medium load	E	P	P
	For high speed and high load	P	N	G
Dimensional stability against humidity		P	P	E
Dimensional stability against temperature (low linear expansion)		P	P	E
Dimensional stability against thermal aging		G	G	P
Load bearing deformation (creep property)		G	G	G
High strength, high rigidity, edge characteristics		P	G	E
Fatigue strength		P	P	E
Impact resistance strength		G	E	G
Operating environment temperature	200 to 250 °C	P	P	E
	-50 to 20 °C	G	G	G
Operating environment atmosphere:	Hot water and steam	G	G	E
	organic solvent	P	P	E
	Acid and alkali	G	G	G
	Radiation	P	P	E
Surface roughness of mating metal	1.5S or more	P	G	E
Molding processability (flowability, etc.)		G	G	P

E : Excellent, G : Good, P : Possible, N : No

Table 6-5-3 Sliding Characteristics of Same and Different Types of SUMIPLOY Resins *48hr

	P=0.2MPa			P=0.5MPa			
	Limiting PV Value	Min. μ	μ-stability	Limiting PV Value	Min. μ	μ-stability	Wear coefficient*
FS2200 - FS2200	100	0.06	E	150	0.08	E-G	9.7×10^{-5}
E3010 - E3010	70	0.11	E	125	0.08	E	1.7×10^{-5}
FS2200 - E3010	80	0.1	E	125	0.09	E	-

E : Excellent, G : Good

Figure 6-5-1 Photograph of a Molding of SUMIPLOY

Applications

- Applications where the use of lubricating oil causes contamination of the product
  Spinning machinery, food processing machinery, ice making machinery, packaging machinery, air compressors, etc.
- Applications used at high or low temperatures (temperatures at which oil and grease deteriorate or solidify)
  Furnace belts, conveyors, bogies, dryers, refrigeration equipment, copiers, and OA equipment, etc.
- Applications for machines that are difficult to lubricate
  Elevators, drainage pumps, and general industrial machinery
- Applications used in dusty areas
  Construction machinery and spinning machinery
- Applications for operation in chemicals
  Chemical pumps, gasoline metering equipment, agitators, and general chemical machinery
- Applications where soundproofing and muffling are important
  Brakes, clutch, and engine area
- Applications where rusting is a problem
  Automobile undercarriage and equipment that uses steam

7. Powder Applications of PES

Features of SUMIKAEXCEL PES Powder

Powder grades of SUMIKAEXCEL PES are suitable for the following applications:

- Adhesives and paint and coating compounds in solvent solutions
- Hollow fiber membranes and cast films (flat films) in solvent solutions
- Compounds and epoxy reinforcing applications

The following powder grades are available.

Table 7-1 SUMIKAEXCEL PES Powder Grades

Powder Grade	RV (reduced viscosity)*	Main applications
3600P	0.36	Compound
4100P	0.41	Paints and coating agents, and adhesives
4800P	0.48	Hollow fiber membranes and adhesives
5003PS	0.50	Paints and coating agents, adhesives, and epoxy strengthening agents
5200P	0.52	Hollow fiber membranes
5900P	0.59	Hollow fiber membranes

The reduced viscosity is measured in a 1% solution of dimethylformamide (DMF).

Table 7-2 Grade Lineup for SUMIKAEXCEL PES

<table>
<tr><td colspan="2">Reduced viscosity</td><td>0.36</td><td>0.41</td><td>0.48</td><td>0.52</td><td>0.59</td></tr>
<tr><td colspan="2" rowspan="2">Powder</td><td>3600P</td><td>4100P</td><td>4800P</td><td>5200P</td><td>5900P</td></tr>
<tr><td></td><td></td><td colspan="2">5003PS*</td><td></td></tr>
<tr><td rowspan="3">Pellet</td><td>Unreinforced</td><td>3600G</td><td>4100G</td><td>4800G</td><td></td><td></td></tr>
<tr><td rowspan="2">Glass fiber reinforced</td><td>3601GL20</td><td>4101GL20</td><td></td><td></td><td></td></tr>
<tr><td>3601GL30</td><td>4101GL30</td><td></td><td></td><td></td></tr>
</table>

* End OH containing grade

Physical Properties of SUMIKAEXCEL Powder Grades

Properties of SUMIKAEXCEL 3600P, 4100P, and 4800P

To obtain the physical properties for the following grades: 3600P, 4100P, and 4800P, please refer to the physical properties for pellet-type grades: 3600G, 4100G, 4800G.

Table 7-3 Physical Properties of 3600G, 4100G and 4800G

		Test method	Unit	3600G/4100G/4800G
General Physical Properties	Density	ISO 1183	g/cm³	1.37
	Mold shrinkage (MD)	Internal	%	0.60
	Mold shrinkage (TD)	Internal	%	0.60
	Water absorption (23°C, 24hr)	ISO 62	%	1.0
Mechanical properties	Tensile strength	ISO 527-1,2	MPa	85
	Tensile yield strain	ISO 527-1,2	%	6.5
	Flexural strength	ISO 178	MPa	130
	Flexural modulus	ISO 178	MPa	2,600
	Izod impact strength (unnotched)	ISO 180/1U	kJ/m²	Does not break
	Izod impact strength (notched)	ISO 180/1A	kJ/m²	8
	Rockwell hardness (M scale)	ISO 2039-2	-	95
Thermal properties	Deflection temperature under load (0.45MPa)	ISO 75	°C	214
	Deflection temperature under load (1.80MPa)	ISO 75	°C	205
	Coefficient of linear thermal expansion (MD)	ISO 11359-1,2	10^{-5}/K	5.5
	Coefficient of linear thermal expansion (TD)	ISO 11359-1,2	10^{-5}/K	5.5
Electrical properties	Relative dielectric constant (dry:100Hz)	IEC 62631-2-1	-	3.5
	Relative dielectric constant (dry:1MHz)	IEC 62631-2-1	-	3.4
	Relative dielectric constant (dry:1GHz)	IEC 60250	-	3.4
	Dielectric dissipation factor (dry:100Hz)	IEC 62631-2-1	-	0.002
	Dielectric dissipation factor (dry:1MHz)	IEC 62631-2-1	-	0.004
	Dielectric dissipation factor (dry:1GHz)	IEC 60250	-	0.004
	Volume resistivity	IEC 62631-3-1	Ω·m	$>10^{13}$
	Dielectric strength (1mm)	IEC 60243-1	kV/mm	43
	Tracking resistance	IEC 60112	V	150
Flammability	Flame retardant rank	IEC 60695-11-10	-	V-0
	Limiting oxygen index (1.6mm)	ASTM D2863	%	38

Properties of SUMIKAEXCEL 5003P and 5003PS

- SUMIKAEXCEL 5003P/5003PS is an amorphous resin that has a glass transition temperature of 230°C.
- Possesses excellent adhesive properties due to the large number of terminal hydroxyl groups, which range from 0.6 to 1.4 per 100 polymer repeating units.
- All other properties are similar to those of other grades of SUMIKAEXCEL PES.

Paint and Coating Applications

SUMIKAEXCEL 4100P and 5003PS grades are utilized as paints and coating agents. The following characteristics have been specially enhanced in the 5003PS grade: hardness after heating, chemical resistance, and adhesion toward metals.
This section describes the paints and coating agents that use SUMIKAEXCEL 5003PS.

Features of Paints and Coating Agents of SUMIKAEXCEL 5003PS

- Stable even after long periods of usage in the air at a temperature of 250°C, and when used under conditions of repetitive heating and cooling cycles (between 0°C and 250°C).
- Adhesive properties and bonding: Demonstrates outstanding adhesion to glass, ceramic, iron, stainless steel, aluminum, and aluminum alloys.
- Solvent resistance: Demonstrates the highest solvent resistance among most amorphous resins.
- Resistance to hydrolysis: Polyethersulfone resin itself has outstanding hydrolysis resistance, yet 5003PS possesses even greater resistance to hydrolysis.
- Film formation properties: Has superior film formation properties and provides effective protection for base materials.
- Flame retardancy: Has high flame retardancy without utilizing any flame retardant components.
- Transparency: Has excellent transparency and does not change the appearance of the base material, even after application.
- Hygienic properties: Does not contain additives, such as plasticizers, thus making it highly hygienic.

Coating Procedures for SUMIKAEXCEL 5003PS (Example of Solution Method)

- Remove all oil and grease from the base material. If necessary, sandblast or etch the surface.
- Dissolve 5003PS in a solvent solution.
- Apply this solution to the base material, using any of the following methods: immersion, brush application, or spraying. Allow to air dry for 20 minutes.
- Heat-treat the material in hot air at a temperature of 350 to 400°C for 30 minutes.

Gelation Prevention

The SUMIKAEXCEL PES solution may become a gel, and it is described as liquid crystal related to both PES molecules and the solvent.

(Features)

- The solution may become cloudy and the whole solution may solidify.
- If a gel is formed, it is difficult to dissolve again even if a solvent is added.
- The gel is the core of the gelation of the ungelatinized solution.
- The gel is the core of the gelation of the ungelatinized solution.
- By applying temperature, it melts and returns to the original solution.

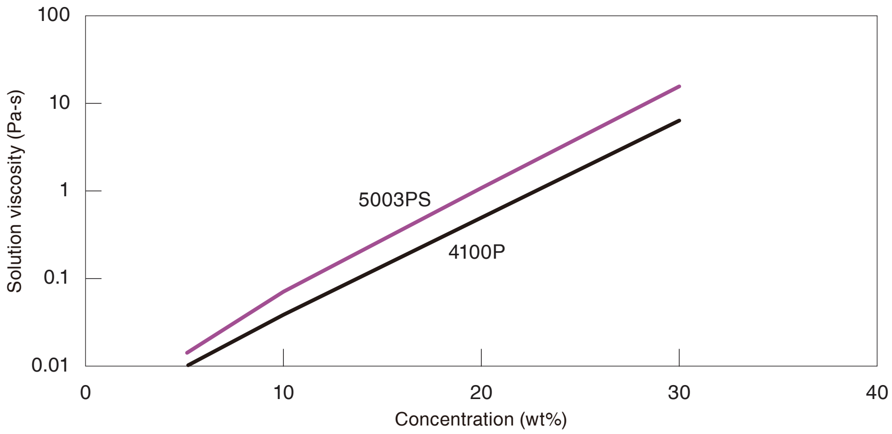
(Gelation prevention)

- Do not apply excessive shear stress. Do not use a homogenizer.
- Do not leave PES in a highly concentrated state for a long period of time. Do not leave swollen PES in unstirred solvent.
- The use of mixed solvents is recommended.

Concentration-Viscosity Correlation

The following figure shows the concentration-viscosity correlation of NMP solutions of SUMIKAEXCEL 4100P and 5003PS.

Figure 7-1 Concentration-Viscosity Correlation of NMP Solutions of SUMIKAEXCEL 4100P and 5003PS



Heat Resistance of SUMIKAEXCEL 5003PS Coating on Aluminum Sheet (Example)

Table 7-4 Heat Resistance Under Continuous Service (in the Air at a Temperature of 250°C)

Evaluation items	Time (hr)		
	0	115	235
Change in appearance	-	No change	No change
Cross-cut Adhesion Test*1	100/100	100/100	100/100
Corrosion Resistance Test*2	No corrosion	No corrosion	No corrosion

Table 7-5 Repetitive Heating and Cooling Cycle Test (2 minutes in ice water at 0°C↔ 2 minutes in oven at 250°C)

Evaluation items	Number of cycles (times)		
	0	25	50
Change in appearance	-	Almost no change	Slight occurrence of foam around edges
Cross-cut Adhesion Test*1	100/100	100/100	100/100
Corrosion Resistance Test*2	No corrosion	No corrosion	No corrosion

(*1) The test procedure for cross-cut adhesion is as follows: Using a safety razor, create a mesh of intersecting cuts (the shape of lines on a checkerboard) into a base material that has been coated with SUMIKAEXCEL 5003PS. The cuts must be deep enough to reach the base material and should be spaced 1mm apart, to form a series of 1mm x 1mm squares, over an area of 100mm2. Place adhesive tape over the area of the cuts and apply pressure, then remove the tape. Check the squares to determine the number of squares that still contain the PES coating.

(*2) The test procedure for corrosion resistance is as follows: Place several drops of a solution containing 15% (vol) nitric acid onto the test surface that has been coated with SUMIKAEXCEL 5003PS. Cover the surface with a glass plate and let it stand for 24 hours. Observe any changes in the surface appearance.

Applications as Impact Modifier for Epoxy Based Systems

SUMIKAEXCEL 5003PS is utilized in the creation of epoxy-based composite materials. The advantages of adding SUMIKAEXCEL 5003PS to epoxy-based composites are as follows:

- Improves the breaking strength of epoxy.
- Has a very high Tg.
- Has excellent mechanical properties(Table 7-8).

Enhancing the Plasticity of Epoxy Resins

SUMIKAEXCEL 5003PS is essentially plastic in behavior, thus has both a high Tg and flexural modulus. Therefore, it has the ability to add plasticity to epoxy resins without degrading the overall performance of the composite itself. The table below indicates a large increase in breaking strength (G1C). It is also apparent that Tg does not decrease significantly.

Table 7-6 Effects When Blended with TGDDM / 4, 4'-DDS

Concentration of 5003PS (%)	Flexural modulus (GPa)	Tg(°C)	G_{1C}(kJ/m^2)
0	3.34	205	0.28
10	3.21	205	0.41
15	3.07	200	0.47

(Note)
1) G_{1C} values were measured under flat surface distortion conditions at -65°C.
2) Tg values were measured using torsion DMA.

Results of Comparing Epoxy Resin and As4CF at a Polymer Concentration of 30% (wt)

Table 7-7 Comparison between SUMIKAEXCEL PES and PEI

Evaluation items	Unit	PEI	5003PS
CAI (Compression after impact)	MPa	194	223
Compressive Strength	MPa		
(Room Temperature)		1697	1731
(82°C)		1434	1648
(82°C)/Wet		N/A	1076
Viscosity at 88°C		130	100

N/A : no data available

Application of SUMIKAEXCEL PES to Aircraft and Sporting Goods Fields

Epoxy thermosetting resins are utilized as the resin matrix in CFRPs (carbon fiber reinforced polymers).
Although epoxy resins possess excellent mechanical and thermal properties, it is more susceptible to fracture than thermoplastic resins. For applications in the area of aircraft and sporting equipment, it is mandatory that its fracture toughness (compression after impact [CAI] strength) is improved. If 5003P is added to epoxy resin, a reaction occurs, which increases the resin's plasticity, toughening it against impact fractures that may cause delamination within the resin matrix.

- Procedures for SUMIKAEXCEL 5003P
  The 5003P is dissolved directly in the epoxy base resin and mixed until a homogeneous solution is obtained. Next, the hardener is mixed into the solution. As the epoxy mixture hardens, it reacts with the hydroxyl radicals in the 5003P, forming a special morphology that contains a "sea island structure" (matrix and discontinuous phase), thus providing improved impact resistance. Either of the two following procedures can be utilized in order to obtain a homogeneous solution of 5003P in epoxy base resin: the 5003P can be ground finely and dissolved directly in the epoxy base resin in an N_2 atmosphere at a temperature of approximately 150°C. Alternately, the 5003P can first be dissolved uniformly in a solvent, then the solvent is later removed. The epoxy base resin is then mixed into this remaining compound to obtain a homogeneous solution.
- Amounts of 5003P for Usage in Composites (Example)
  - Per unit of matrix range
    Epoxy base resin (100 phr) : Hardening agent (30 to 40 phr) : 5003P (30 phr)
  - Per unit of prepreg
    Up to 10wt%
- Usage in Aircraft Structural Composites
  In order to utilize 5003P in structural composites for aircraft, precisely-sized fine particles of 5003P (tough balls), are sprinkled onto the surface of CF prepreg, which has been produced according to the above section entitled "Procedures for SUMIKAEXCEL 5003P". Next, several dozen of these CF prepreg layers are laminated together. This process improves the impact resistance, due to the PES particles that are located on the boundaries of each surface.
  Furthermore, a variety of creative laminating methods have also been invented thus far.

  (Example : structural composite standards for Boeing aircraft)
  - CAI (compression after impact) value must be 310MPa or greater
  - CS (compressive strength under hot/wet conditions) value must be 1,100MPa (at 82°C) or greater.

Adhesive Applications

SUMIKAEXCEL PES can be utilized as a heat resistant adhesive. It possesses particularly outstanding adhesive strength toward metals.

Features

- Bonded surfaces possess high tensile adhesive shear strength and T-peel adhesive strength. Its characteristics are well balanced, as it also possesses both rigidity and flexibility.
- PES possesses the highest heat resistance of most commercial thermoplastic resin adhesives. It possesses an extremely high tensile fracture adhesion strength of 20MPa, even at a temperature of 200°C.
  As well, for short periods of time, it can be utilized repeatedly at temperatures of up to 250°C.
- PES has outstanding chemical resistant and heat resistant properties.
- PES does not contain any solvents or volatile components and demonstrates excellent adhesion toward a variety of materials, including unprimed metals such as aluminum, stainless steel, steel, and brass.

Adhesion Method

- Hot melt type adhesion method using SUMIKAEXCEL PES film
  - Cut the film to the size of the objects being bonded (adherends).
  - Roughen the adherend surfaces using sandpaper or a disc sander, then clean the surfaces with acetone or toluene.
  - Sandwich the film between the adherends, apply a small amount of pressure using a jig, then heat the joint for 10 to 30 minutes at a temperature of 300 to 360°C. An adequate level of pressure will be achieved if the melted resin just begins to ooze out from between the adherends, as flash.
  - A strong bond will be obtained if the joint is left to stand in cold conditions.

- Adhesion method using an adhesive solution
  Solvent Solutions for SUMIKAEXCEL 5003PS
  When 5003PS is dissolved in a single solvent, it is unstable and PES precipitates, so a mixed solvent system is usually used. (Solution stability is low in a single solvent, thus causing gelation.)

Table 7-8 Examples of Mixed Solvent Solutions for SUMIKAEXCEL 5003PS

Solvent	Solvent	Mixing ratio (volume ratio)
A	Dimethylformamide	20
	Cyclohexanone	80
	Methyl ethyl ketone	25
B	N-methyl-2-pyrrolidone	2
	Toluene or xylene	1
C	N-methyl-2-pyrrolidone	60
	Toluene or xylene	30
	Silicon flow modifier	0.5-1
	Methyl ethyl ketone	35
D	Sulfolane	1
	□-butyrolactone	1
E	Sulfolane	1
	Acetone or methyl ethyl ketone	1

Adhesion Method

As the strength of PES adhesives will vary depending on the thermal treatment conditions, it is necessary to determine the appropriate conditions in accordance with each particular application.

(Condition 1) Dry for 2 hours at a temperature of 130°C

(Condition 2) Dry for 1 hour at a temperature of 100°C, then continue drying for 15 minutes at a temperature of 350°C

Properties of SUMIKAEXCEL 5003PS Adhesives

It has excellent adhesive strength at high temperatures. For example, Tables 7-9 and 7-10 show the changes in adhesive strength when the temperature increases to 220°C and the results for the adhesive strength retention rate for aging at 150°C when 18-8 stainless steel is bonded together using a SUMIKAEXCEL 5003PS adhesive.

Table 7-9 Effects of Temperature on Peel Strength

Features	Peel strength (MPa)
23	37
150	26
220	14

The peel strength was measured at a peel speed of 12.5mm/min.

Table 7-10 Effects of High Temperatures on Retention Time and Peel Strength

Retention time at 150°C (hr)	Peeling strength at 150°C (MPa)
0	26
1000	21

Even after being held at 150°C for 1000 hours, 81% of the initial adhesive strength is retained.

Cartridge Filters Utilizing PES Membranes (Courtesy of Toyo Roshi)

This cartridge filter is composed of a polyethersulfone (PES) membrane filter and polypropylene. It possesses superior resistance to both heat and chemicals.

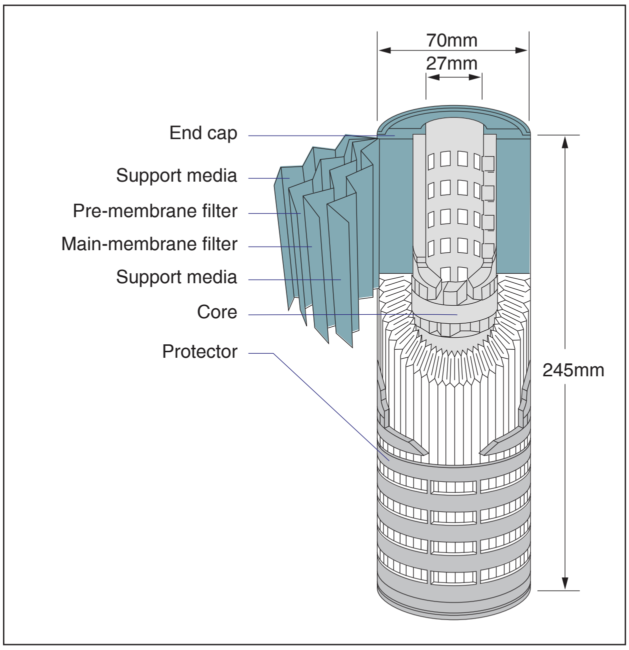
■ Features

- Minimal amounts of eluted substances are produced, thus minimizing the amount of cartridge cleaning required as a pretreatment process.
- As it utilizes asymmetric media and incorporates a pre-membrane filter having a different aperture size, it possesses high filtration efficiency and a high flow rate, thus has a long filtration life.
- Both autoclave sterilization and in-line steam sterilization can be performed.
- As the media itself is inert, sample constituent absorption is very minimal.

■ Applications

- Precision filtration of ultrapure water in the electronics industry
- Particle removal and disinfecting of process gases and vented air

Figure 7-2



8. Approvals

SUMIKAEXCEL PES conforms to many industrial standards and specifications, and has received certifications. The following is a list of the certifications that have been obtained.

Flame retardancy

SUMIKAEXCEL PES conforms to UL94 V-0. UL is a product safety standard established by Underwriters Laboratories Inc. Standard grades are registered in UL746B.

Food Contact Field

U.S.A.

Confirmed that some grades of SUMIKAEXCEL PES meet the requirements set forth in the “FDA 21 CFR § 177.2440” of the food packaging material regulations in the United States.

Europe

Confirmed that some grades of SUMIKAEXCEL PES meet the requirements determined in the “Commission Regulation (EU) No. 10/2011” for food packaging material regulations in Europe.

Japan

Some grades of SUMIKAEXCEL PES contain ingredients on the positive list under Article 18, Paragraph 3 of the Revised Food Sanitation Act and Notification No. 370. Confirmation certificates issued by the Hygienic Olefin And Styrene Plastics Association have been obtained for SUMIKAEXCEL PES 3600P, 4100P, 4800P, 5200P, 5400P, 5900P, 5003PS, 3600G, 4100G, and 4800G. There are grades other than those listed here, so please contact us for the latest acquisition status. The Japan Hygienic Olefin And Styrene Plastics Association was dissolved in March 2021. Their work was taken over by the Food Contact Materials Safety Center. The confirmation certificate remains valid.

Water Contact Field

NSF61 “Drinking Water System Components” has been obtained for some grades of SUMIKAEXCEL PES. For details, please visit the NSF site <https://www.nsf.org/>.

Medical Field

Some grades of SUMIKAEXCEL PES have been tested for ISO 10993 and USP CLASS VI. For more information, please contact us.

TECHNICAL NOTE

Ultra-High Heat Resistant Engineering Plastics

SUMIKAEXCEL™ PES

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