LEONA™

Polyamide resin LEONA™ Handbook

Asahi KASEI

<Polyamide resin> レオナ™ —Contents

LEONA

Contents

<Polyamide resin> レオナ™ LEONA®

General specification about LEONA

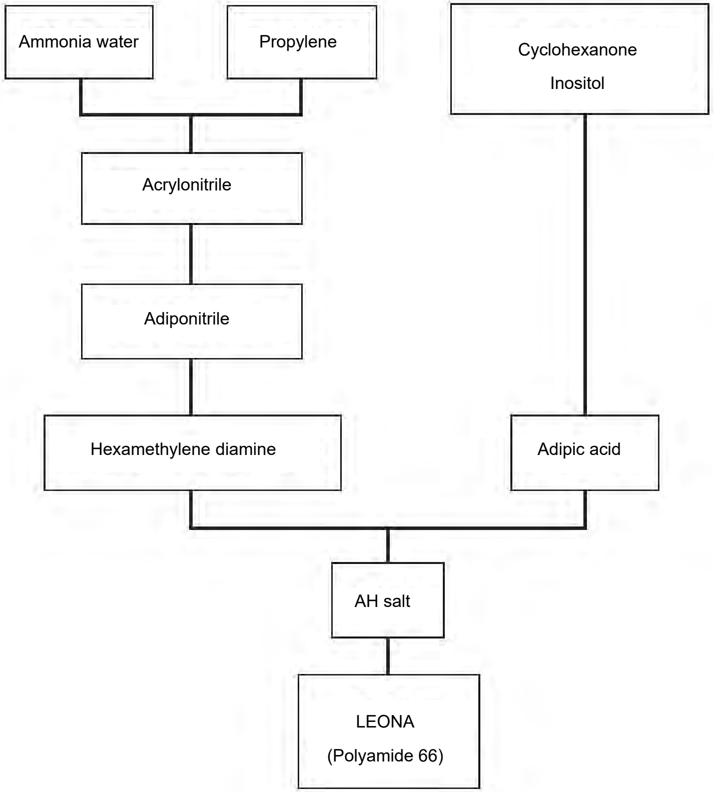
1-1 Definition of LEONA

LEONA is the general term of polyamide resin (polyamide resin, code: PA) manufactured and sold by Asahi Kasei.The polyamide resin is abbreviated to polyamide for convenience in this technical data.

1-2 Manufacturing process of LEONA

LEONA is produced by the company from raw materials to products (resin) through the exclusive technology of the company.Figure 1 is the diagram of the manufacturing process.

Figure-1 LEONA Manufacturing Flow Chart



1-3 Features of LEONA

LEONA has the following features:

(1) Features of LEONA as engineering resin (engineering plastics)

Features of unreinforced LEONA

Advantages	① Good heat resistance ② Excellent and balanced obdurability, durability and electrical characteristics ③ Good oil resistance
Disadvantages	① Relatively poor dimensional stability due to water absorption② Poor acid resistance

Features of glass fiber reinforced LEONA

Advantages	① Outstanding strength and rigidity ② Excellent and balanced heat resistance, obdurability, durability and oil resistance ③ Improved dimensional stability due to smaller water absorption than unreinforced material
Disadvantages	2 Common anisotropy, weld line strength, screw wear in molding processing and other disadvantages of glass fiber reinforced resin

(2) Features of LEONA as engineering resin (Polyamide 66)

Tables 1 and 2 list the features of 5 engineering plastics (polyamide, POM, PC, modified PPO and PBT).

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Table 1: Features of 5 engineering plastics (unreinforced)

Item	Test methods ASTM, UL	Unit	(LEONA) Polyamide 66	PBT	POM	PC	Modified PPO
Melting point	–	℃	265	224	180	–	–
Glass-transition temperature	–	℃	50	22	−56	150	–
Relative density	D 792	–	1.14	1.31	1.42	1.20	1.09
Water absorption (24hr)	D 570	%	1.3	0.08	0.22	0.24	0.07
Tensile strength	D 638	kgf/cm²	830	560	610	630	650
Fracture strain	D 638	%	60	300	60	100	60
Bending strength	D 790	kgf/cm²	1200	870	910	950	800
Flexural modulus	D 790	kgf/cm²	29000	25000	26400	23000	25000
Izod impact strength (notch)	D 256	kgf·cm/cm	4.5	4	6.5	13	27
Rockwell hardness	D 785	–	R120 (M80)	R118 (M75)	M80	M80	R118
Taber wear abrasion test (CS-17)	D1044	mg/10³cycle	6	10	14	13	20
Friction coefficient (against steel)	–	–	–	0.13	0.15	–	0.33
Heat deflection temperature (18.6kgf/cm²)	D 648	℃	70	58	123	135	130
Coefficient of linear expansion	D 696	×10⁻⁵/℃	8.1	9.4	10.0	7.0	6.0
UL long-term heat-resistance temperature (including impact strength)	UL746	℃	105	120	80	110	100
Flame retardance	UL 94	–	V-2	HB	HB	V-2	V-0
Volume resistivity	D 257	Ω·cm	10^{15}	10^{14}	10^{14}	10^{16}	10^{16}
Insulation resistance (dielectric breakdown strength)	D 149	kv/mm	31	17	20	90	16
Dielectric constant (60~10⁶Hz)	D 150	–	4.1~3.4	3.3~3.1	3.7~	3.04~2.98	~2.65
Arc track resistance	D 495	sec	128	190	240	120	75

The data except LEONA is extracted from "Polyamide resin manual (edited and revised by Fukumoto) Nikkan Kogyo Shimbun"

Table 2: Features of 5 engineering plastics (GF reinforced)

Item	Test methods ASTM, UL	Unit	(LEONA) Polyamide 66	PBT	POM	PC	Modified PPO
Melting point	–	℃	265	224	180	–	–
Glass-transition temperature	–	℃	50	22	~56	150	–
Relative density	D 792	–	1.39	1.52	1.61	1.43	1.27
Water absorption (24hr)	D 570	%	1.0	0.07	(0.29)	0.20	0.06
Tensile strength	D 638	kgf/cm²	1900	1400	1280	1250	1200
Fracture strain	D 638	%	6	4	3	4	5
Bending strength	D 790	kgf/cm²	2700	2000	2000	1900	1400
Flexural modulus	D 790	kgf/cm²	91000	90000	77000	78000	77000
Izod impact strength (notch)	D 256	kgf·cm/cm	11	7	8.6	15	12
Rockwell hardness	D 785	–	R120 (M96)	R121	M79	M90	L108
Taber wear abrasion test (CS-17)	D1044	mg/10³cycle	15	25	40	33	35
Friction coefficient (against steel)	–	mg/10³cycle	–	0.15	0.15	–	0.30
Heat deflection temperature (18.6kgf/cm²)	D 648	℃	250	210	163	145	140
Coefficient of linear expansion	D 696	×10⁻⁵/℃	3.3	2.0	6.0	2.7	2.5
UL long-term heat-resistance temperature (with impact)	UL746	℃	125	140	100	–	110
Flame retardance	UL 94	–	HB	HB	HB	V-2	HB~V-1
Volume resistivity	D 257	Ω·cm	10^{15}	10^{14}	10^{14}	10^{16}	10^{16}
Insulation resistance (dielectric breakdown strength)	D 149	kv/mm	33	23	23	60~150	22
Dielectric constant (60~10⁶Hz)	D 150	–	–	–	–	–	–
Arc track resistance	D 495	sec	114	150	130	120	100

Conversion method for S㈵ unit　Pressure: 1kgf/cm2＝0.098MPa　Energy intensity: 1kgf・cm/cm＝9.80J/m

The data except LEONA is extracted from "Polyamide resin manual (edited and revised by Fukumoto) Nikkan Kogyo Shimbun"

(3) Chemical structure and characteristics of polyamide

Table 3: Polyamide Resin

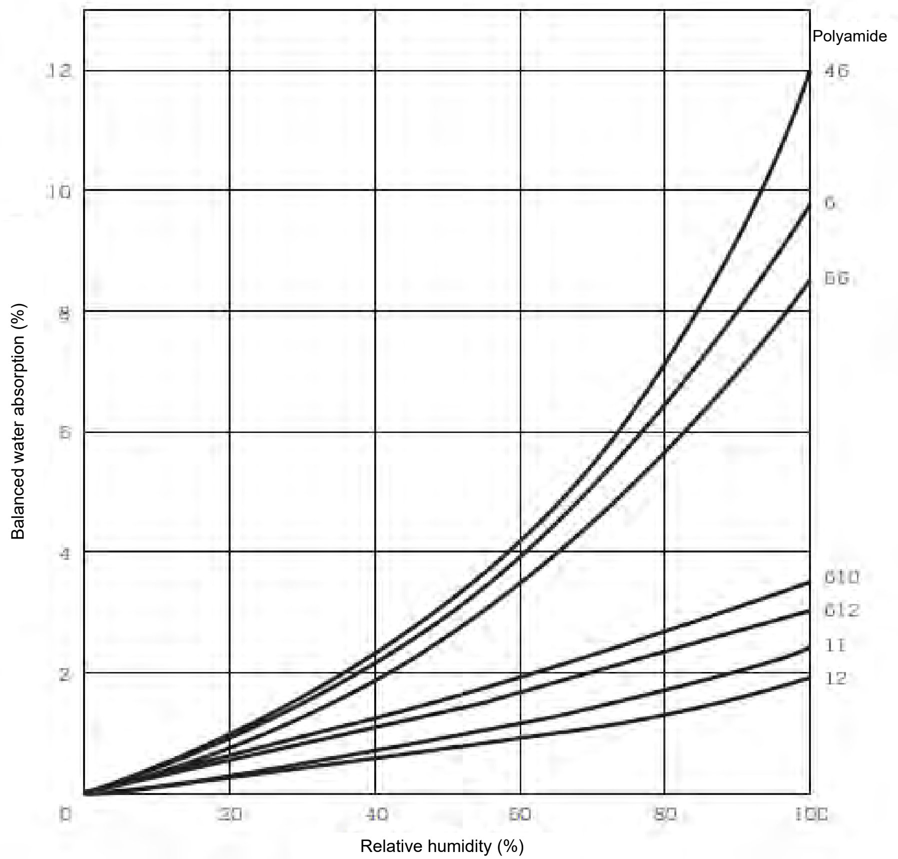
mp: melting point

① Polyamide 6	$-[NH(CH_2)_5CO]_n-$	mp：220℃
② Polyamide 66	$-[NH(CH_2)_6NHCO(CH_2)_4CO]_n-$	mp：265℃
③ Polyamide 6106	$-[NH(CH_2)_6NHCO(CH_2)_8CO]_n-$	mp：215℃
④ Polyamide 612	$-[NH(CH_2)_6NHCO(CH_2)_{10}CO]_n-$	mp：215℃
⑤ Polyamide 11	$-[NH(CH_2)_{10}CO]_n-$	mp：187℃
⑥ Polyamide 12	$-[NH(CH_2)_{11}CO]_n-$	mp：176℃
⑦ Polyamide 46	$-[NH(CH_2)_4NHCO(CH_2)_4CO]_n-$	mp：290℃
⑧ Other	(Aromatic polyamide)	

Tables 4 and 5 list the features.Figure 2 shows the balanced water absorption of polyamide.

Water absorption of polyamide
The chemical structure of polyamide determines its water absorption.In polyamide resins, the polyamide with higher acylamino concentration is easier to absorb water.The water absorption has a certain upper limit.
The status of no longer absorbing water reached by the polyamide resin exposed in the air is called balanced water absorption, the value of which changes with the relative humidity. The constant relative humidity corresponds to constant value (Figure 2).
The water absorption is increased proportionally with the exposure duration and remains unchanged when reaching the balanced water absorption.
After water absorption, the toughness, impact resistance and flexibility of the polyamide are increased, but the strength and dimensional stability are decreased.
"LEONA" products unsealed and placed for long time shall be subject to hot air drying or vacuum drying at about 80℃ and the water absorption shall be reduced to below 0.35% before injection molding.

Figure-2 Balanced Water Absorption of Polyamide (unreinforced type)



(4) Grade and general physical properties of LEONA
LEONA polyamide 66, as the substrate, is added various processing agents and further modified and processed into the modified engineering plastic grades with special features when giving play to its basic features.Table 6 is the list of general grades. Different grades of LEONA have slightly different physical properties.Tables 7~10 list the physical properties.

General specification
Water absorption characteristics
Moisture dependency
Temperature dependency
Evaluation methods
Specifications and acts
Long-term characteristics
When replacing the metal
Product design
Mold for injection molding
Injection molding technology
Fault cases and countermeasures of molding products

General specification about LEONA

Table 4: Features of Representative Polyamide Resin (unreinforced type)

Item	Test methods ASTM, UL	Unit	Polyamide 6	(LEONA) Polyamide 66	Polyamide 11	Polyamide 12	Polyamide 610	Polyamide 46
Melting point	—	℃	220	265	187	176	215	290
Glass-transition temperature	—	℃	50	50	37	50	50	60
Relative density	D 792	—	1.14	1.14	1.04	1.02	1.08	1.18
Water absorption (24hr)	D 570	%	1.8	1.3	0.23	0.21	0.30	—
Tensile strength	D 638	kgf/cm²	740	830	550	500	580	1000
Fracture strain	D 638	%	200	60	330	350	>200	50
Bending strength	D 790	kgf/cm²	1250	1200	690	740	950	1450
Flexural modulus	D 790	kgf/cm²	26000	29000	10000	11000	20000	32000
Izod impact strength (notch)	D 256	kgf・cm/cm	5.6	4.5	4	4~6	5~6	9
Rockwell hardness	D 785	—	R114	R120	R108	R105	R116	R123
Taber wear abrasion test (CS-17)	D1044	mg/10³cycle	6	7	5	5	4	—
Heat deflection temperature (18.6kgf/cm²)	D 648	℃	63	70	50~60	50~60	60	150
Coefficient of linear expansion	D 696	×10⁻⁵/℃	8.5	8.1	9.1	12	12	10
UL long-term heat-resistance temperature (including impact strength)	UL746	℃	105	105	90	—	—	—
Flame retardance	UL 94	—	V-2	V-2	V-2	V-2	HB~V-2	HB
Volume resistivity	D 257	Ω・cm	10^{15}	10^{15}	10^{14}	10^{14}	10^{14}	10^{15}
Insulation resistance (dielectric breakdown strength)	D 149	kv/mm	31	28	17	17	20	—
Dielectric constant (60~10_6Hz)	D 150	—	4.0~3.7	4.1~3.4	3.7 (1kHzWet)	3	3.1	3.5
Arc track resistance	D 495	sec	121	128	123	120	120	—

The data except LEONA is extracted from "Polyamide resin manual (edited and revised by Fukumoto) Nikkan Kogyo Shimbun"

Table 5: Features of Representative Polyamide Resin (glass fiber reinforced type)

Item	Test methods ASTM, UL	Unit	Polyamide 6	(LEONA) Polyamide 66	Polyamide 11 GF30%	Polyamide 610 GF30%	Polyamide 46 GF30%
Melting point	—	℃	220	265	187	215	290
Glass-transition temperature	—	℃	50	50	37	50	60
Relative density	D 792	—	1.36	1.39	1.26	1.32	1.41
Water absorption (24hr)	D 570	%	12	1.0	0.12	0.21	-
Tensile strength	D 638	kgf/cm²	1600	1900	950	1600	2000
Fracture strain	D 638	%	5	6	5	5	15
Bending strength	D 790	kgf/cm²	2400	2700	1460	2300	3100
Flexural modulus	D 790	kgf/cm²	75000	91000	32000	70000	87000
Izod impact strength (notch)	D 256	kgf・cm/cm	11	11	9.5	13	11
Rockwell hardness	D 785	—	R120	R120	R116	R118	R123
Taber wear abrasion test (CS-17)	D1044	mg/10³cycle	(12)	15	—	(10)	-
Heat deflection temperature (18.6kgf/cm²)	D 648	℃	190	250	173	185	285
Coefficient of linear expansion	D 696	×10⁻⁵/℃	2.5	3.3	3.0	2.5	3
UL long-term heat-resistance temperature (including impact strength)	UL746	℃	115	125	115	-	-
Flame retardance	UL 94	—	HB	HB	HB	HB	HB
Volume resistivity	D 257	Ω・cm	10^{15}	10^{15}	10^{14}	10^{14}	10^{15}
Insulation resistance (dielectric breakdown strength)	D 149	kv/mm	60	33	20	30	-
Dielectric constant (60~10_6Hz)	D 150	—	—	4	-	-	3.9
Arc track resistance	D 495	sec	131	114	120	120	-

Conversion method for S特 unit Pressure: 1kgf/cm2＝0.098MPa Energy intensity: 1kgf・cm/cm＝9.80J/m

The data except LEONA is extracted from "Polyamide resin manual (edited and revised by Fukumoto) Nikkan Kogyo Shimbun"

1-4 LEONA grade list

Table-6 ● Unreinforced Grades

Grade	Features	Typical uses
1300S	General grade with balanced liquidity and mechanical properties	Connector and washer
1402S	Grade added heat stabilizer, with good heat aging resistance	Connector and carbon tank
1402SH	Grade added heat stabilizer, with good heat aging resistance Grade improving the hinge characteristics, plasticization and demoulding deformation	Connector and grab handle
1500	Grade improving mechanical characteristics by high polymer quantification	Zipper and gasket
1502(S)	Grade improving mechanical characteristics by high polymer quantification and with excellent heat aging resistance	Automobile engine compartment parts
1700S	Grade improving mechanical characteristics by supra polymer quantification	Extrusion: cylinder and thin film
1702	Grade improving mechanical characteristics by high polymer quantification and with excellent heat aging resistance	Extrusion: cylinder and thin film
9400S	Grade with good impact, suitable for molding products with thick wall	Railway parts and office furniture

● Glass fiber reinforced grades

Grade	Features	Typical uses
13G15 1300G 13G43	Grade improving strength and rigidity by adding glass fiber (15%, 33% and 43%)	Mechanical parts and electrical parts Auto parts (Auto heater water tank, ABS sensor and fuel injection)
13G25 13G50	Grade improving strength, rigidity and durability by adding glass fiber (25% and 50%)	Auto parts
14G15 1402G	Grade improving strength, rigidity and heat aging resistance by adding glass fiber (15% and 33%)	Parts in automobile engine
14G25 14G33 14G43 14G50	Grade improving strength, rigidity, heat aging resistance, fatigue properties and creep properties by adding glass fiber (25%, 33%, 43% and 50%)	Parts in automobile engine (Engine mount bracket) Mechanical parts and electrical parts
53G33	Grade added glass fiber (33%) and with excellent hydrolysis resistance and calcium chloride resistance	Auto parts
54G33 54G43	Grade added glass fiber (33% and 43%) and with high strength, obdurability and good appearance	Fans, railway parts, Office furniture
93G33	Grade further improving the appearance by adding glass fiber (33%)	Office furniture

● Glass fiber reinforced grades

Grade	Features	Typical uses
90G33	Grade improving the strength, rigidity and appearance and optimizing the liquidity by adding glass fiber (33%)	Auto parts
90G50	Grade improving the strength and rigidity and further improving the appearance by adding glass fiber (50%)	Office furniture and mechanical parts
90G55	Grade improving the strength, rigidity weather fastness and appearance by adding glass fiber (55%)	Exterior decoration parts of automobile
90G60	Grade maintaining 90G55 rigidity and optimizing the surface smoothness	Exterior decoration parts of automobile
91G40 91G55 91G60	Grade with high strength, rigidity and good appearance, optimized surface smoothness and low warping by glass fiber and inorganic fillers (40%, 55% and 60%)	Exterior decoration parts of automobile Office furniture Mechanical parts

● Composite special grades

Grade name	Features	Typical uses
CR103	Grade with low abradability, low warping and good heat resistance	Gear and auto parts
CR301	Insulating components with low abradability and good electrical characteristics and suitable for switches	Slide switch insulator
CR302	Grade with low abradability, good electrical characteristics and improved welding resistance characteristics	Slide switch insulator
MR001	Grade added mineral fillers (40%) to improve heat resistance, rigidity, warping and reduce deformation	Sockets
1330G	Grade with low friction, low abrasion and high rigidity and added glass fiber and fluororubber	Various bearings
TR161	Grade with medium impact and added elastomer	Clip and zipper
TR382	Grade with high impact and added elastomer	Carbon tank and wire cable tie
94N05 WG143	Nanocomposite grade (WG143 added glass fiber and nanocomposite)with good rigidity, strength, uniform creep properties, low abradability and good weather fastness of color materials (note: color refers to the color other than white, black and gray)	Residential equipment, building materials and auto parts

● Flame retardant grades

Grade name	Features	Typical uses
FR200	Halogen-free flame retardant, flame retardant rating of UL94V-0 and improved softness and toughness	Electrical and electronic components (Connector and switch)
FR370	General halogen-free flame retardant unreinforced grade with flame retardant rating of UL94V-0	Electrical and electronic components (Connector and switch)
FR650	Halogen-free flame retardant unreinforced grade with flame retardant rating of UL94V-0, meeting IEC60335(GWIT)	Electrical and electronic components (Connector and switch)
FG170	UL94V-0 added glass fiber (15%)	Electrical and electronic components (Connector and switch)
FG172	UL94V-0 added glass fiber (20%)	Electrical and electronic components (Connector and switch)
FG171	UL94V-0 added glass fiber (25%)	Electrical and electronic components (Connector and switch)
FG173	UL94V-0 added glass fiber (30%)	Electrical and electronic components (Connector and switch)
FH772	Halogen-free flame retardant, added glass fiber (25%), flame retardant rating of UL94V-0, good performance in electric leakage resistance	Electrical and electronic components (Connector and switch)
FR250	Unreinforced material with improved oxygen index and good hinge and clip performance	Automotive wiring harness

● Color concentrate

Grade name	Features	Typical uses
LC020	Color concentrate added high-concentration dye for coloring (with various colors)	Diluted by 20~50 times

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Table-7 List of Physical Properties of each Grade Test methods <ISO>

	Test item	Test methods (ISO)	Unit	Grade name	Unreinforced grades: 1300S 1402S	1402SH	1500 1502S	1700S 1702	9400S	Glass fiber reinforced grades: 13G15 14G15	1300G 1402G	13G43	13G25 14G25	14G33	14G43 (Black)	13G50 14G50 (Black)	53G33	54G33
Physical properties	Density	1183	g/cm³	DRY	1.14	1.14	1.14	1.14	1.14	1.25	1.39	1.5	1.32	1.39	1.5	1.58	1.35	1.39
	Balanced water absorption		%	WET	2.5	2.5	2.5	2.5	2.8	2.1	1.7	1.4	1.9	1.7	1.4	1.3	1.1	1.9
Mechanical properties	Tensile yield strength	527	MPa	DRY	82	82	84	84	80	–	–	–	–	–	–	–	–	–
				WET	52	48	51	50	40	77	–	–	116	–	–	–	–	–
	Tensile yield strain	527	%	DRY	4	4.5	4.5	4.5	4	–	–	–	–	–	–	–	–	–
				WET	24	25	26	27	22	6	–	–	5.5	–	–	–	–	–
	Tensile breaking strength	527	MPa	DRY	–	–	–	–	–	107	190	207	190	208	221	237	203	183
				WET	–	–	–	–	–	73	135	150	112	143	160	183	161	113
	Breaking strain	527	%	DRY	–	–	–	–	–	2.5	3	3	4	4	2	2	4	4
				WET	>100	>100	>100	>100	>100	11	5	4.5	9	6	4	4	6	9
	Tensile modulus	527	GPa	DRY	3	3	2.9	3	2.7	5.8	10	12.7	8.2	9.8	14.9	16.9	9.5	9.7
				WET	1.2	1.1	1.0	1.1	0.7	3.6	8	10.2	5.9	7.8	11.5	13	7.5	6.1
	Bending strength	178	MPa	DRY	113	111	110	115	97	162	275	303	275	302	352	371	296	270
				WET	42	38	39	39	30	116	202	225	170	213	261	269	250	165
	Flexural modulus	178	GPa	DRY	2.7	2.6	2.7	2.8	2.3	4.8	9	11.7	7.8	9.6	13.1	13.6	9.7	9
				WET	1.1	0.9	0.9	0.9	0.7	3.3	6.8	8.7	5	6.7	10.6	11	7.8	5.3
	Charpy impact strength	179	Notch/with out notch KJ/m²	DRY	6/NB	6/NB	5/NB	7/NB	7/NB	6/26	11/72	12/84	10/68	13/90	14/NB	14/NB	13/92	12/98
				WET	15/NB	16/NB	30/NB	28/NB	41/NB	5/38	16/83	18/85	14/92	16/97	20/101	21/95	15/92	19/98
	Rockwell hardness	2039	M scale/R scale	DRY	80/120	80/120	80/120	80/120	80/120	94/120	96/120	96/118	96/120	96/120	95/118	95/118	–/118	93/120
				WET	55/108	55/108	55/105	55/105	–	71/–	75/112	80/–	74/–	75/–	80/–	80/–	–/–	68/110
Thermal properties	Coefficient of linear expansion (flow direction)	ASTM D 696	×10⁻⁵/K	DRY	8	8	8	8	–	4	3	3	3	2	2	2	2	3
	Heat deflection temperature	75	℃ 1.8MPa	DRY	70	60	65	70	60	235	250	255	245	250	255	255	208	230
			℃ 0.45MPa	DRY	190	160	195	215	165	260	265	260	260	260	260	260	–	250
Electrical properties	Comparative tracking index	IEC 60112	V	DRY	600 (1300S) 525 (1402S)	525	600 (1500) 525 (1502S)	– –	–	600 (13G15) 425 (14G15)	600 (1300G) 425 (1402G)	600	600 (13G25) 425 (14G25)	425	–	525 –	–	600
Flame retardance	UL (0.75mm)	UL94		DRY	V2	V2	–	–	–	HB	HB	HB	HB	HB	HB	HB	–	HB
	GWFI (3mm)	IEC 60695-2-12	℃	DRY	960	960	–	–	–	–	–	–	–	–	–	–	–	–
Other	Molding shrinkage (3mm) Flow direction/ right-angle direction	(Asahi Kasei method)	%		1.3~2.0	1.3~2.0	1.3~2.0	1.3~2.0	–	0.7/1.2	0.4/0.9	0.3/0.7	0.5/0.9	0.4/0.8	0.4/0.7	0.4/0.7	0.3/0.9	0.4/0.9
	Features				For general injection	Short molding cycle	For HMW extrusion	For UHMW extrusion	For injection molding of products with high molecular weight and thick wall	GF15% reinforced	GF33% reinforced	GF43% reinforced	GF25% reinforced	GF33% reinforced	GF43% reinforced	GF50% reinforced	Calcium chloride resistance	High toughness
	Typical uses				Connector Strand Carbon tank Washer	Connector -Clip	Zipper Sheet	Thin film Cylinder Sheet	Railway parts Office furniture	Mechanical parts, electrical parts and auto parts (micro motor, radiator and gear shift lever parts) Automobile engine compartment parts (auto heater water tank, fuel injection, ABS sensor and engine support)							Auto parts	Fans Railway parts

The above physical values are the representative values measured according to the stipulated test methods and are for reference only when the material is selected according to the product usage.The physical values will be updated in the improvement of material formulas.

1. Water absorption is the equilibrium water content in the atmosphere at 23°C and 50%RH
2. Dry state: just after molding; wet state: balanced water absorption, 23℃, 50%RH
3. The former units are converted according to the following formula.
(The right side in the formula is the former unit and the left side is SI unit)

Specific heat:	1J/(kg·K) = 2.389×10^{-4} cal/(g·℃)
Stress:	1MPa=10.2kgf/cm²
Energy intensity	1J/m=0.102kgf·cm/cm
Thermal conductivity:	1W/(m·K) =0.860kcal/(m·h·℃)

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List of Physical Properties of each Grade Test methods <ISO>

	Test item	Test methods (ISO)	Unit	Grade name	54G43	93G33	90G33	90G50	90G55 (Black)	90G60 (Black)	91G40	91G55	91G60	FR200	FR370	FG170	FG172
					Glass fiber reinforced grades									Flame retardant grades			
Physical properties	Density	1183	g/cm³	DRY	1.5	1.39	1.39	1.58	1.64	1.71	1.46	1.68	1.72	1.16	1.16	1.48	1.52
	Balanced water absorption		%	WET	1.6	1.9	1.4	1.2	1.1	1	1.3	–	1.0	2.4	2.3	1.2	1.1
Mechanical properties	Tensile yield strength	527	MPa	DRY	–	–	–	–	–	–	–	–	–	75	83	–	–
				WET	–	–	–	–	–	–	82	–	–	44	55	–	–
	Tensile yield strain	527	%	DRY	–	–	–	–	–	–	–	–	–	3.5	4.5	–	–
				WET	–	–	–	–	–	–	3.5	–	–	24	22	–	–
	Tensile breaking strength	527	MPa	DRY	200	174	180	250	232	189	125	180	173	69	80	131	136
				WET	131	107	150	200	163	138	78	150	142	–	–	100	107
	Breaking strain	527	%	DRY	4	5.5	2.5	2	2	2	3	3	3	10	15	2.5	2.5
				WET	7.5	9.5	3	3	3	3	6	4	5.4	>100	>50	3.5	3
	Tensile modulus	527	GPa	DRY	12.2	9.4	10.2	18.0	18.6	18.2	7.4	15	17.5	3.5	3.6	7.5	9.1
				WET	7.7	5.3	9.3	17.0	14.8	13.7	5.2	14	16.4	1.1	1.6	5.7	6.6
	Bending strength	178	MPa	DRY	290	233	238	355	394	324	186	250	255	117	124	188	208
				WET	191	150	216	239	269	210	130	220	235	37.2	54.1	146	152
	Flexural modulus	178	GPa	DRY	10.6	7.3	10.0	14.2	15.4	15.8	6.8	14.0	16.4	2.9	3.6	7.5	8
				WET	7	4.8	8.1	12	12.3	12.2	4.9	12.0	15.7	1	1.5	4.7	5
	Charpy impact strength	179	Notch/without notch KJ/m²	DRY	14/99	12/98	6/55	16/88	13/82	11/56	3/39	5/–	6/–	4/NB	4/58	6/44	7/64
				WET	21/109	23/98	12/54	16/84	13/71	15/54	3/56	6/–	6.1/–	11/NB	6/NB	5/45	11/62
	Rockwell hardness	2039	M scale/R scale	DRY	93/118	90/–	90/120	90/120	95/120	95/120	89/120	102/120	95/120	80/118	85/120	95/–	95/–
				WET	–	–	–	–	88/115	88/117	–	–/–	88/117	–/90	55/110	55/–	55/–
Thermal properties	Coefficient of linear expansion (flow direction)	ASTM D 696	$\times 10^{-5}$/k	DRY	–	3	3	2	2	2	3	–	2	8	7	3	3
	Heat deflection temperature	75	℃ 1.8MPa	DRY	230	210	220	225	225	210	183	220	200	62	78	240	240
			℃ 0.45MPa	DRY	245	230	235	240	240	230	220	–	217	203	239	256	256
Electrical properties	Comparative	IEC 60112	V	DRY	600	–	–	–	450	475	–	–	–	600	600	200	250
Flame retardance	UL (0.75mm)	UL94		DRY	HB	HB	HB	HB	HB	HB	–	–	HB	V-0	V-0	V-0	V-0
	GWFI (3mm)	IEC 60695-2-12	℃	DRY	–	–	–	–	–	–	–	–	–	960	960	960	960
Other	Molding shrinkage (3mm) Flow direction/ right-angle direction	(Asahi Kasei method)	%		0.3/0.7	0.3/0.8	0.4/0.9	0.2/0.5	0.2/0.5	0.2/0.5	0.7/0.8	0.2/1.0	0.2/0.6	1.3~2.0	0.9~1.6	0.6/1.0	0.4/0.9
Features					High toughness	Good appearanc	Good appearanc	High rigidity	High rigidity Good appearance Weather fastness	High rigidity Surface smoothness High weather fastness	High rigidity Good appearance Surface smoothness	High rigidity Good appearance Surface smoothness	High rigidity and good appearance Surface smoothness	Halogen-free High toughness	Halogen-free	Halogen GF15%	Halogen GF20%
Typical uses					Fans Railway parts	Office furniture	Auto parts	Residential equipment and building materials	Auto outside parts			Residential equipment and building materials Mechanical parts	Auto Outside parts	Electrical and electronic parts (connector and switch)			

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List of Physical Properties of each Grade Test methods <ISO>

	Test item	Test methods (ISO)	Unit	Grade name	Unreinforced grades FG171	FG173	FH772	FR250	Composite special grades CR103	CR301	CR302	MR001	1330G	TR161	TR382	94N05	WG143
Physical properties	Density	1183	g/cm^3	DRY	1.54	1.65	1.41	1.15	1.45	1.48	1.52	1.52	1.48	1.11	1.08	1.17	1.4
	Balanced water absorption		%	WET	0.8	0.8	1.3	2.8	1.5	1.5	1.4	1.5	1.4	1.9	1.7	2.2	1.9
Mechanical properties	Tensile yield strength	527	MPa	DRY	–	–	–	–	–	–	–	–	–	72	53	88	–
				WET	–	–	–	–	–	–	–	59	–	46	35	58	–
	Tensile yield strain	527	%	DRY	–	–	–	–	–	–	–	–	–	4.5	5.5	4	–
				WET	–	–	–	–	–	–	–	14	–	22	28	20	–
	Tensile breaking strength	527	MPa	DRY	154	174	136	78	131	85	140	93	144	64	45	–	170
				WET	121	137	94	46	100	59	92	58	107	–	–	–	100
	Breaking strain	527	%	DRY	2.5	2	3	11	4	2	2	5.5	4	15	60	–	4
				WET	3	2	5	43	7	11	2.5	19	6	>100	>100	>100	8
	Tensile modulus	527	GPa	DRY	10.2	11.7	9.8	2.9	8.1	7	10	5.9	9.8	2.4	1.9	3.5	10
				WET	8.2	10.5	6.7	0.8	5.2	4.1	7.6	3.4	6.7	1.1	0.7	1.6	5.5
	Bending strength	178	MPa	DRY	244	259	209	105	203	140	197	150	235	88	73	–	250
				WET	180	188	154	41	143	92	148	84	165	38	30	–	150
	Flexural modulus	178	GPa	DRY	9.7	10.3	9.6	2.8	6.7	7.4	9.8	5.8	8.7	2.2	2	3.2	9.6
				WET	7.9	8.7	6.6	1.0	4.2	4.1	7.1	3.1	6	1	0.7	1.5	5.5
	Charpy impact strength	179	Notch/ without notch KJ/m^2	DRY	11/67	11/50	8/58	5/–	4.6/	3/51	4/38	3/62	10/71	15/NB	80/NB	5/–	10/–
				WET	12/67	10/52	10/58	17/–	5.5/	3/90	5/46	3/125	13/78	NB/NB	NB/NB	9/–	16/–
	Rockwell hardness	2039	M scale/R scale	DRY	95/–	100/–	–/–	80/118	94/120	85/–	90/–	85/120	89/120	–/114	–/107	85/120	95/120
				WET	55/–	60/–	–/–	–/90	74/94	–	–	60/108	60/108	–/98	–/89	–	–/–
Thermal properties	Coefficient of linear expansion (flow direction)	ASTM D 696	$\times 10^{-5}/K$	DRY	3	3	3	–	4	4	–	6	3	7	11	–	–
	Heat deflection temperature	75	℃ 1.8MPa	DRY	240	245	241	60	240	188	247	118	246	66	58	75	–
			℃ 0.45MPa	DRY	256	262	258	–	250	249	260	229	261	209	183	255	210
Electrical properties	Comparative tracking index	IEC 60112	V	DRY	275	275	600	–	–	–	–	–	–	–	–	–	–
Flame retardance	UL (0.75mm)	UL94		DRY	V-0	V-0	V-0	–	HB	Equivalent	Equivalent	HB	HB	–	Equivalent	HB	HB
	GWFI (3mm)	IEC 60695-2-12	℃	DRY	960	960	960	–	–	–	–	–	–	–	–	–	–
Other	Molding shrinkage (3mm) Flow direction/ right-angle direction	(Asahi Kasei method)	%	DRY	0.4/0.9	0.3/0.7	0.4/1.2	1.1/1.2	0.5~1.1	0.5~1.3	0.5~1.0	1.0~1.1	0.5/1.0	1.7~2.2	1.7~2.5	1.0~2.0	0.3/0.8
Features					Halogen GF25%	Halogen GF30%	Non-halogen GF25%	High oxygen index	Low abradability	Low abradability	Low abradability Electrical characteristics Soldering resistance	Heat resistance	Low friction and wear	Medium impact	High impact	Nanocomposite	Nanocomposite +GF33%
Typical uses					Electrical and electronic parts (connector and switch)			Auto Harness	Gears	Slide switch Insulator		Sockets	Various bearings	Clip Zipper	Carbon tank Bandage	Auto parts, residential equipment and building materials	

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Table-8 List of Physical Properties of each Grade Test methods <ASTM>

	Test item	Test methods (ASTM)	Unit	Grade name	Unreinforced grades					Glass fiber reinforced grades								
					1300S 1402S	1402SH	1500 1502S	1700S 1702	9400S	13G15 14G15	1300G 1402G	13G43	13G25 14G25	14G33	14G43 (Black)	13G50 14G50 (Black)	53G33	54G33
	Relative density	D792	–	DRY	1.14	1.14	1.14	1.14	1.14	1.25	1.39	1.50	1.32	1.39	1.50	1.58	1.35	1.39
	Water absorption	–	%	WET	2.5	2.5	2.5	2.5	2.8	2.1	1.7	1.4	1.9	1.7	1.4	1.3	1.1	1.9
Mechanical properties	Tensile strength	D638	MPa	DRY	79	79	79	80	79	108	186	196	180	210	230	235	215	181
				WET	57	55	57	59	44	79	132	157	110	135	160	170	170	118
	Breaking strain	D638	%	DRY	50	50	80	100	60	2.5	3	3	3	3	2.5	2.5	3	3
				WET	250	270	270	300	260	8	5	4	6	5	4	4	5	7
	Bending strength	D790	MPa	DRY	118	118	118	118	108	167	289	314	290	325	360	390	309	289
				WET	54	50	54	54	44	108	216	235	175	210	250	280	261	167
	Flexural modulus	D790	GPa	DRY	2.8	2.8	2.8	2.8	2.6	4.9	9.3	11.8	8.1	10.4	13	14.5	8.4	9.1
				WET	1.2	1.0	1.2	1.2	0.8	2.5	6.3	8.3	4.7	6.3	9.5	9.8	6.7	5.0
	Izod impact strength (With notch)	D256	J/m	DRY	39	39	49	49	54	49	127	127	105	130	140	140	135	137
				WET	147	196	176	245	274	59	147	206	160	170	–	190	158	196
	Rockwell hardness	D785	M scale/R scale	DRY	80/120	80/120	80/120	80/120	80/120	94/120	96/120	96/118	96/120	96/120	95/118	95/118	–/118	93/120
				WET	55/108	55/108	55/105	55/105	–	71/–	75/112	80/–	74/–	75/–	80/–	80/–	–/–	68/110
	Taber abrasion test	D1044	$\times 10^{-6}$kg/1000T	WET	7	7	5	4	–	9	15	19	12	15	19	22	–	–
Thermal properties	Coefficient of linear	D696	$\times 10^{-5}$/K	DRY	8	8	8	8	–	4	3	3	3	2	2	2	2	3
	Heat deflection	D648	℃ 1.82MPa	DRY	70	70	70	70	–	240	250	250	250	250	250	250	208	240
			℃ 0.46MPa	DRY	230	230	230	230	190	258	260	260	260	260	260	260	–	250
	Thermal conductivity:		W/(m·K)	DRY	0.2	0.2	0.2	0.2	–	–	0.3	0.4	0.3	0.3	0.4	0.4	0.4	–
	Specific heat		J/(kg·K)	DRY	1670	1670	1670	1670	–	–	1590	–	–	–	–	–	1.3	–
Electrical properties	Dielectric	D 149	KV/mm	DRY	20	20	20	20	20	26	28	30	29	33	–	21	–	31
	Surface resistivity	D 257	Ω	DRY	10^{13}	10^{13}	10^{14}	10^{14}	10^{14}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	–	10^{15}	–	10^{15}
	Volume resistivity	D 257	Ω·cm	DRY	10^{14}	10^{14}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	–	10^{15}	–	10^{15}
Flame retardance	U L (0.75mm)	(UL94)	–	DRY	V2	V2	–	–	–	HB	HB	HB	HB	HB	HB	HB	–	HB
	Oxygen index	D2863	%	DRY	26	26	–	23	–	–	23	–	–	–	–	–	–	–
	Molding shrinkage (3mm) Flow direction/ right-angle direction	(Asahi Kasei method)	%	DRY	1.3~2.0	1.3~2.0	1.3~2.0	1.3~2.0	–	0.7/1.2	0.4/0.9	0.3/0.7	0.5/0.9	0.4/0.8	0.4/0.7	0.4/0.7	0.3/0.9	0.4/0.9
Features					For general injection molding	High cycle hinge characteristics	For HMW extrusion molding	For UHMW extrusion molding	For injection molding of products with high molecular weight and thick wall	GF15% reinforced	GF33% reinforced	GF43% reinforced	GF25% reinforced	GF33% reinforced	GF43% reinforced	GF50% reinforced	Calcium chloride resistance	High toughness and good appearance
Typical uses					Connector, bandage, cylinder and gasket	Connector and grab handle	Zipper and sheet	Thin film Cylinder Sheet	Railway parts Office furniture	Mechanical parts, electrical parts and auto parts (micro motor, radiator and gear shift lever parts) Automobile engine compartment parts (auto heater water tank, fuel injection, ABS sensor and engine support)							Auto parts	Fans Railway parts

The above physical values are the representative values measured according to the stipulated test methods and are for reference only when the material is selected according to the product usage.The physical values will be updated in the improvement of material formulas.

1. Water absorption is the balanced water absorption in the atmosphere at 23°C and 50%RH
2. Dry state: just after molding; wet state: balanced water absorption, 23℃, 50%RH
3. The former units are converted according to the following formula.

Specific heat:	1J/(kg·k)=2.389x10^{-4}cal/(g·℃)
Stress:	1MPa=10.2kgf/cm²
Energy intensity	1J/m=0.102kgf·cm/cm
Thermal conductivity:	1W/(m·k)=0.860kcal/(m·hr·℃)

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List of Physical Properties of each Grade Test methods <ASTM>

	Test item	Test methods (ASTM)	Unit	Grade name	Glass fiber reinforced grades									Flame retardant grades			
					54G43	93G33	90G33	90G50	90G55 (Black)	90G60 (Black)	91G40	91G55	91G60	FR200	FR370	FG170	FG172
	Relative density	D792	–	DRY	1.50	1.39	1.39	1.58	1.64	1.71	1.46	1.68	1.72	1.16	1.16	1.48	1.52
	Water absorption	–	%	WET	1.6	1.9	1.4	1.2	1.1	1.0	1.3	–	1.0	2.4	2.3	1.2	1.1
Mechanical properties	Tensile strength	D638	MPa	DRY	186	167	194	235	221	190	127	191	183	79	83	132	153
				WET	132	108	157	196	181	148	98	159	150	47	58	108	123
	Breaking strain	D638	%	DRY	3	4	3	2.5	2	2	3	4	3.3	25	7	2.5	2.5
				WET	4	9	4	3	3	3	3.5	6	7.6	80	70	2.7	2.7
	Bending strength	D790	MPa	DRY	304	275	294	373	348	300	206	262	267	118	128	191	216
				WET	177	157	245	304	284	234	166	231	246	44	56	152	177
	Flexural modulus	D790	GPa	DRY	11.0	8.6	9.6	15.5	15.7	16.0	6.5	13.9	16.2	2.9	3.3	6.4	7.6
				WET	5.9	4.5	7.6	12.1	12.7	12.9	5.6	11.9	15.5	1.1	1.3	4.9	5.9
	Izod impact strength (With notch)	D256	J/m	DRY	147	132	98	127	110	95	30	54	63	29	29	49	75
				WET	226	240	118	133	118	100	35	63	64	118	98	59	92
	Rockwell hardness	D785	M scale/R scale	DRY	93/118	90/–	90/120	90/120	95/120	95/120	89/120	102/120	95/120	80/118	85/120	95/–	95/–
				WET	–	–	–	–	88/115	88/117	–	–/–	88/117	–/90	55/110	55/–	55/–
	Taber abrasion test	D1044	$\times 10^{-6}$ kg/1000T	WET	–	–	–	–	–	–	–	–	–	8	7	24	24
Thermal properties	Coefficient of linear expansion (flow direction)	D696	$\times 10^{-5}$/K	DRY	–	3	3	2	2	2	3	–	2	8	7	3	3
	Heat deflection temperature	D648	℃ 1.82MPa	DRY	240	210	220	225	225	225	220	–	–	66	80	248	248
			℃ 0.46MPa	DRY	250	–	–	–	–	–	–	–	–	209	240	255	255
	Thermal conductivity:		W/(m・K)	DRY	–	–	–	–	0.3	0.3	–	–	–	0.2	–	–	–
	Specific heat		J/(kg・K)	DRY	–	–	–	–	1930	1840	–	–	–	1670	–	–	–
Electrical properties	Dielectric	D 149	KV/mm	DRY	32	–	–	–	28	28	–	–	–	19	22	27	28
	Surface resistivity	D 257	Ω	DRY	10^{15}	–	–	–	10^{13}	10^{13}	–	–	–	10^{13}	10^{13}	10^{14}	10^{14}
	Volume resistivity	D 257	Ω・cm	DRY	10^{15}	–	–	–	–	–	–	–	–	10^{14}	10^{14}	10^{15}	10^{15}
Flame retardance	UL (0.75mm)	(UL94)	–	DRY	HB	HB	HB	HB	–	–	–	–	HB	V0	V0	V0	V0
	Oxygen index	D2863	%	DRY	–	–	–	–	–	–	–	–	–	32	36	38	37
	Molding shrinkage (3mm) Flow direction/ right-angle direction	(Asahi Kasei method)	%	DRY	0.3/0.7	0.3/0.8	0.4/0.9	0.2/0.5	0.2/0.5	0.2/0.5	0.7/0.8	0.2/1.0	0.2/0.6	1.3~2.0	0.9~1.6	0.6/1.0	0.4/0.9
Features					High toughness and good appearance	Good appearance	Good appearance	High rigidity Good appearance	High rigidity Good appearance Weather fastness	High rigidity Surface smoothness High weather fastness	High rigidity Good appearance Surface smoothness	High rigidity Good appearance Surface smoothness	High rigidity, good appearance and surface smoothness High weather fastness	Halogen-free and high toughness	Halogen-free	Halogen GF15%	Halogen GF20%
Typical uses					Fans and railway parts	Office furniture	Auto parts	Residential equipment, building materials and mechanical parts	Auto outside parts			Residential equipment, building materials and mechanical parts	Auto Outside parts	Electrical and electronic parts (connector and switch)			

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List of Physical Properties of each Grade Test methods <ASTM>

	Test item	Test methods (ASTM)	Unit	Grade name	Flame retardant grades				Composite special grades								
					FG171	FG173	FH772	FR250	CR103	CR301	CR302	MR001	1330G	TR161	TR382	94N05	WG143
	Relative density	D792	–	DRY	1.54	1.65	1.41	1.15	1.45	1.48	1.52	1.52	1.48	1.11	1.08	1.17	1.4
	Water absorption	–	%	WET	0.8	0.6	1.3	2.8	1.0	1.5	1.4	1.5	1.4	1.9	1.7	2.2	1.9
Mechanical properties	Tensile strength	D638	MPa	DRY	162	167	150	82	139	88	128	98	157	70	54	80	179
				WET	127	142	–	48	106	64	98	67	118	47	37	57	106
	Breaking strain	D638	%	DRY	2.5	2.5	2.3	17	6	3	3	6	3	20	70	14	6
				WET	3.5	3.5	–	85	9	3.5	3.5	7	3	220	220	>100	10
	Bending strength	D790	MPa	DRY	256	250	220	112	213	147	191	157	245	98	79	127	262
				WET	190	221	–	46	151	93	157	98	177	49	39	59	159
	Flexural modulus	D790	GPa	DRY	8.9	10.8	9.3	2.8	6.6	5.9	8.8	5.6	8.0	2.5	2.0	3.3	9.5
				WET	7.2	8.3	–	1.0	4.2	2.9	5.8	3.3	6.3	1.4	1.0	1.8	5.4
	Izod impact strength (With notch)	D256	J/m	DRY	92	88	75	45	51	34	36	34	98	167	1110	40	102
				WET	110	98	–	180	59	39	39	39	118	1200	1320	50	169
	Rockwell hardness	D785	M scale/R scale	DRY	95/–	100/–	–/–	80/118	94/120	85/–	90/–	85/120	89/120	–/114	–/107	85/120	95/120
				WET	55/–	60/–	–/–	–/90	74/94	–	–	60/108	60/108	–/98	–/89	–	–/–
	Taber abrasion test	D1044	$\times 10^{-6}$kg/1000T	WET	–	29	–	–	–	8	–	22	9	7	6	–	–
Thermal properties	Coefficient of linear expansion (flow direction)	D696	$\times 10^{-5}$/K	DRY	3	3	3	8	4	4	–	6	3	7	11	–	–
	Heat deflection temperature	D648	℃ 1.82MPa	DRY	250	252	248	65	–	191	245	160	248	77	73	80	–
			℃ 0.46MPa	DRY	255	260	–	201	–	250	250	240	260	225	215	253	–
	Thermal conductivity:		W/(m•K)	DRY	–	–	–	–	–	–	–	–	–	–	–	–	–
	Specific heat		J/(kg•K)	DRY	–	–	–	–	–	–	–	–	–	–	–	–	–
Electrical properties	Dielectric breakdown strength	D 149	KV/mm	DRY	28	28	–	–	–	–	–	22	–	–	–	–	–
	Surface resistivity	D 257	Ω	DRY	10^{14}	10^{14}	–	–	–	–	–	10^{13}	–	–	–	–	–
	Volume resistivity	D 257	Ω・cm	DRY	10^{15}	10^{15}	–	–	–	–	–	10^{14}	–	–	–	–	–
Flame retardance	UL (0.75mm)	(UL94)	–	DRY	V0	V0	V0	–	HB	Equivalent to HB	Equivalent to HB	HB	HB	–	Equivalent to HB	HB	HB
	Oxygen index	D2863	%	DRY	–	–	–	28	–	–	–	–	–	–	–	28	–
	Molding shrinkage (3mm) Flow direction/ right-angle direction	(Asahi Kasei method)	%	DRY	0.4/0.9	0.3/0.7	0.4/1.2	1.1/1.2	0.5~1.1	0.5~1.3	0.5~1.0	1.0~1.1	0.5/1.0	1.7~2.2	1.7~2.5	1.0~2.0	0.3/0.8
	Features				Halogen GF25%	Halogen GF30%	Non-halogen GF25%	High oxygen index	Low abradability	Low abradability	Low abradability Electrical characteristics Soldering resistance	Heat resistance	Low friction and wear	Medium impact	High impact	Nanocomposite	Nanocomposite +GF33%
	Typical uses				Electrical and electronic parts (connector and switch)			Auto parts	Gears	Slide switch Insulator		Sockets	Various bearings	Clip and zipper	Carbon tank Strand	Auto parts Residential equipment and building materials	

2-1 Balanced water absorption

LEONA has the specific water absorption of polyamide.
Figures 3-5 show the balanced water absorption of 1300S, 1300G and FR370.

Figure-3 Balanced Water Absorption of 1300S

(Slab with 3mm thick at 23℃)

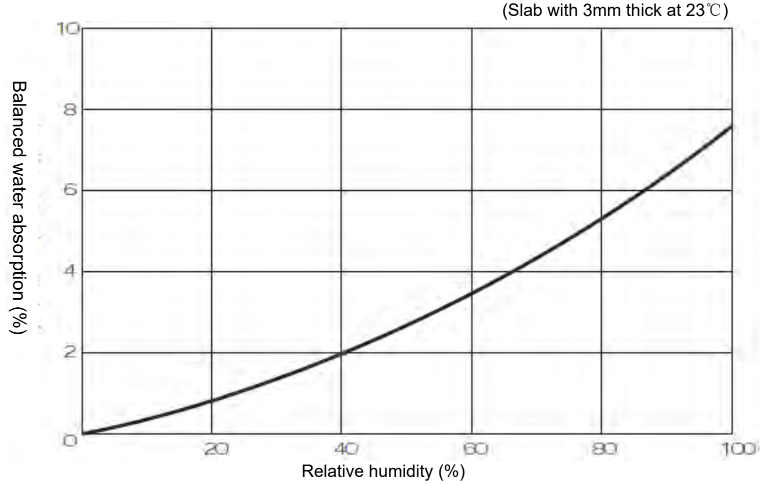


Figure-4 Balanced Water Absorption of 1300G

(Slab with 3mm thick at 23℃)

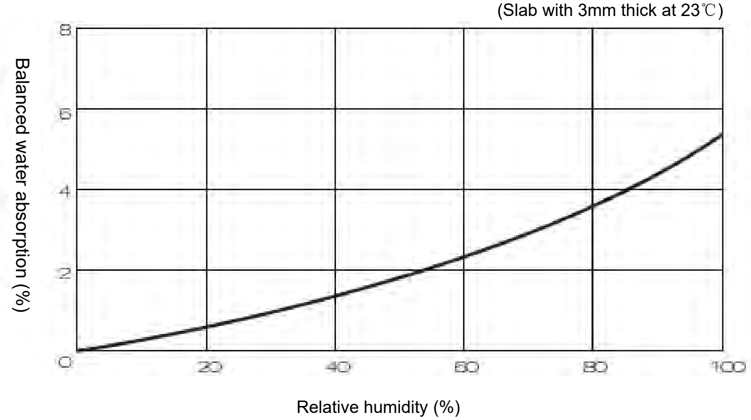
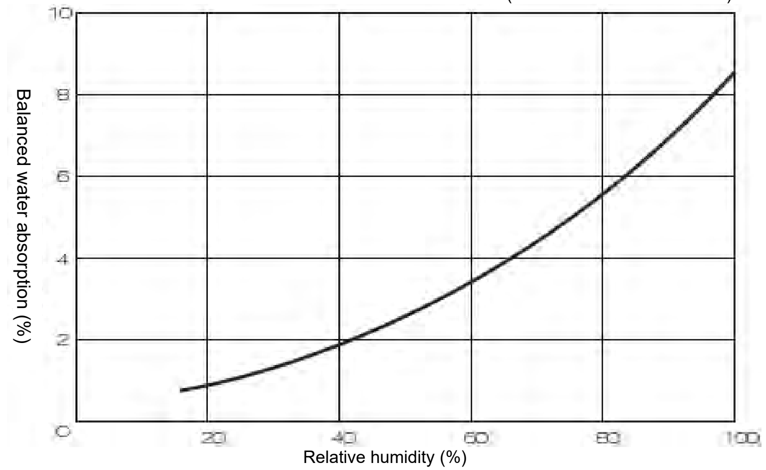


Figure-5 Balanced Water Absorption of FR70

(Slab with 3mm thick at 23℃)



2-2 Humidifying conditions (in the water)

Figures 6~16 show the relationship between the humidifying conditions of LEONA in water (time, water temperature and test piece thickness) and water absorption.

Figure-6 Humidifying conditions and water absorption (in boiling water at ordinary pressure)

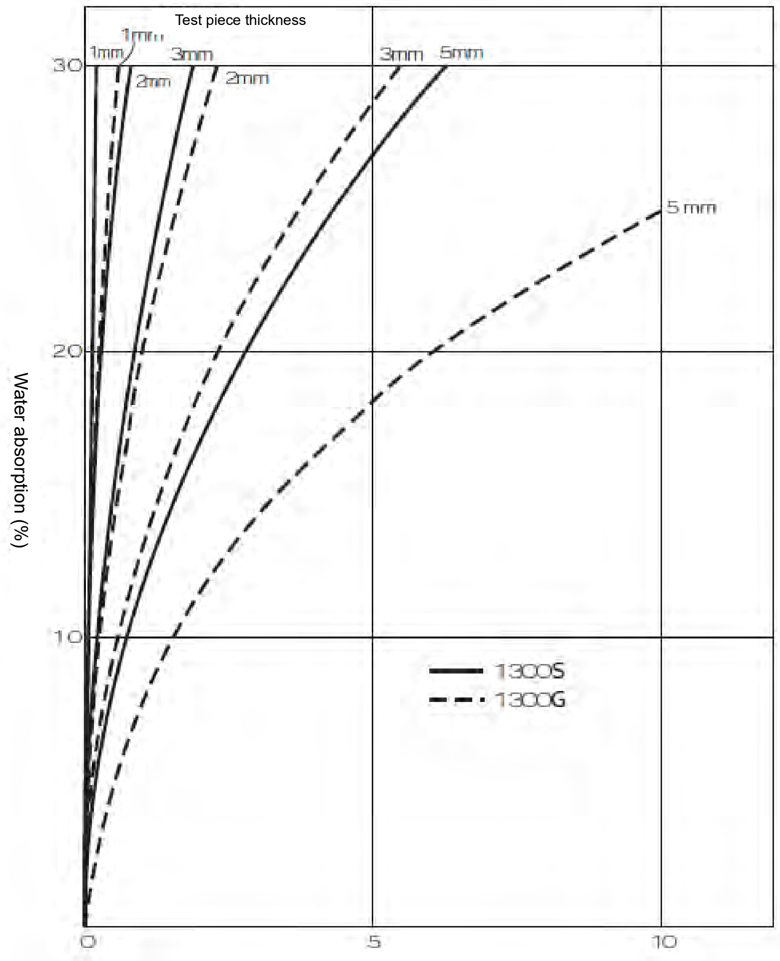


Figure-7 Humidifying conditions and water absorption (in boiling water at ordinary pressure)

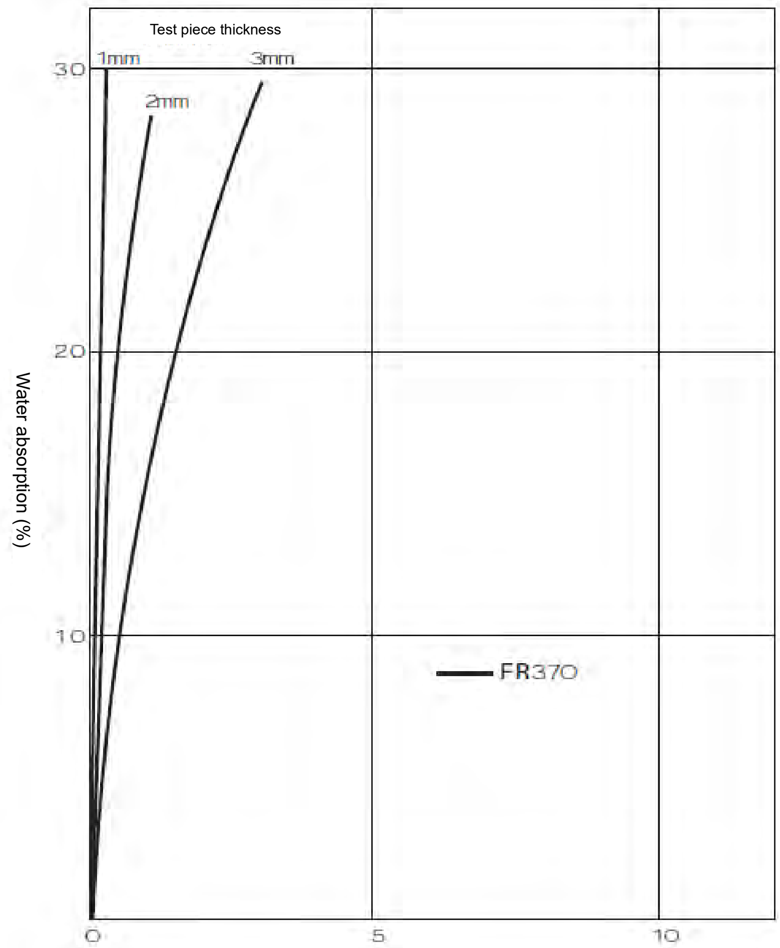


Figure-8 Humidifying conditions and water absorption (in 80℃ water)

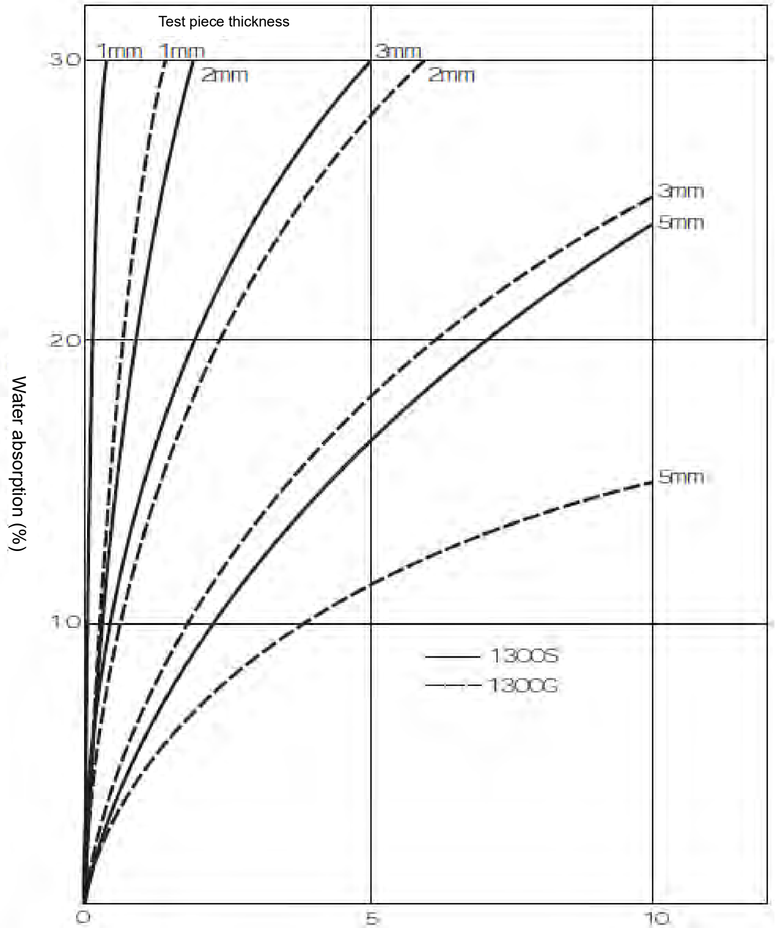
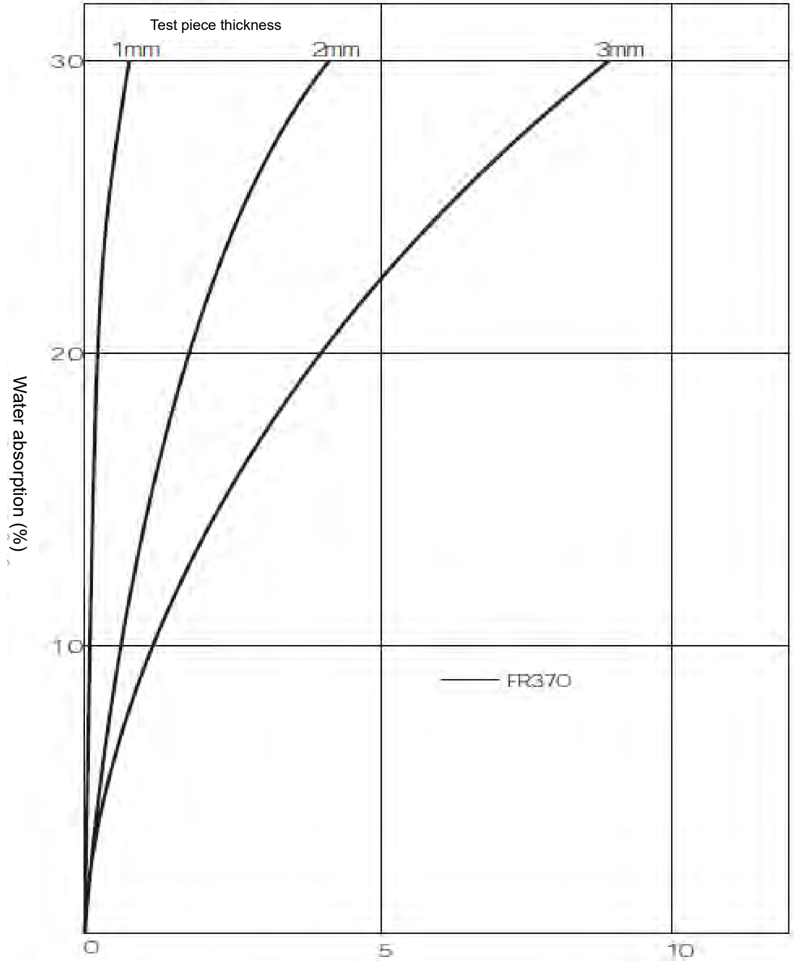


Figure-9 Humidifying conditions and water absorption (in 80℃ water)



LEONA water absorption

Figure-10 Humidifying conditions and water absorption (in 50℃ water)

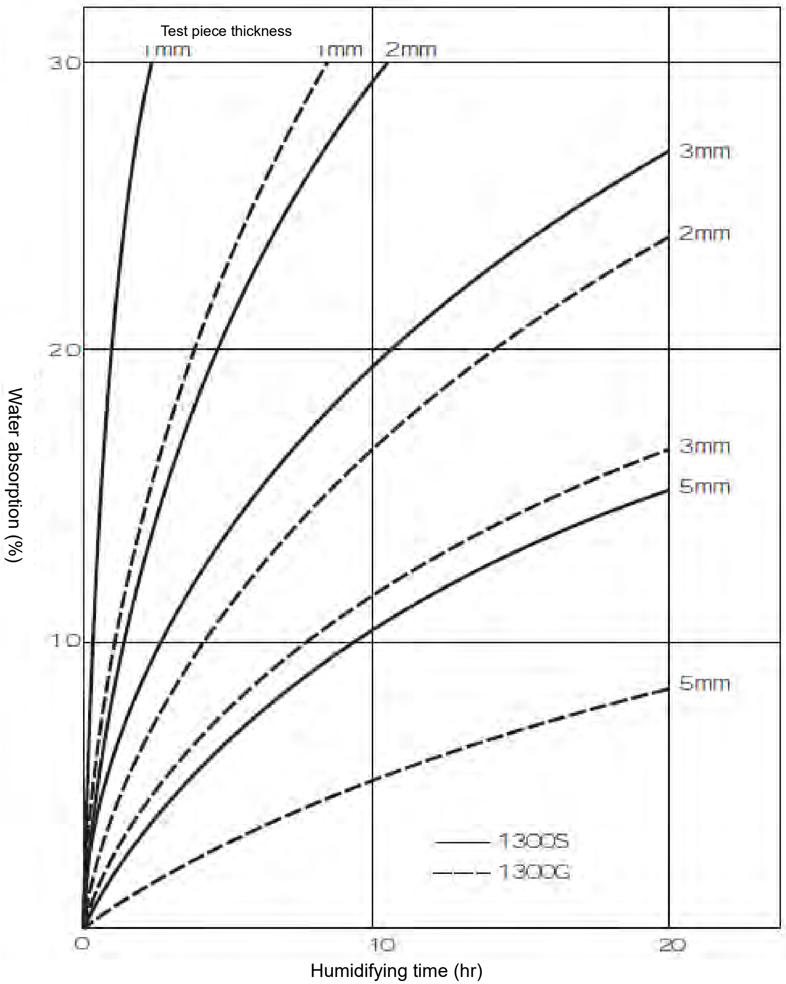


Figure-11 Humidifying conditions and water absorption (in 60℃ water)

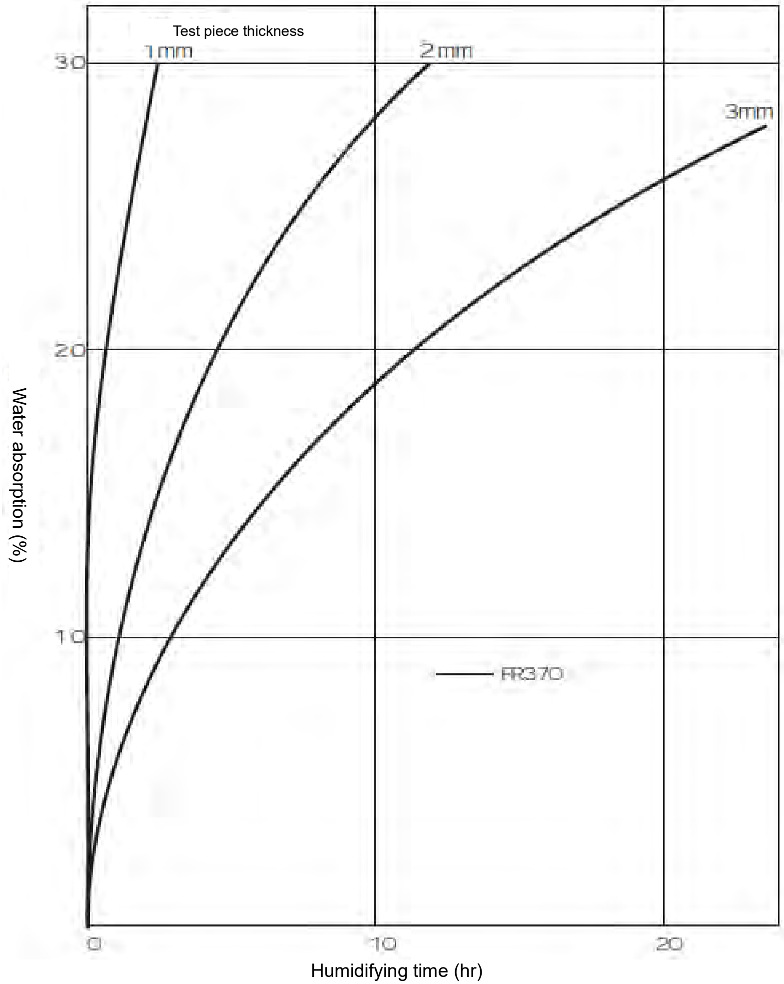


Figure-12 Humidifying conditions and water absorption (in 20℃ water)

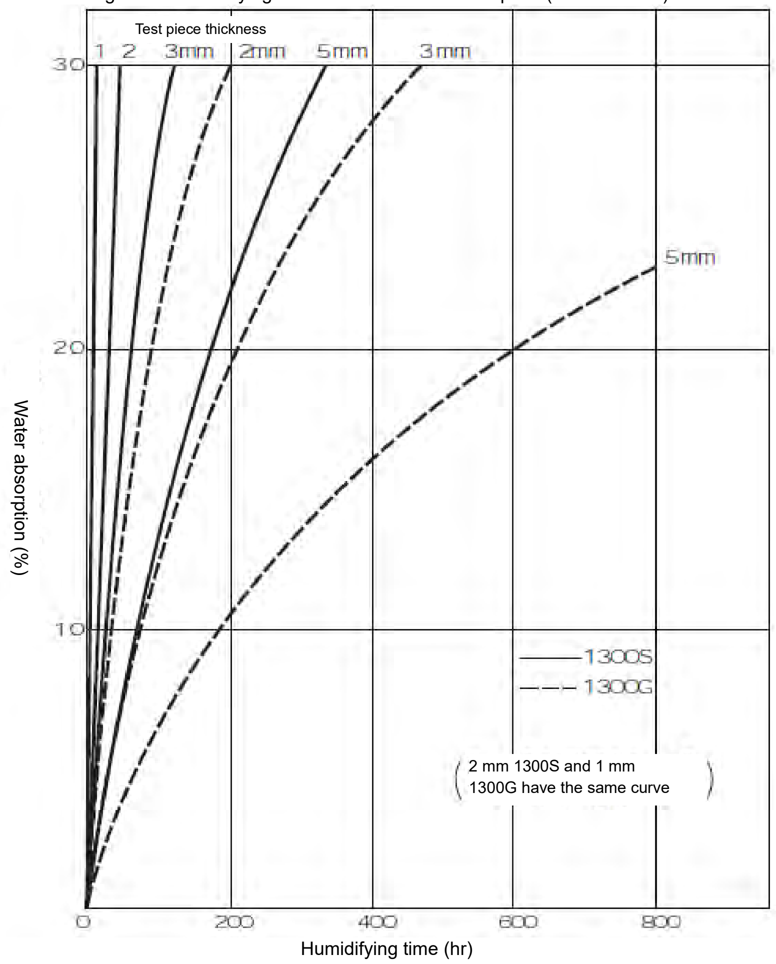


Figure-13 Humidifying conditions and water absorption (in 23℃ water)

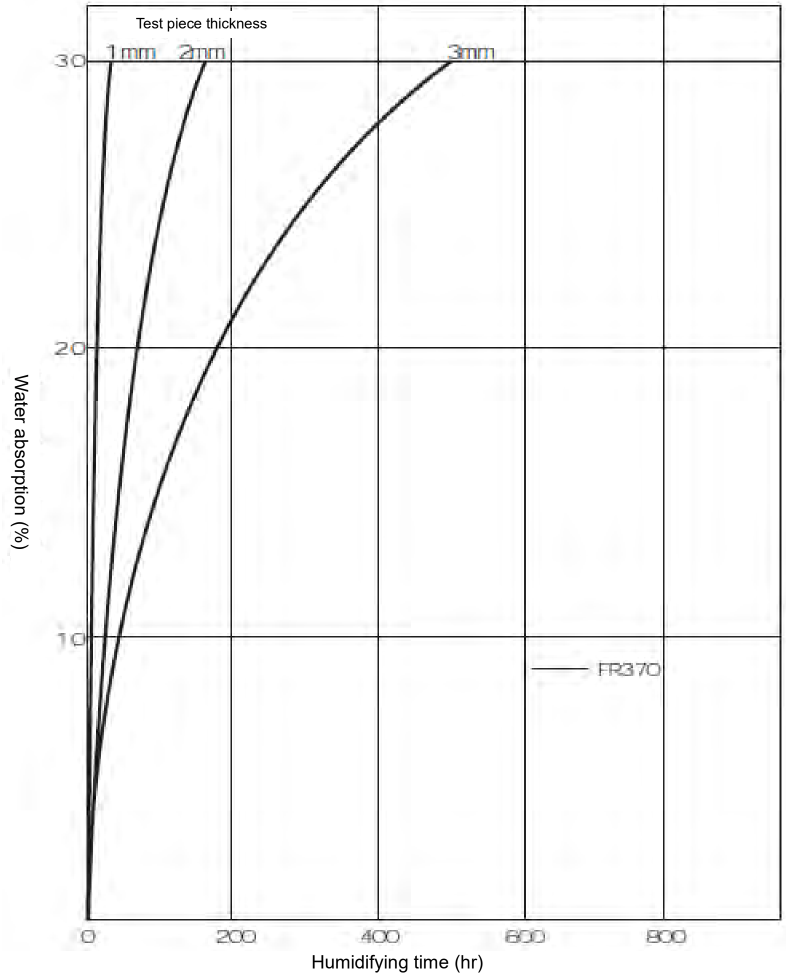


Figure-14 Humidifying conditions to reach balanced water absorption in the air

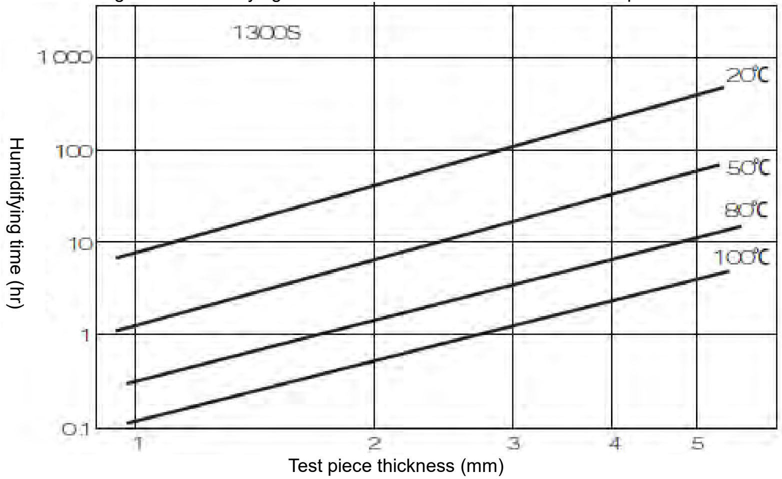


Figure-15 Humidifying conditions to reach balanced water absorption in the air

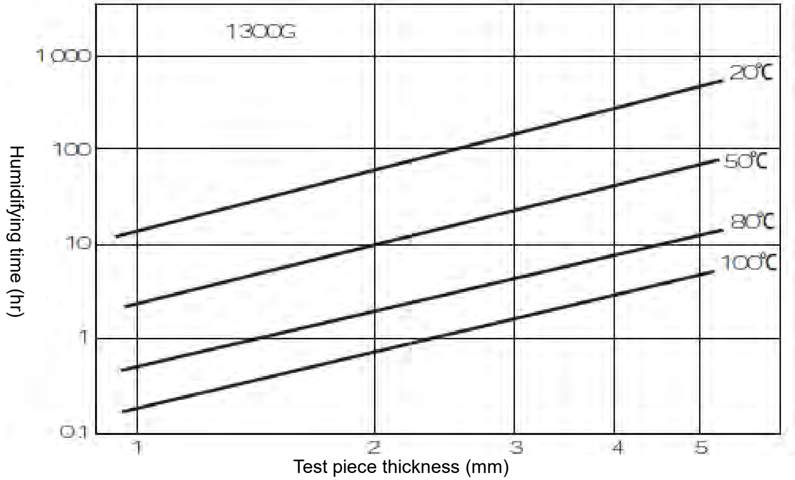
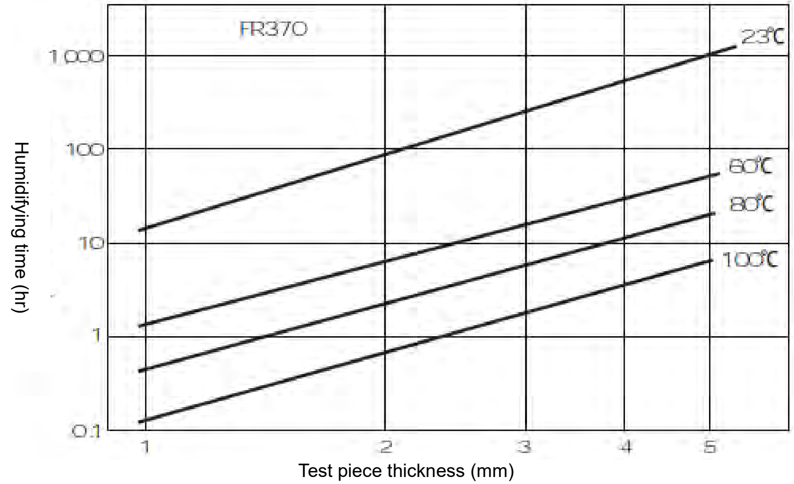


Figure-16 Humidifying conditions to reach balanced water absorption in the air



2-3 Humidifying conditions (in the air)

Figures 17~19 show the humidifying conditions and water absorption of LEONA in the air.

Figure-17 Humidifying conditions and water absorption of 1300S (in the air)

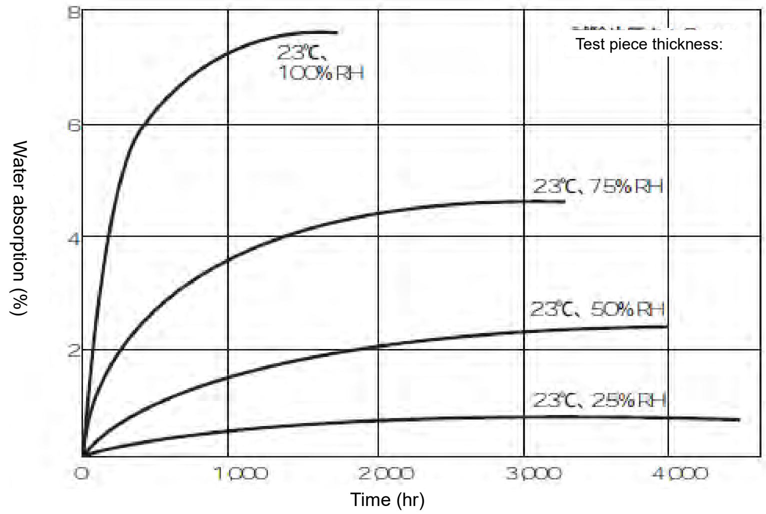


Figure-18 Humidifying conditions and water absorption of 1300G (in the air)

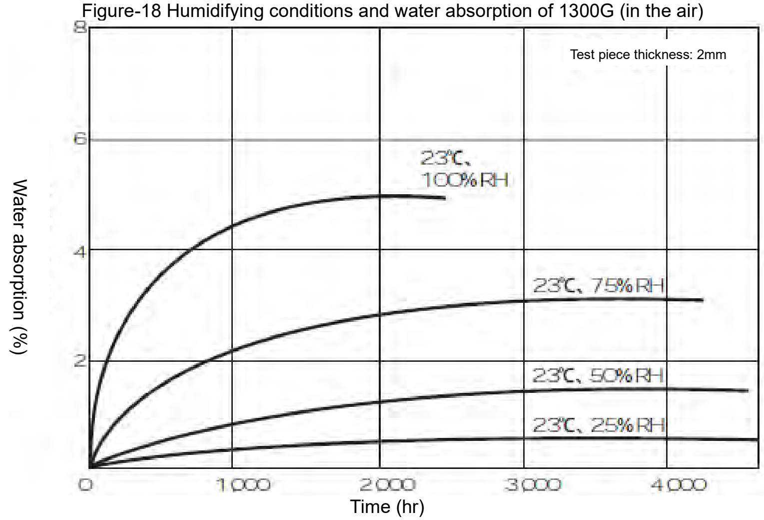
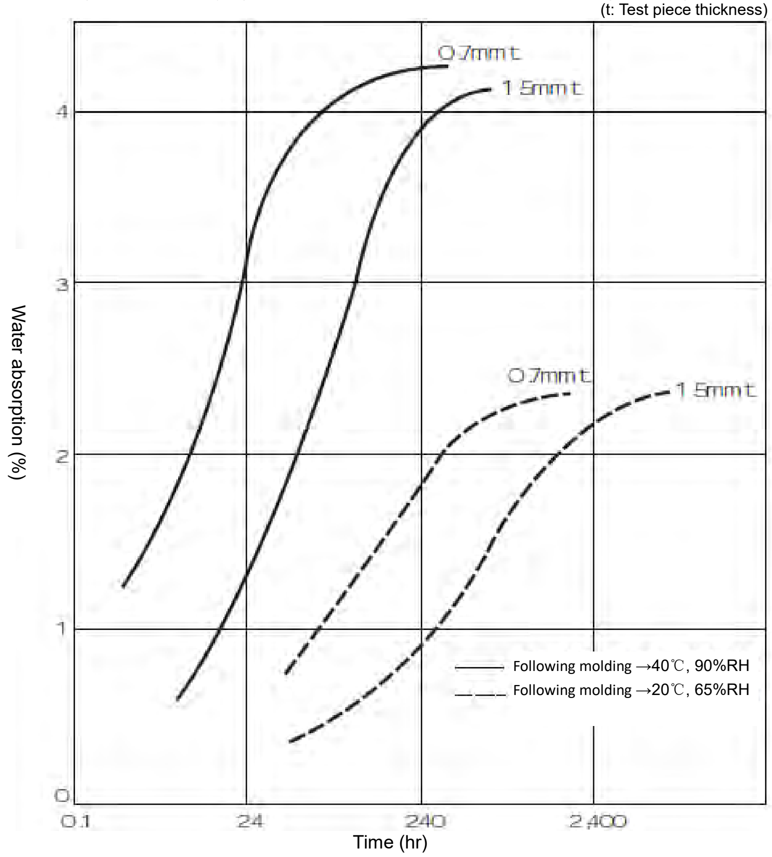


Figure-19 Humidifying conditions and water absorption of 1300G (in the air)



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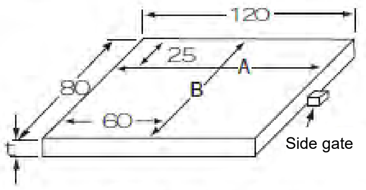
2-4 Dimensional changes

Figures 20~35 show the ongoing changes of LEONA molding products in constant temperature and humidity cabinet. The constant temperature and humidity cabinet is set at 25℃ and 50%RH, but the temperature is 20~30℃ and the humidity is 30~60%RH due to seasonal changes.

The test piece used for measurement is flat-shaped as shown below.

Molding product shape (unit:



Dimensional measurement method
Measurement of dimensions of A part (in flow direction) and B part (in vertical direction of flow) by micrometer

Thickness (1, 2, 3 and 5mm)

The dimensions of the products with glass fiber reinforced grade 1300G are anisotropic. The dimensional change rate in the flow direction and right-angle direction are recorded in the table respectively.

The dimensions of the products 1300S and MR001 are basically not anisotropic, so the average value of the dimensional change rates in two directions is taken.

Figure-20 Changes in water absorption

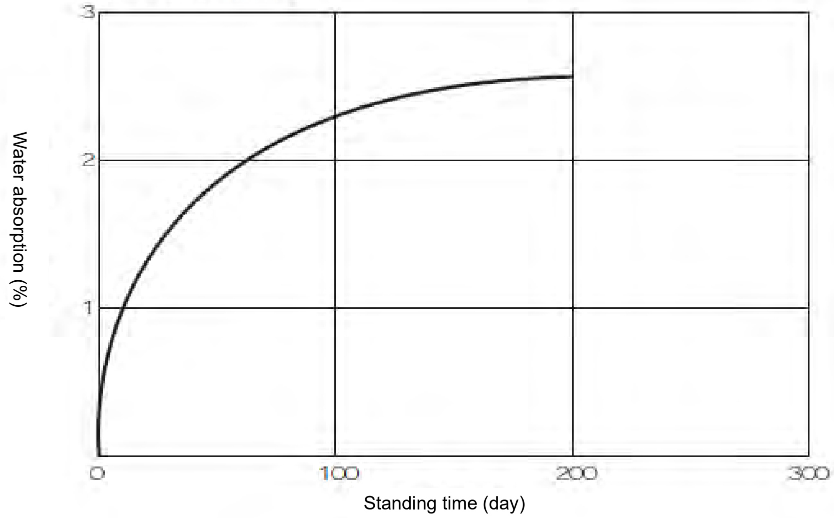


Figure-21 Changes in dimensions

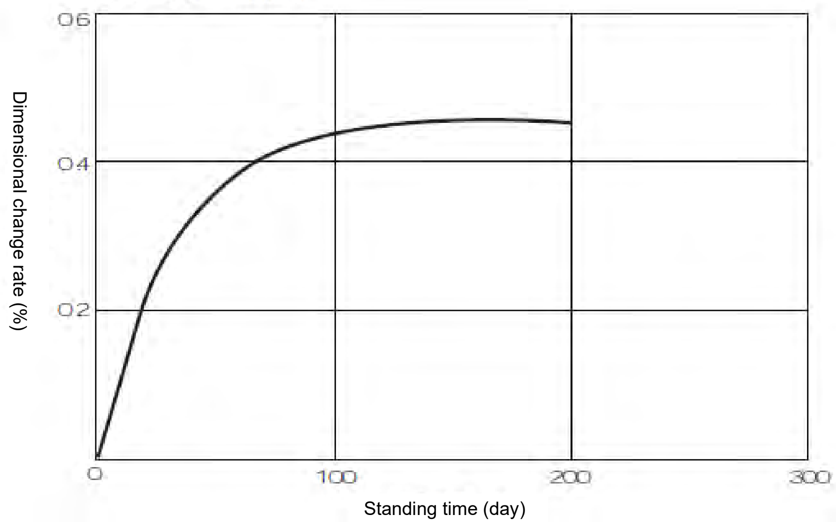


Figure-22 Changes in water absorption

(1300S, 2mmt)

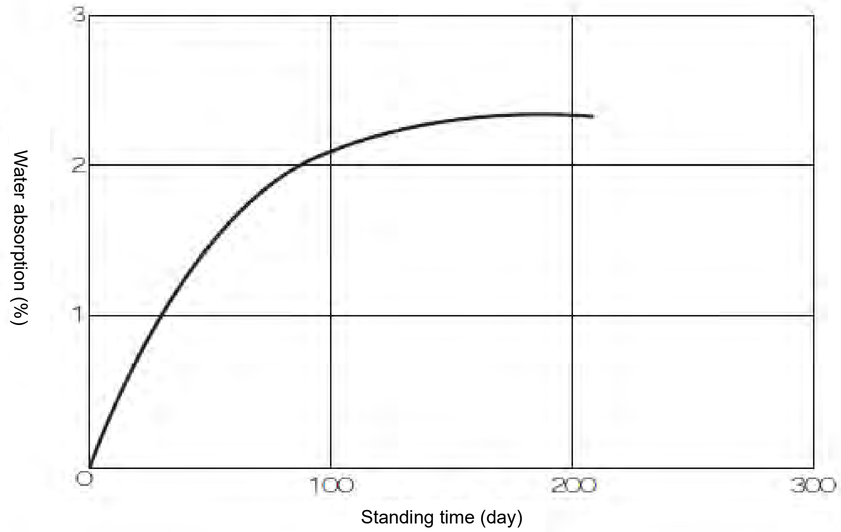


Figure-23 Changes in dimensions

(1300S, 2mmt)

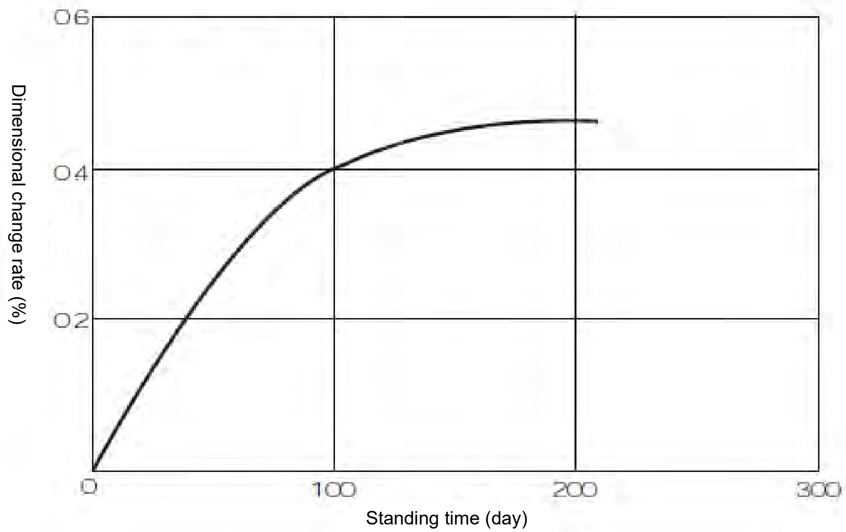


Figure-24 Changes in water absorption

(1300S, 3mmt)

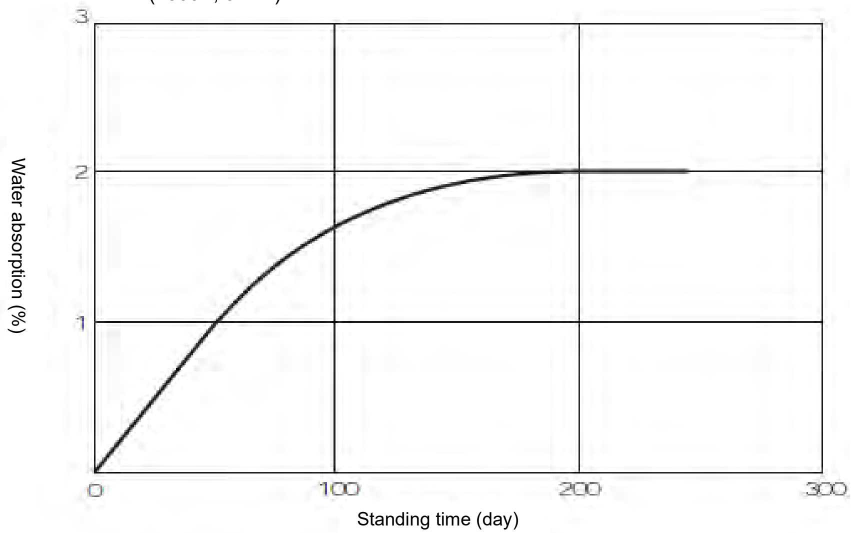


Figure-25 Changes in dimensions

(1300S, 3mmt)

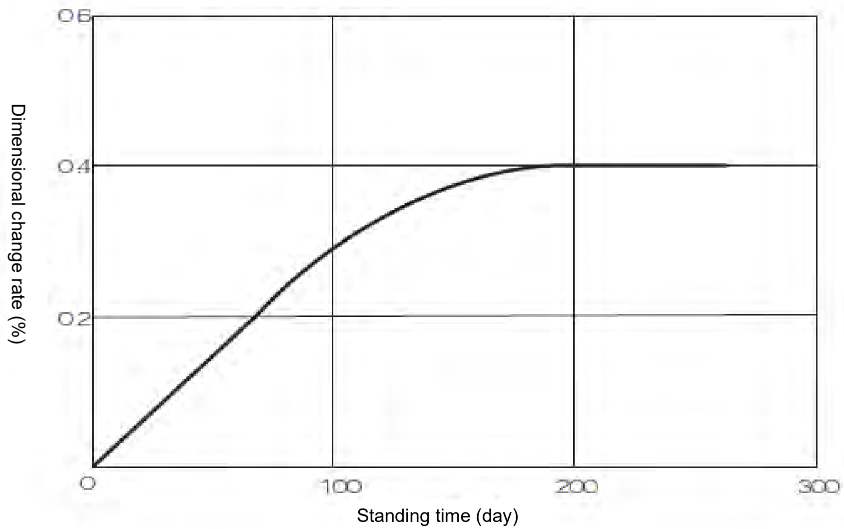


Figure-26 Changes in water absorption

(1300G, 2mmt)

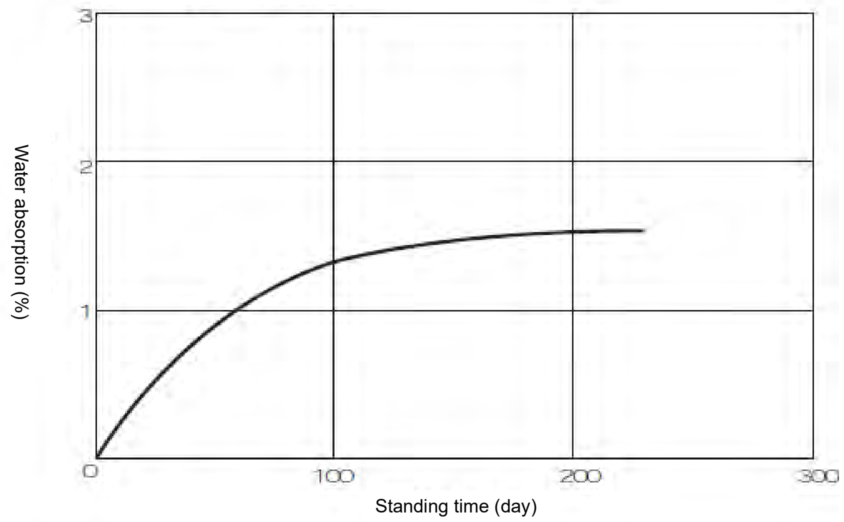


Figure-27 Changes in dimensions

(1300G, 2mmt)

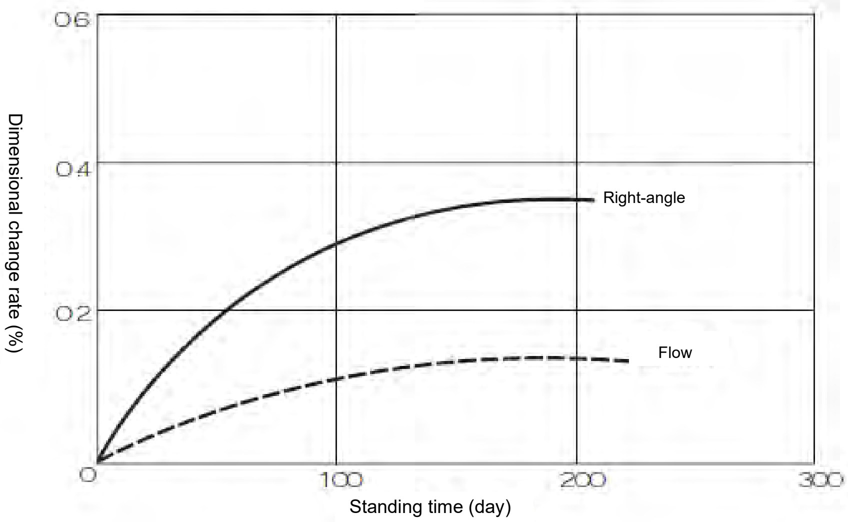


Figure-28 Changes in water absorption

(1300G, 3mmt)

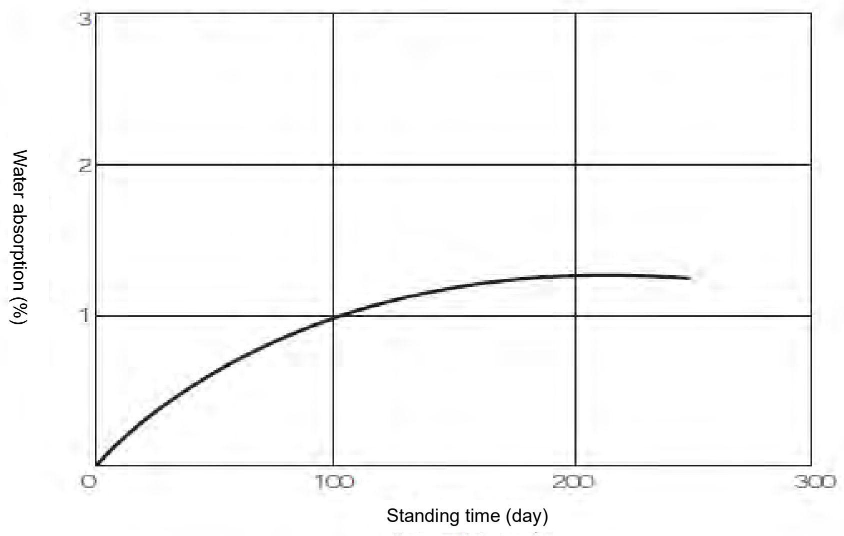


Figure-29 Changes in dimensions

(1300G, 3mmt)

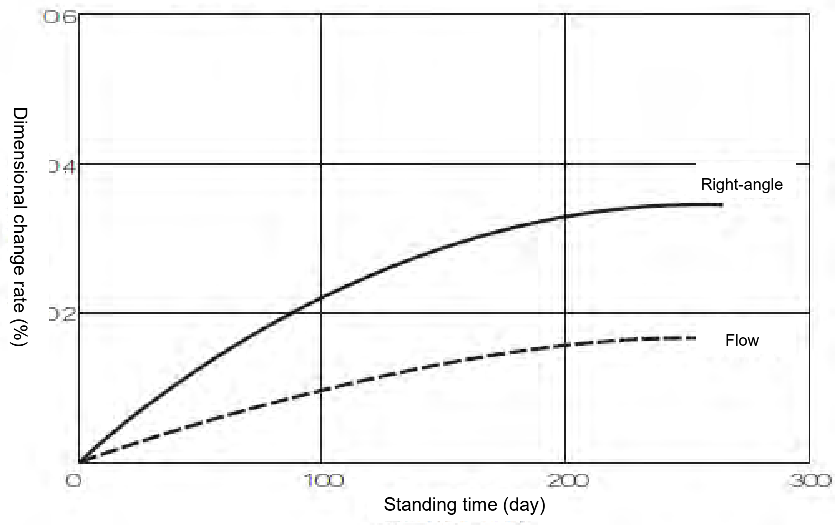


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Figure-30 Changes in water absorption

(1300G, 5mmt)

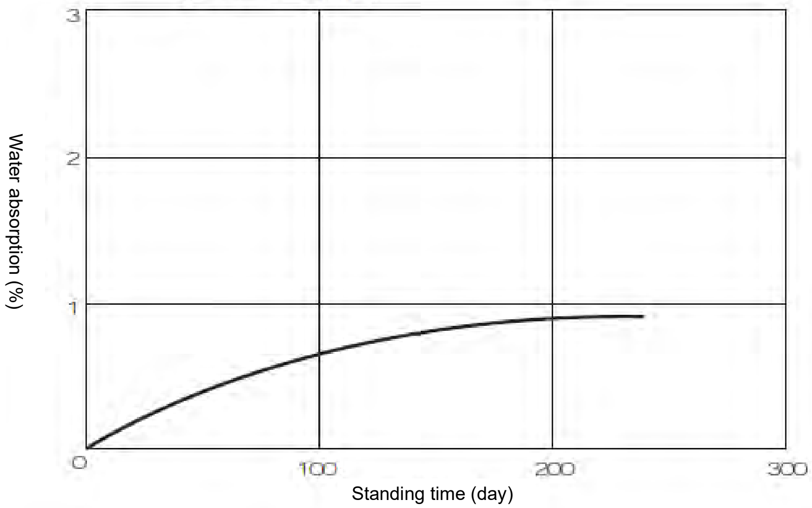

Figure-32 Changes in water absorption

(MR01, 2mmt)

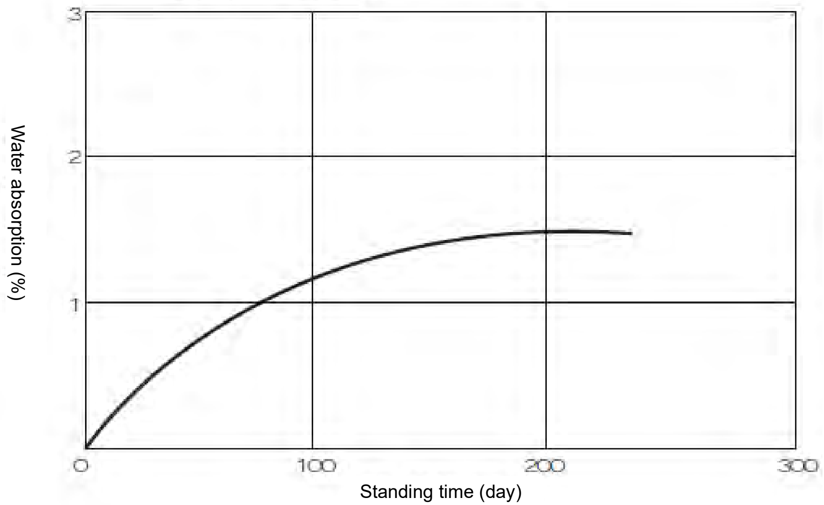

Figure-31 Changes in dimensions

(1300G, 5mmt)

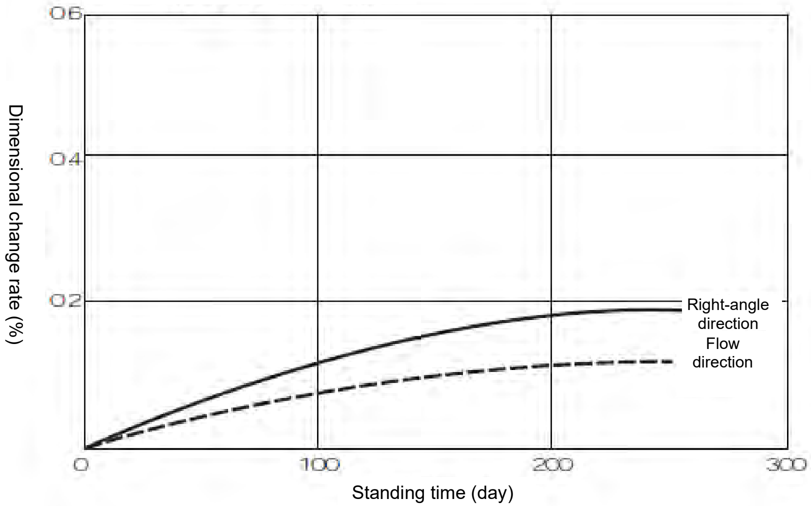

Figure-33 Changes in dimensions

(MR01, 2mmt)

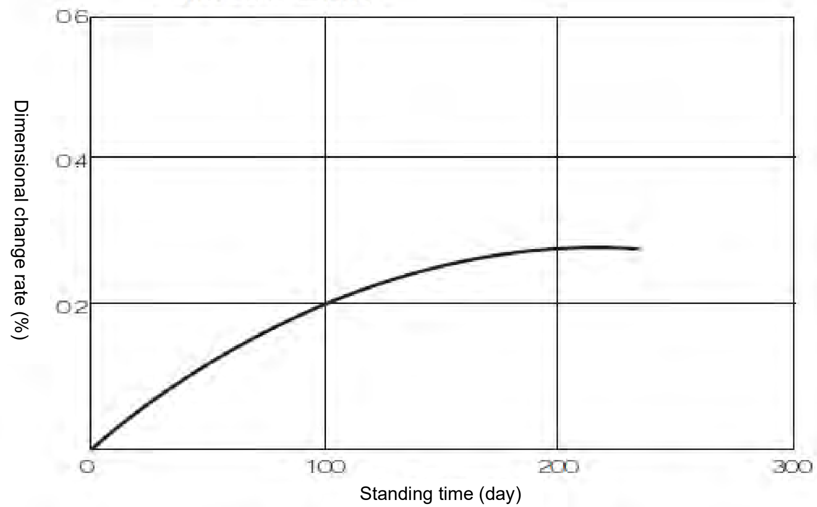

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Figure-34 Changes in water absorption

(MR01, 3mmt)

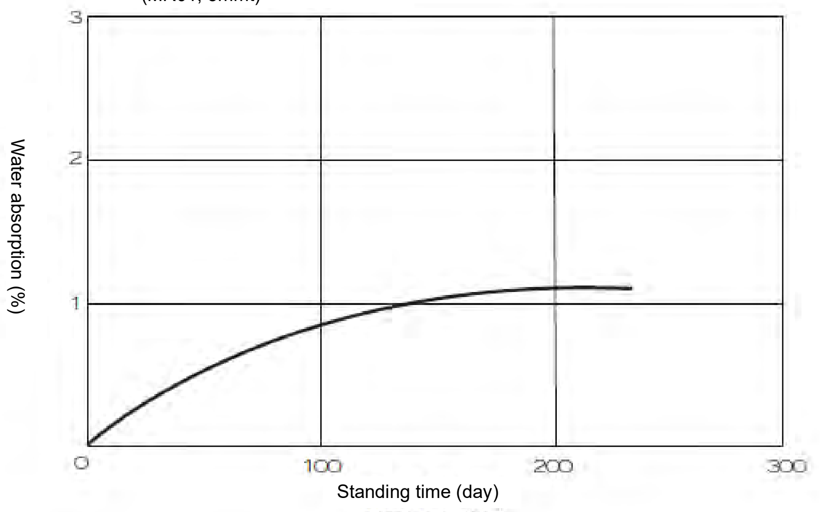
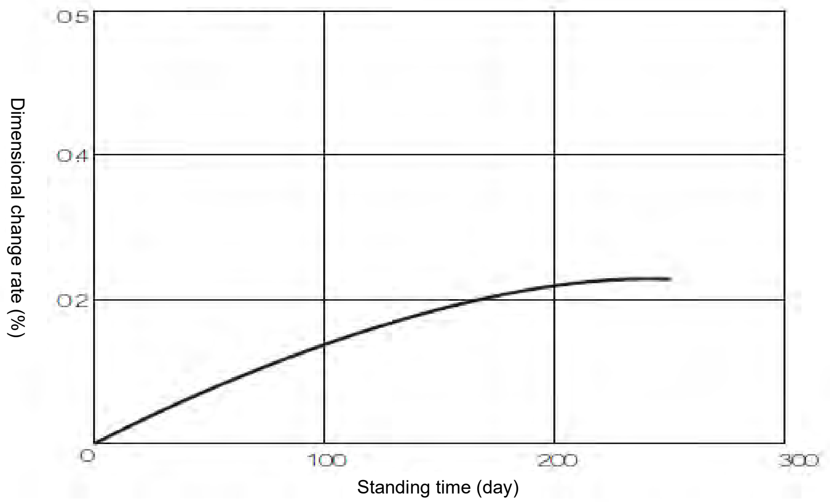


Figure-35 Changes in dimensions

(MR01, 3mmt)



LEONA moisture dependency

3-1 Stress-strain curve (tensile S-S curve) Remark: Strain = strain between clamps (11.4cm)

Figure-36 Stress-strain curve

(1300S)

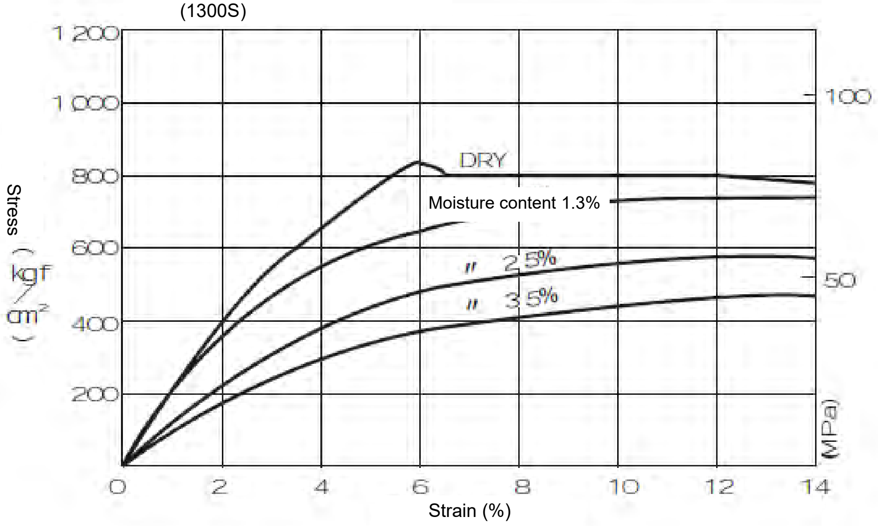


Figure-37 Stress-strain curve

(1300G)

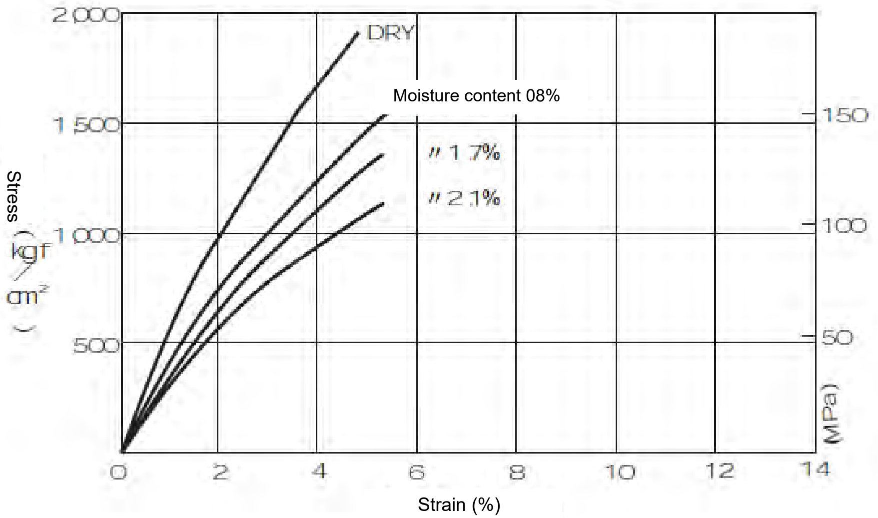
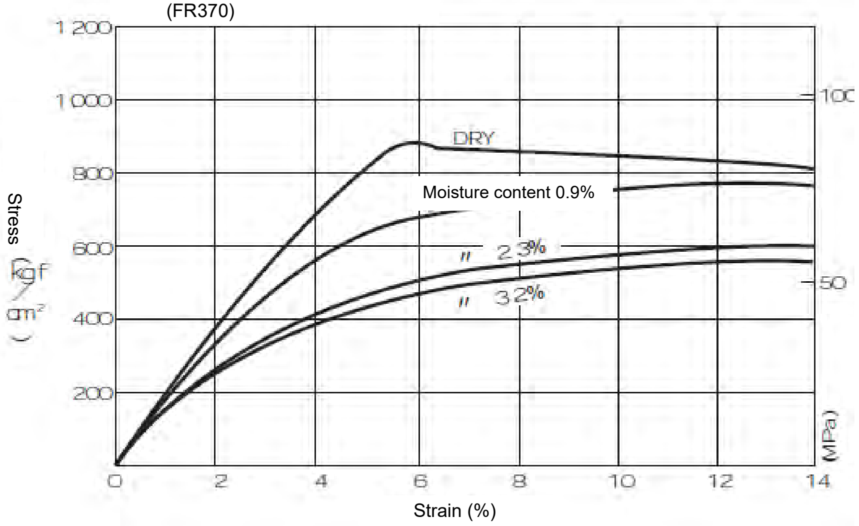


Figure-38 Stress-strain curve

(FR370)



3-2 Change of mechanical properties with water absorption

(1) Tensile strength

Figure-39 Change of tensile strength with water absorption

(1300S)

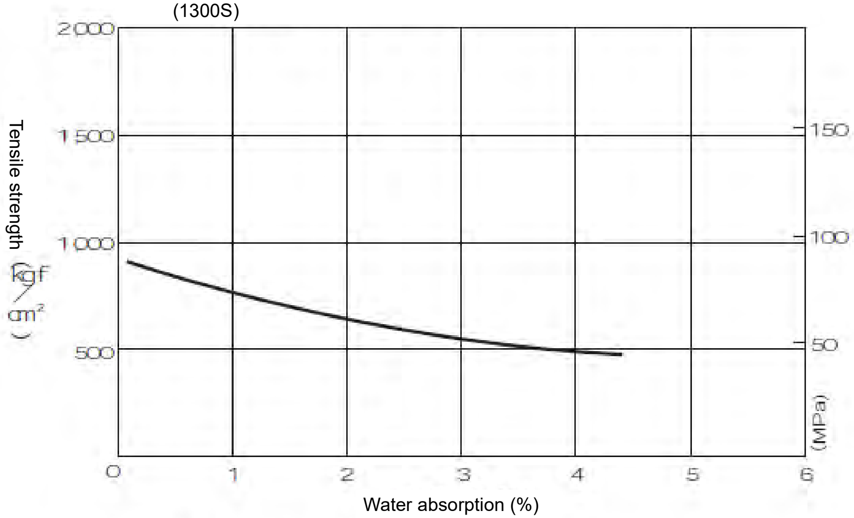


Figure-40 Change of tensile strength with water absorption

(1300G)

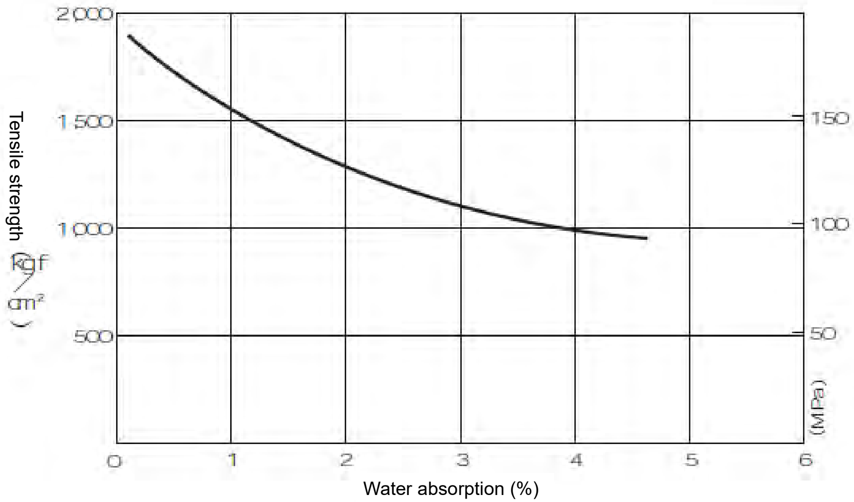
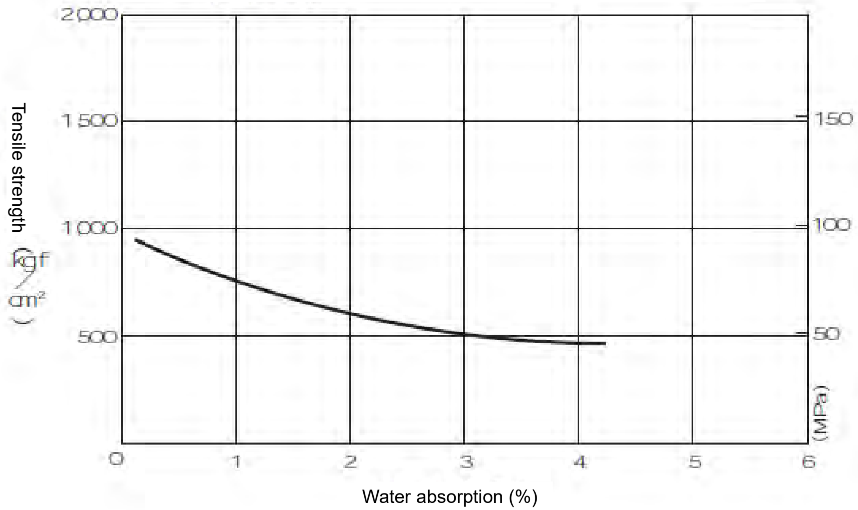


Figure-41 Change of tensile strength with water absorption

(FR370)



(2) Fracture strain

Figure-42 Change of fracture strain with water absorption

(1300S)

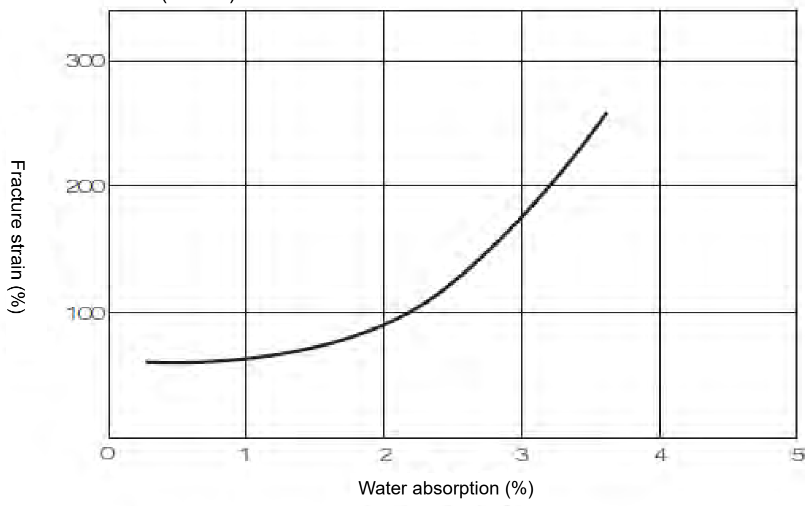


Figure-43 Change of fracture strain with temperature

(1300G)

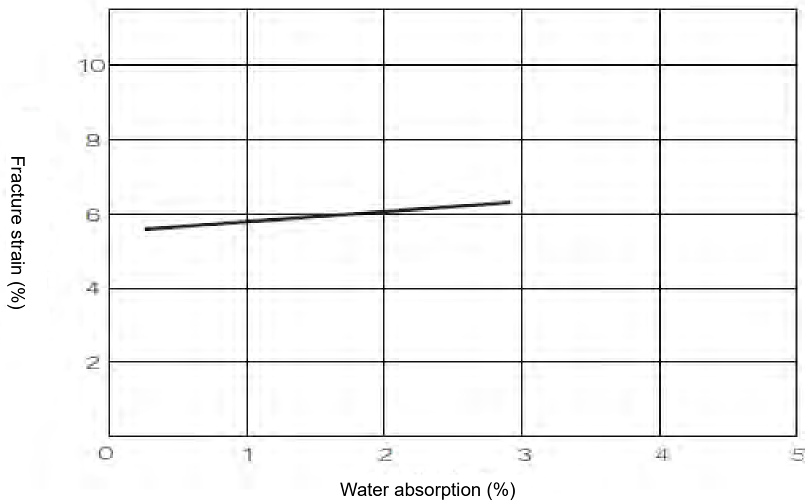
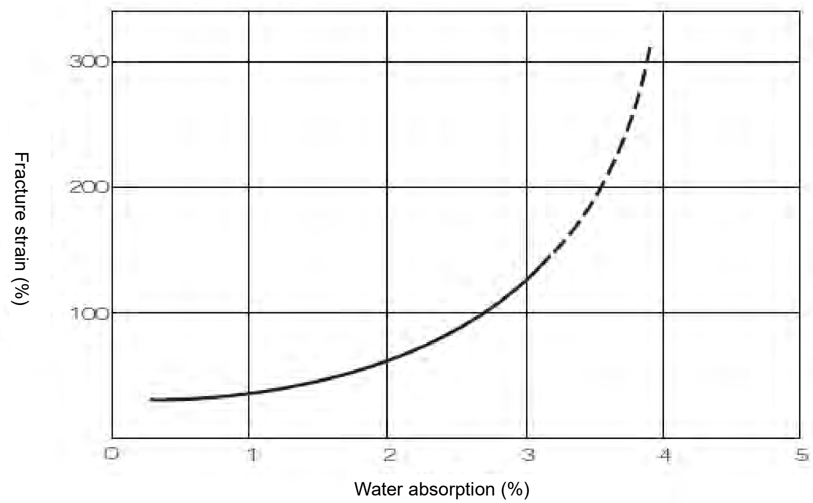


Figure-44 Change of fracture strain with water absorption

(FR370)



LEONA moisture dependency

(3) Flexural modulus

Figure-45 Change of flexural modulus with water absorption

(1300S)

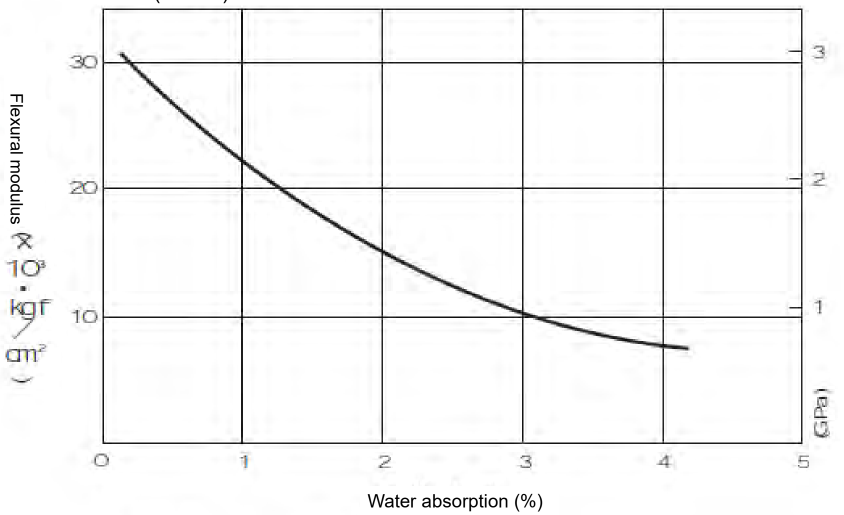


Figure-46 Change of flexural modulus with water absorption

(1300G)

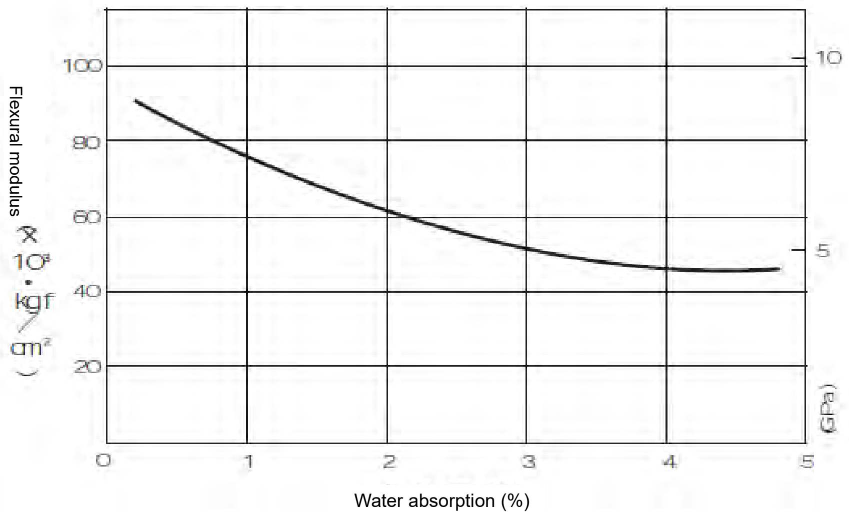
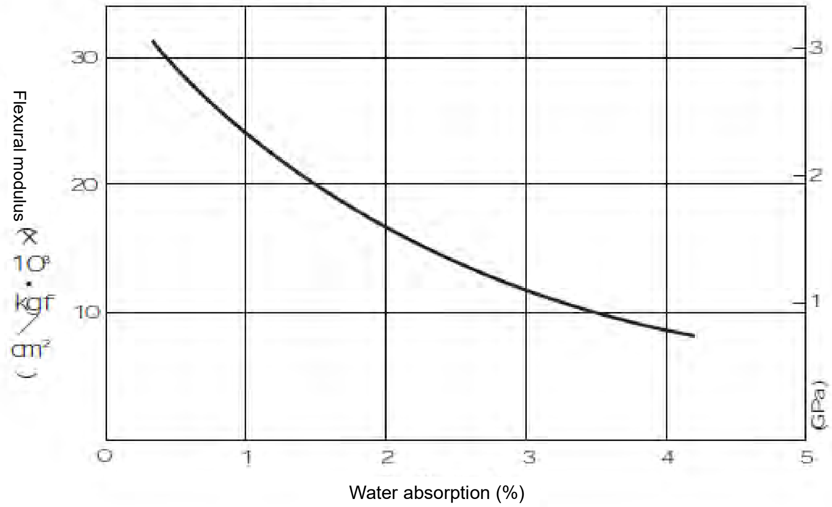


Figure-47 Change of flexural modulus with water absorption

(FR370)



(4) Izod impact strength

Figure-48 Change of izod impact strength with water absorption (1300S)

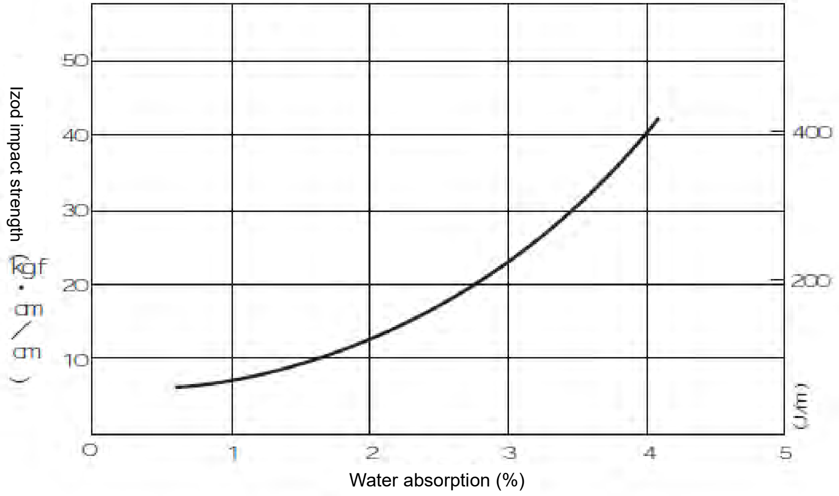


Figure-49 Change of izod impact strength with water absorption (1300G)

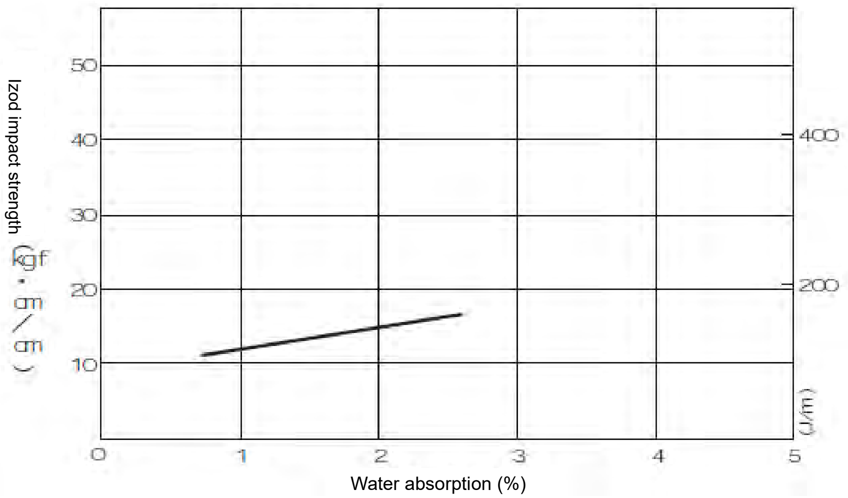
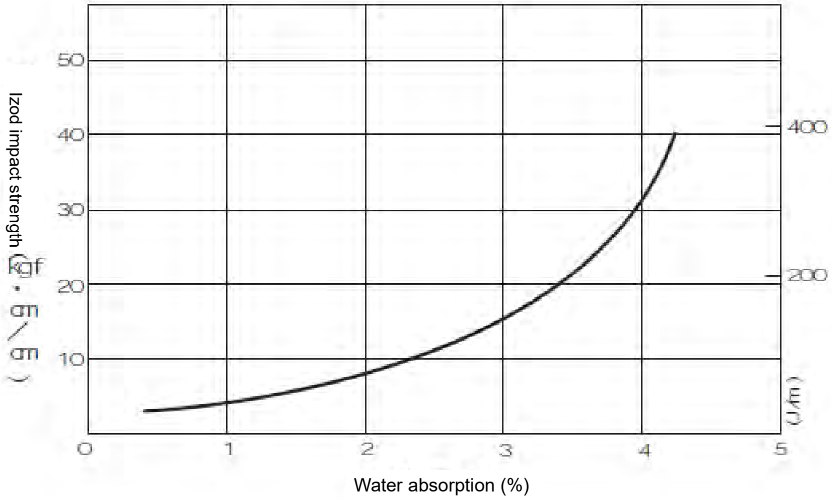


Figure-50 Change of izod impact strength with water absorption (FR370)



(5) Weld line strength

① Tensile strength

Figure-51 Change of weld line tensile strength with water absorption (1300S)

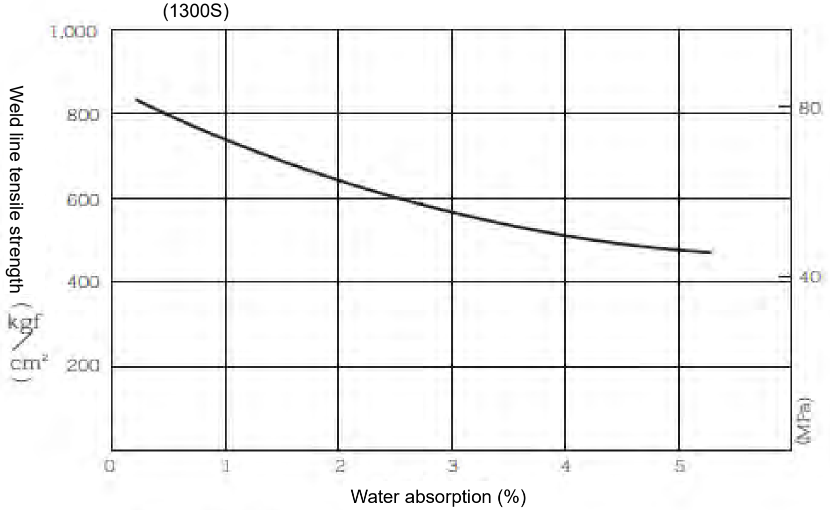


Figure-49 Change of weld line tensile strength with water absorption (1300G)

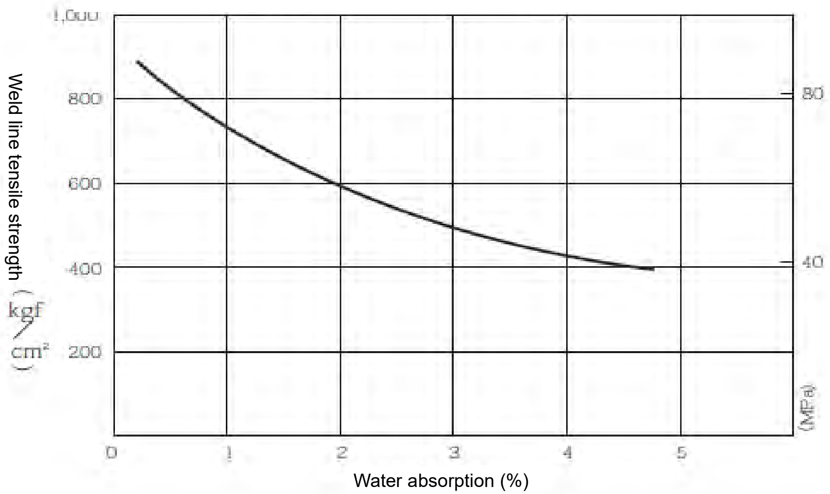
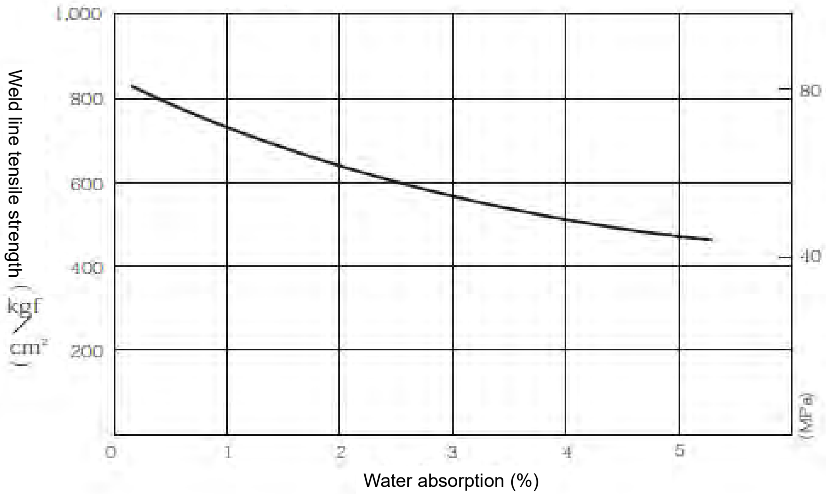


Figure-53 Change of weld line tensile strength with water absorption (FR370)



② Bending strength

Figure-54 Change of weld line bending strength with water absorption

(1300S)

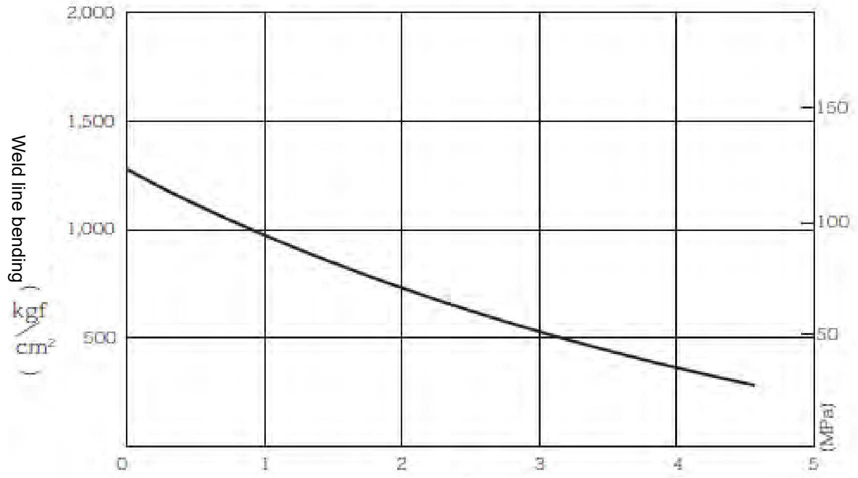


Figure-55 Change of weld line bending strength with water absorption

(1300G)

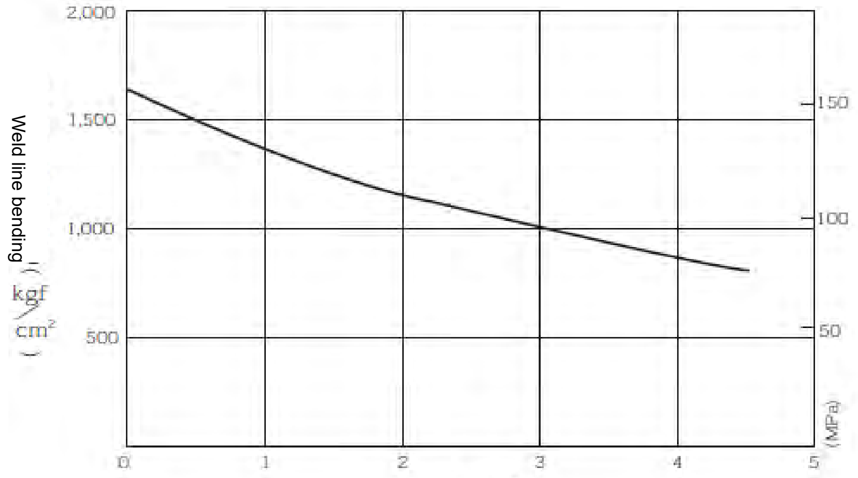
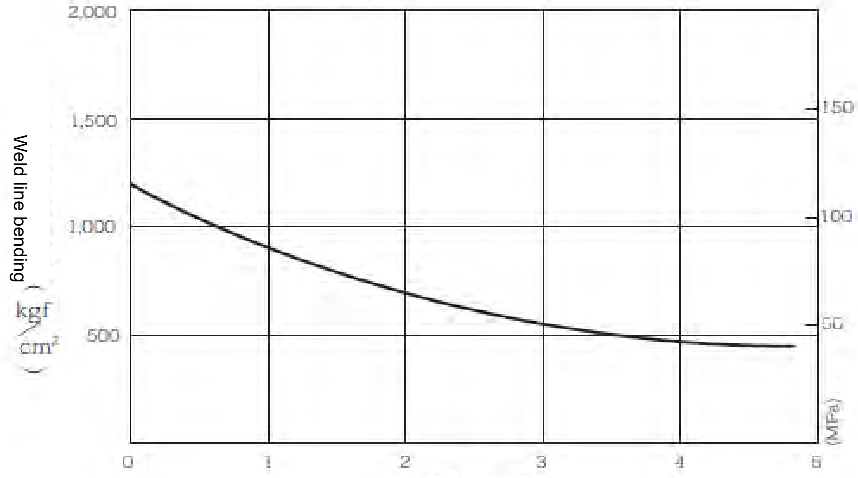


Figure-56 Change of weld line bending strength with water absorption

(FR370)



③ Flexural modulus

Figure-57 Change of weld line flexural modulus with water absorption

(1300S)

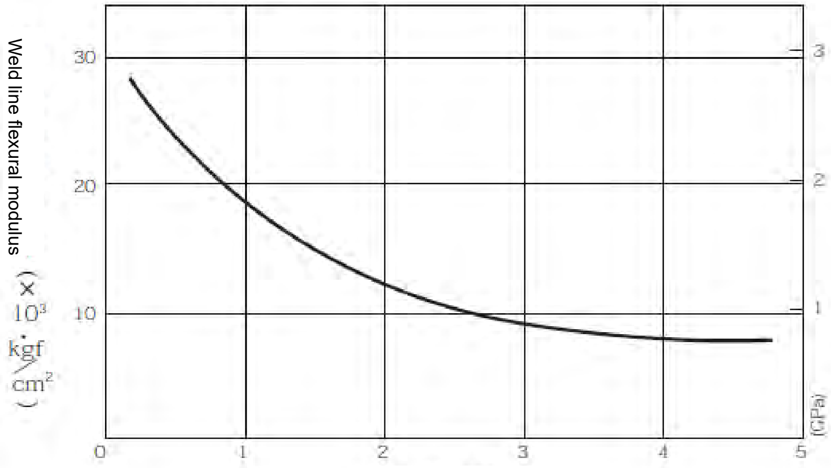


Figure-58 Change of weld line flexural modulus with water absorption

(1300G)

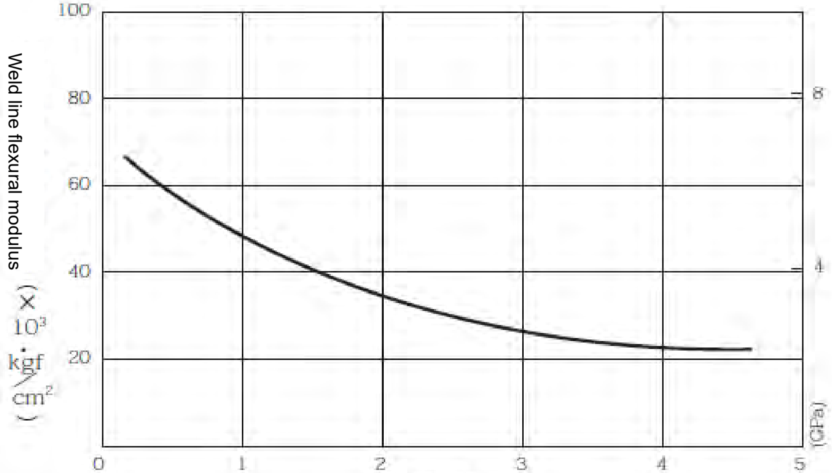
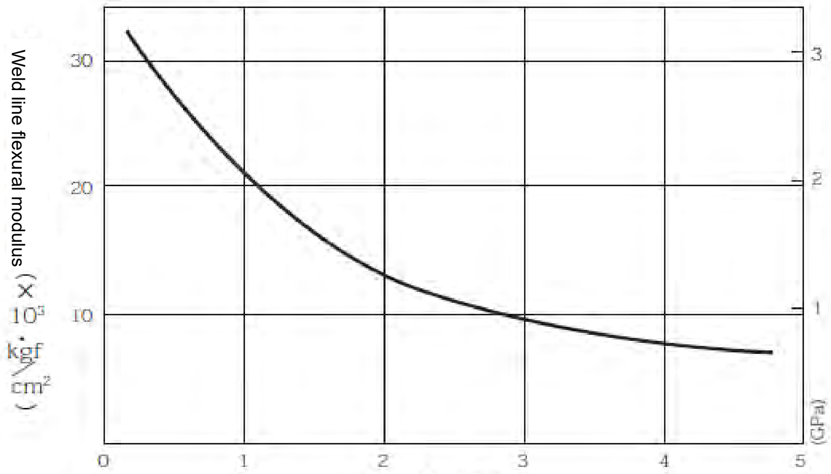


Figure-59 Change of weld line flexural modulus with water absorption

(FR370)



3-3 Change of electrical characteristics with water absorption

(1) Breakdown strength (rate of voltage rise IKV/sec. test piece thickness 1mm)

Figure-60 Change of breakdown strength with water absorption

(1300S)

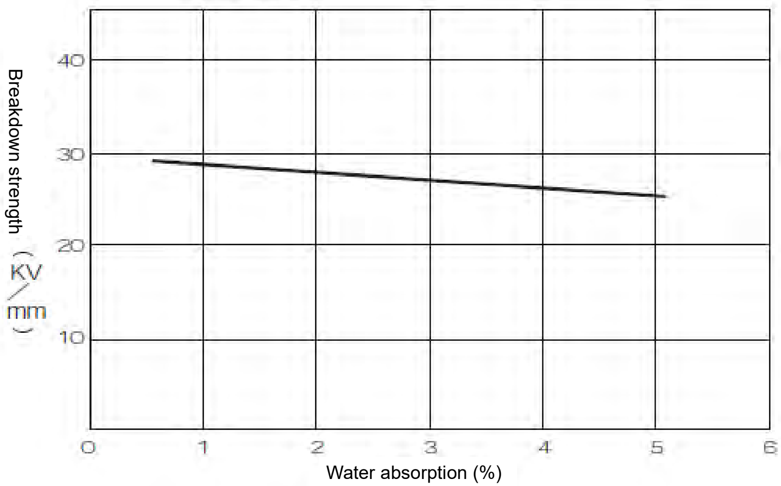


Figure-61 Change of breakdown strength with water absorption

(1300G)

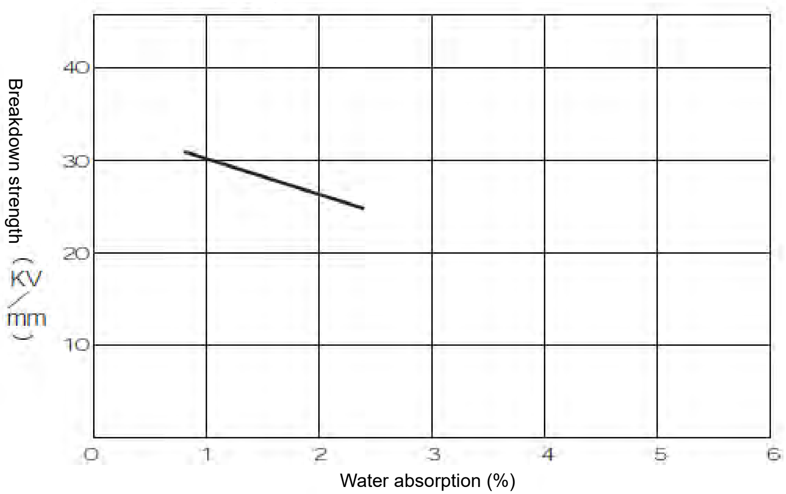
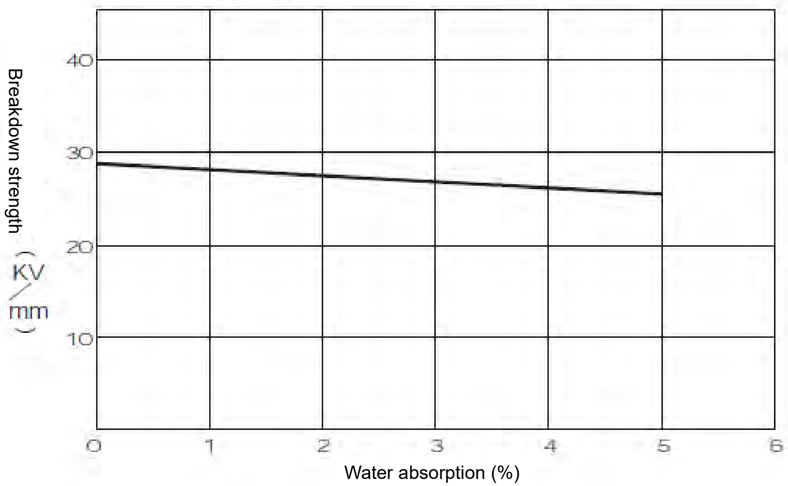


Figure-62 Change of breakdown strength with water absorption

(FR370)



(2) Surface resistivity

Figure-63 Change of surface resistivity with water absorption

(1300S)

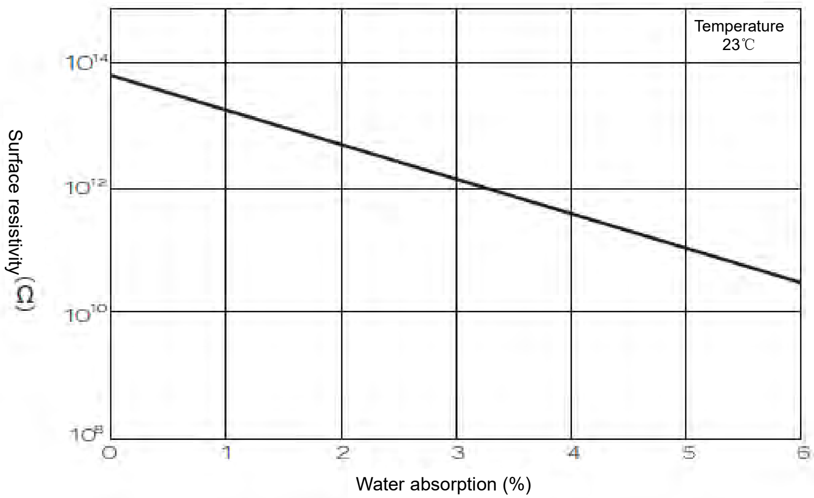


Figure-64 Change of surface resistivity with water absorption

(1300G)

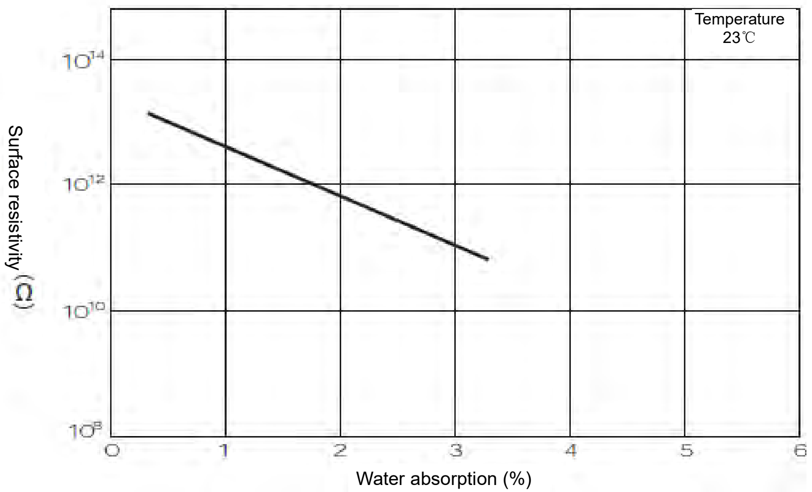
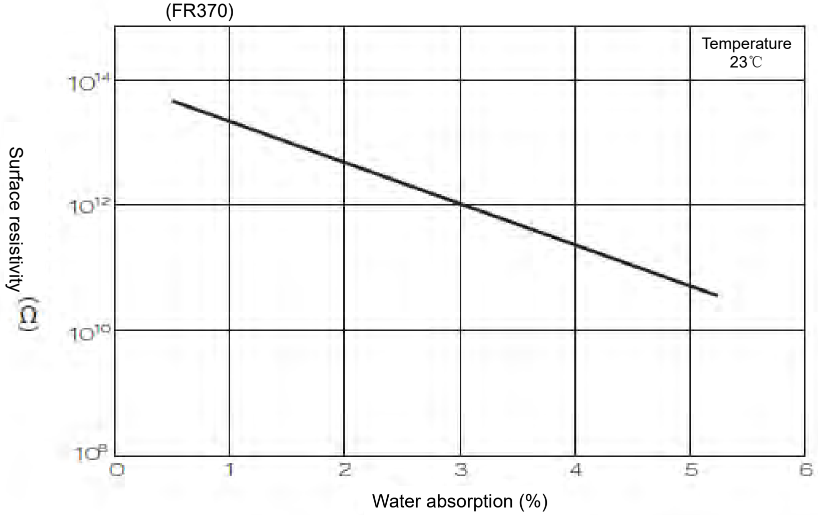


Figure-65 Change of surface resistivity with water absorption

(FR370)



(3) Volume resistivity

Figure-66 Change of volume resistivity with water absorption

(1300S)

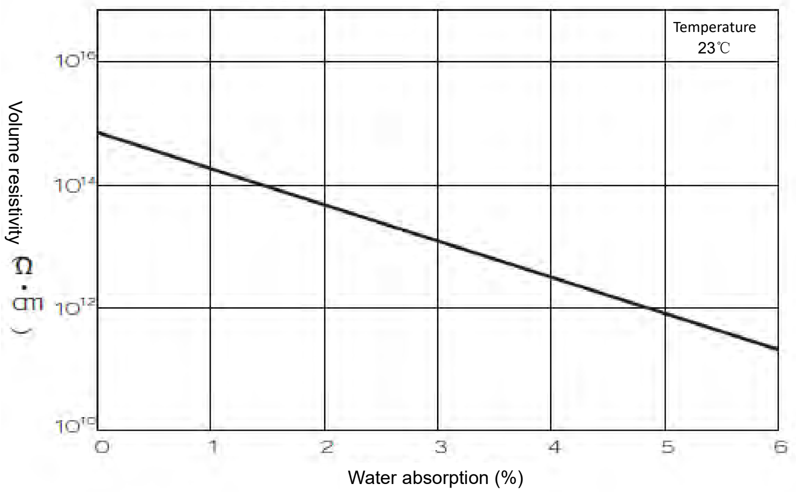


Figure-67 Change of volume resistivity with water absorption

(1300G)

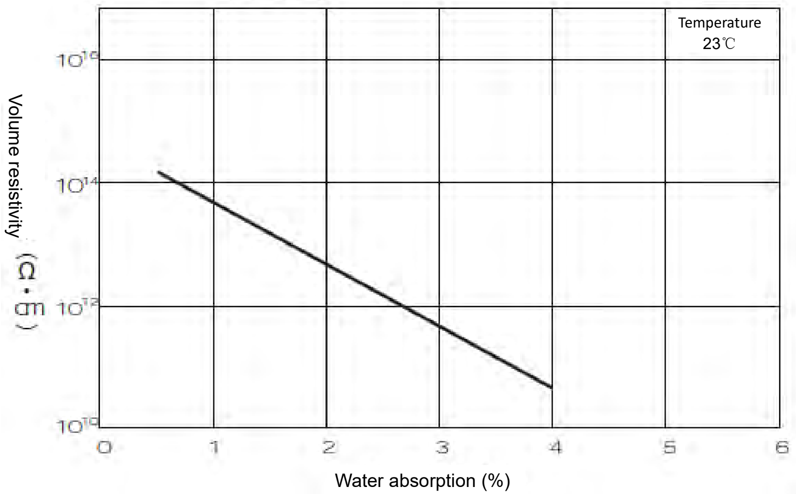
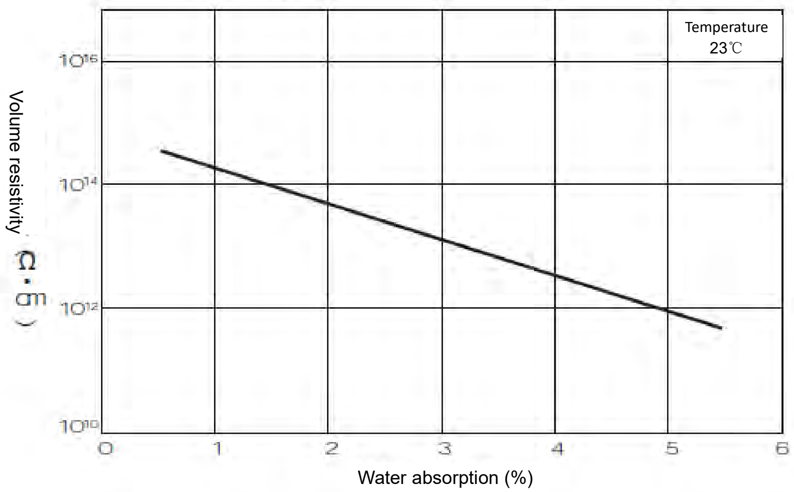


Figure-68 Change of volume resistivity with water absorption

(FR370)



(4) Dielectric constant

Figure-69 Change of dielectric constant with water absorption

(1300S)

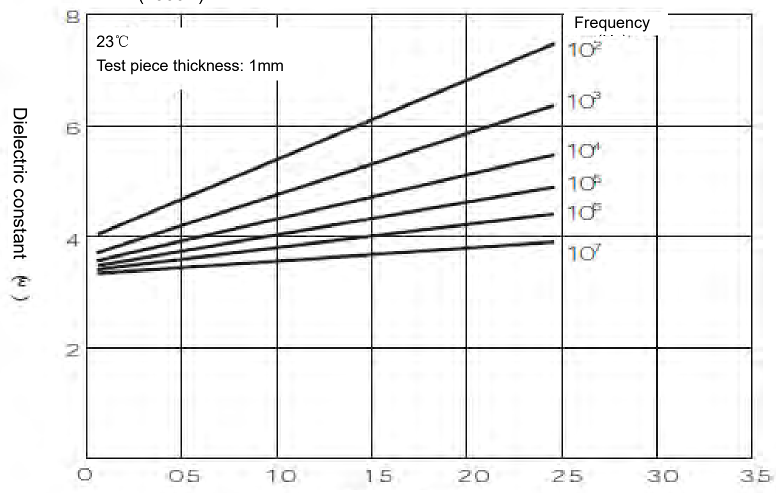


Figure-70 Change of dielectric constant with water absorption

(1300G)

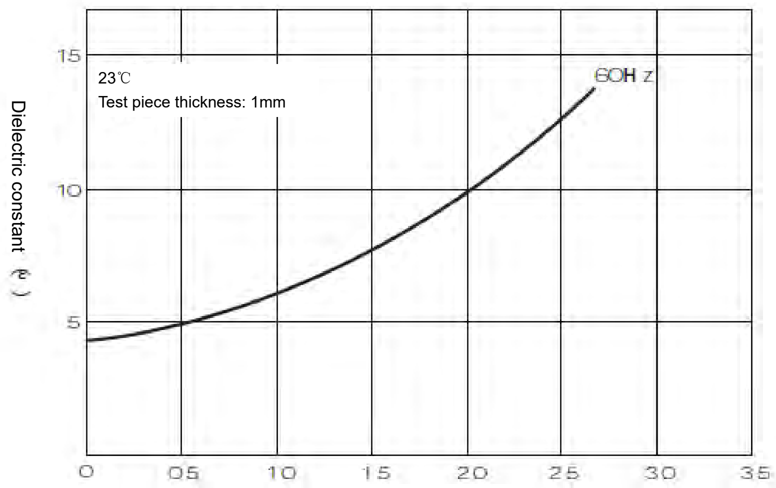


Figure-71 Change of dielectric constant with water absorption

(FR370)

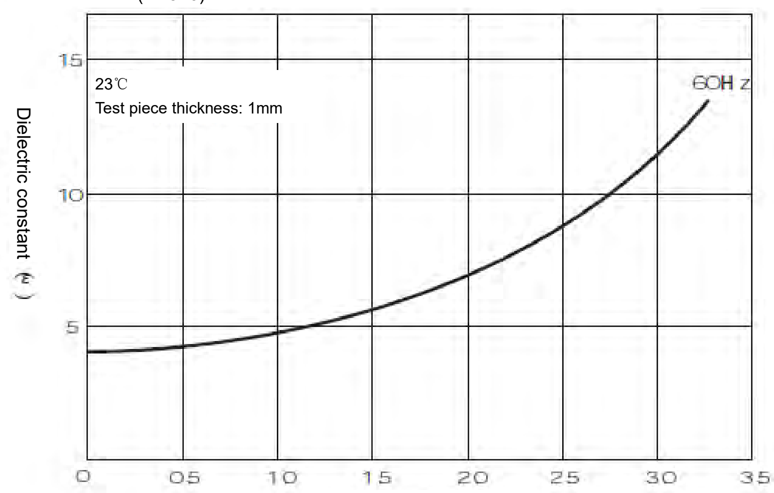
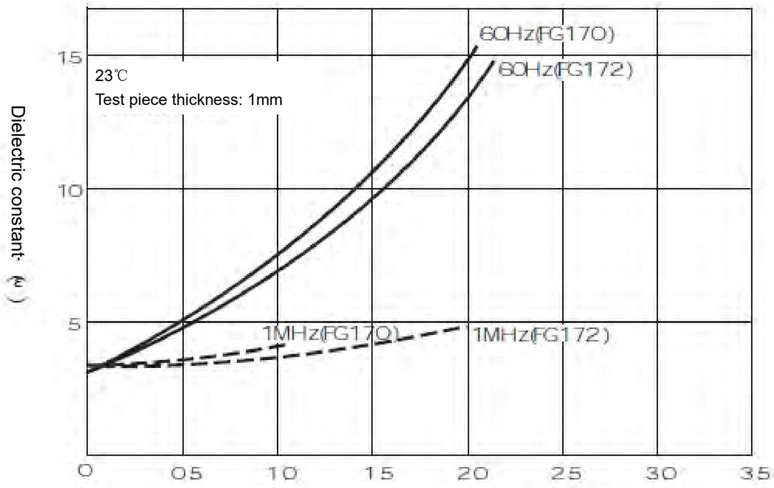


Figure-72 Change of dielectric constant with water absorption

(FG170, FG172)

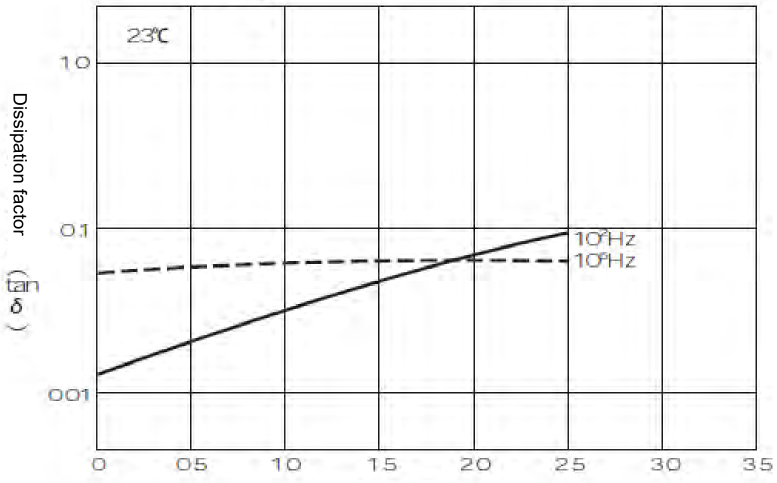


LEONA moisture dependency

(5) Dissipation factor

Figure-73 Change of dissipation factor with water absorption

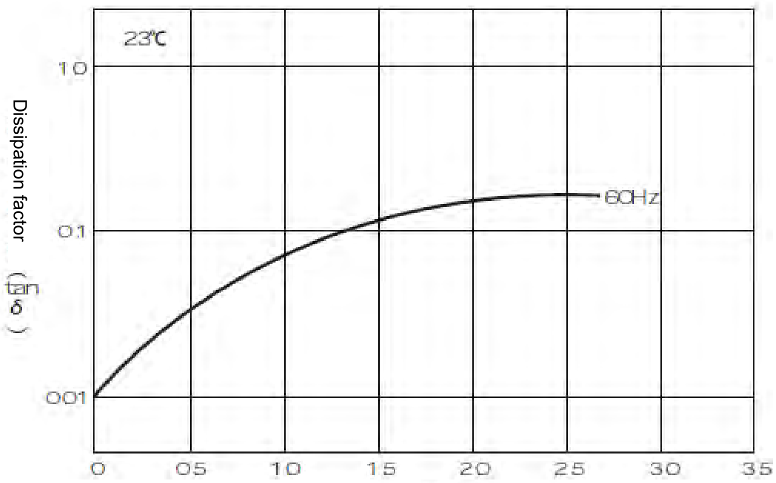
(1300S)



Water absorption (%)

Figure-74 Change of dissipation factor with water absorption

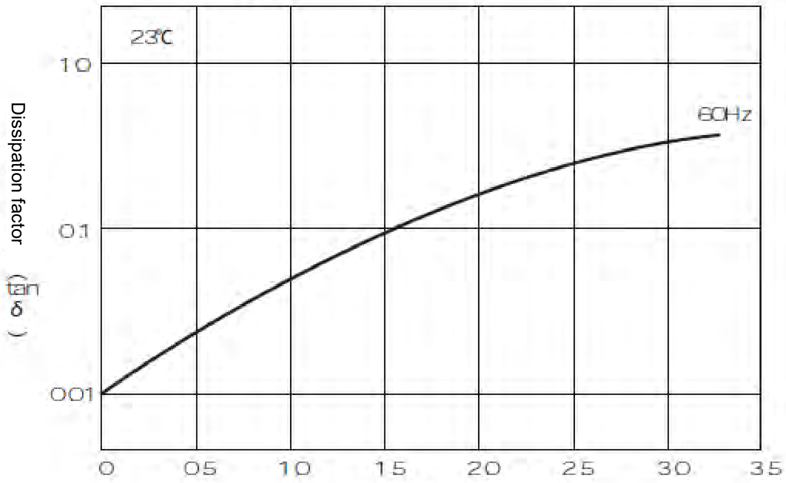
(1300G)



Water absorption (%)

Figure-75 Change of dissipation factor with water absorption

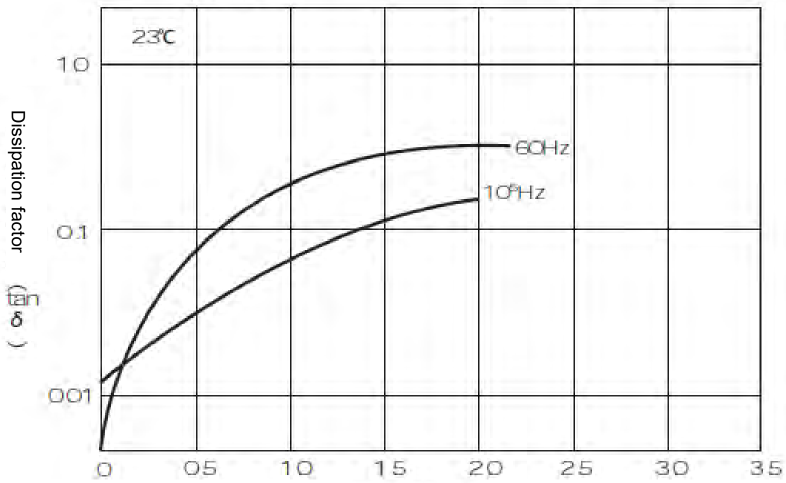
(FR370)



Water absorption (%)

Figure-76 Change of dissipation factor with water absorption

(FG172)



Water absorption (%)

(6) Comparative tracking index

Table-9 Change of comparative tracking index with water absorption

Resin name	Water absorption (%)	Arc track resistance
1300S	0.1	Above 600V
	2.4	Above 600V
	4.0	Above 600V
1300G	0.04	Above 600V
	0.9	Above 600V
	1.5	Above 600V
	2.3	Above 600V
FR 370	0.05	Above 600V
	0.9	Above 600V
	1.8	Above 600V
	2.9	Above 600V

The above physical values are the representative values measured according to the stipulated test methods and are for reference only when the material is selected according to the product usage.The physical values will be updated in the improvement of material formulas.

(7) Arc track resistance

Figure-77 Change of arc track resistance with water absorption

(1300S)

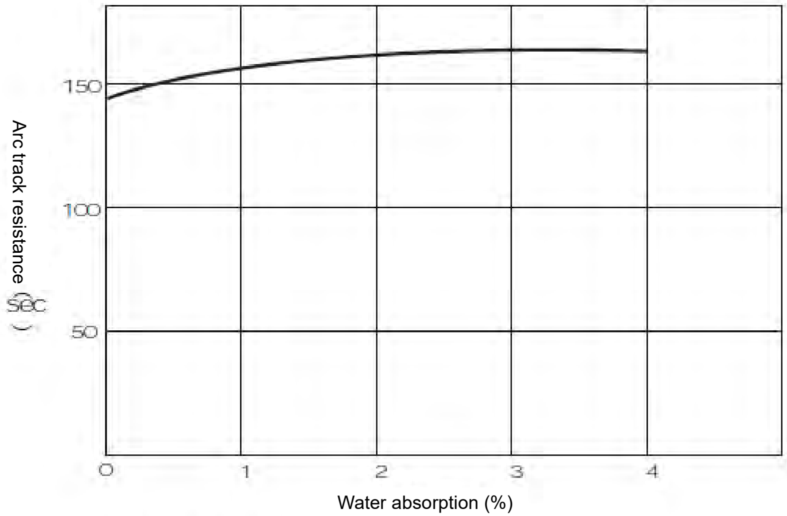


Figure-78 Change of arc track resistance with water

absorption

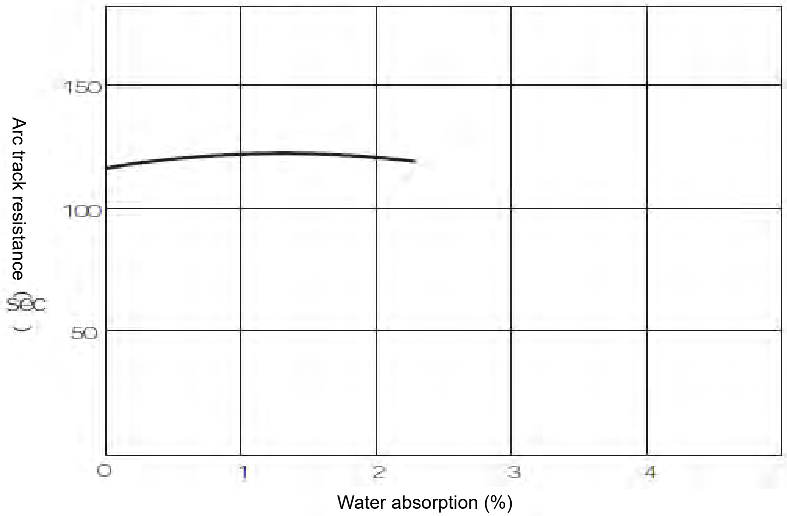
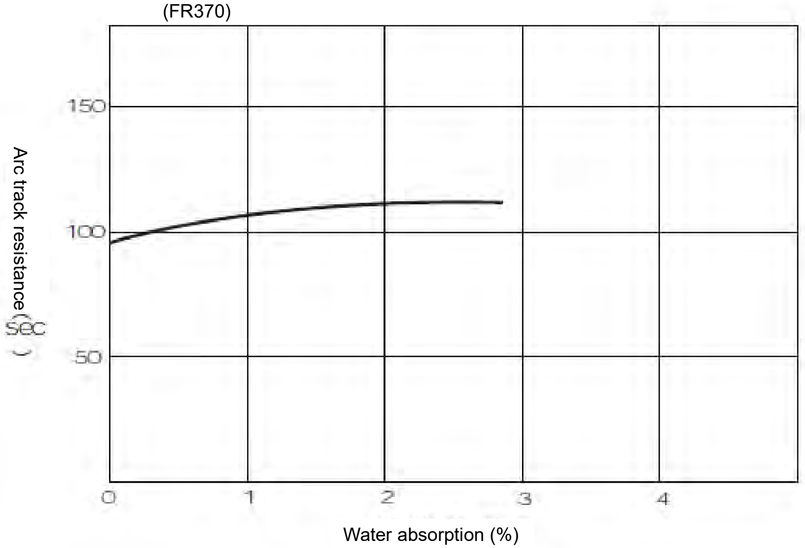


Figure-79 Change of arc track resistance with water absorption



4-1 Stress-strain curve (tensile S-S curve) Remark: Strain = elongation between clamps (11.4cm)

Figure-80 Stress-strain curve

(1300S)

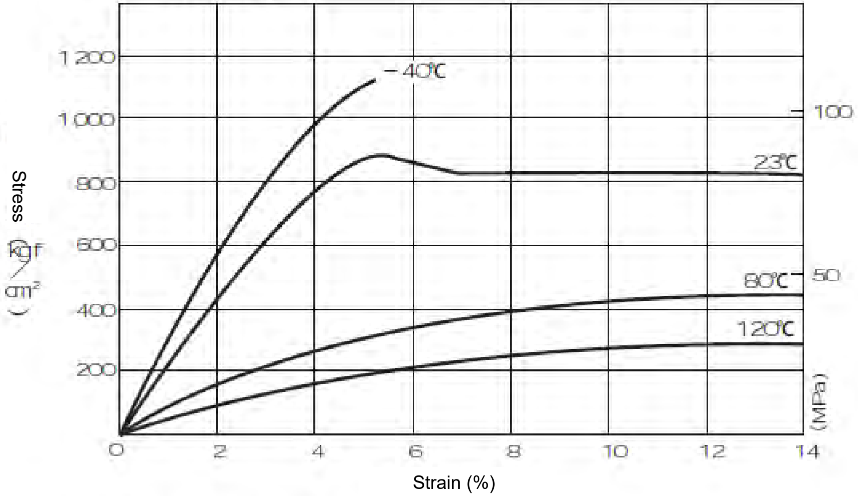


Figure-81 Stress-strain curve

(1300G)

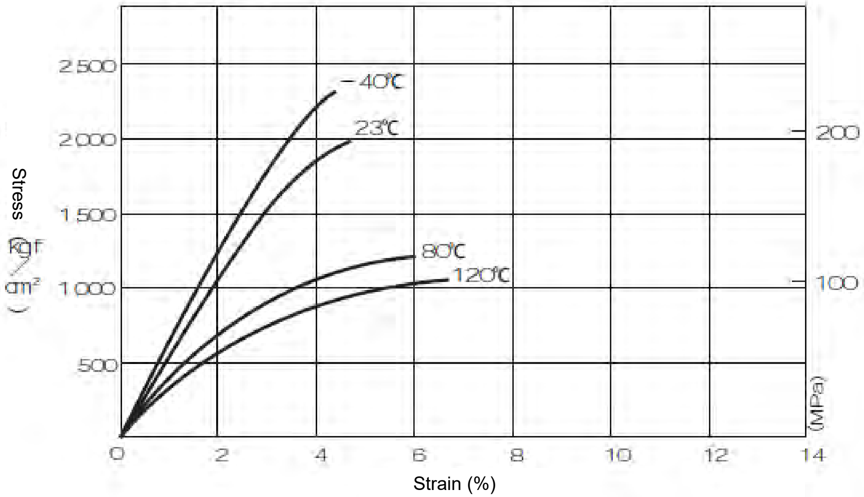
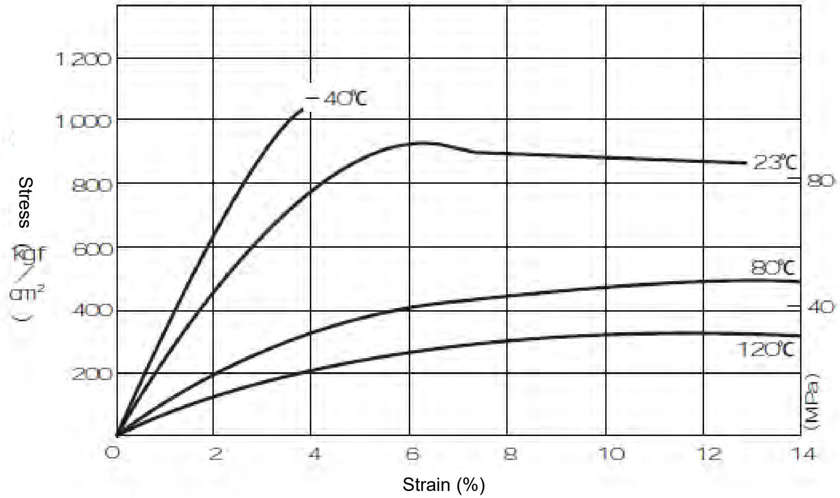


Figure-82 Stress-strain curve

(FR370)



4-2 Change of mechanical physical properties with temperature

(1) Tensile strength

Figure-83 Change of tensile strength with temperature

(1300S)

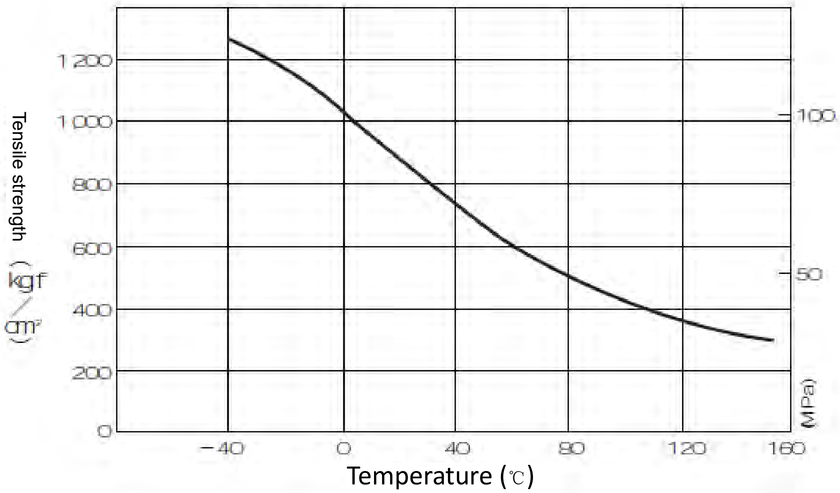


Figure-84 Change of tensile strength with temperature

(1300G)

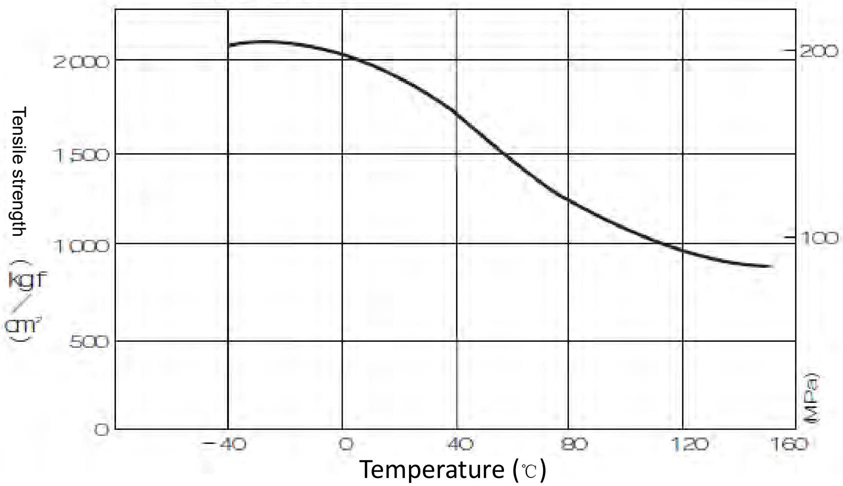
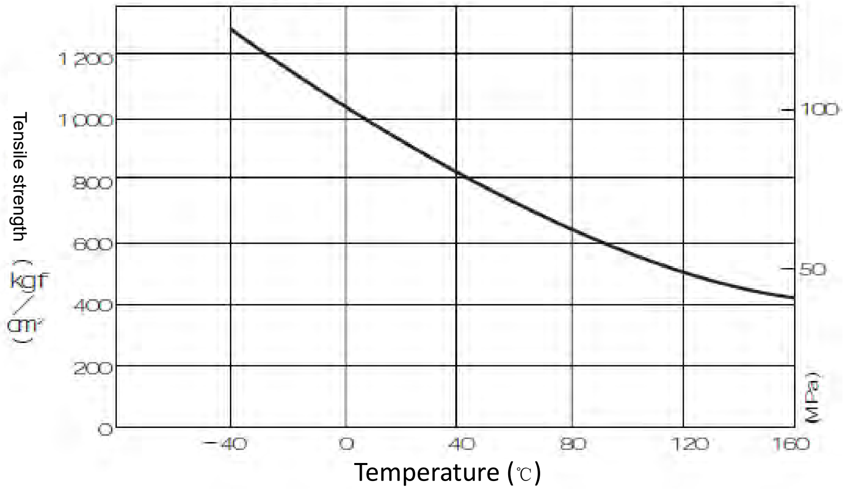


Figure-85 Change of tensile strength with temperature

(FR370)



(2) Fracture strain

Figure-86 Change of fracture strain with temperature

(1300S)

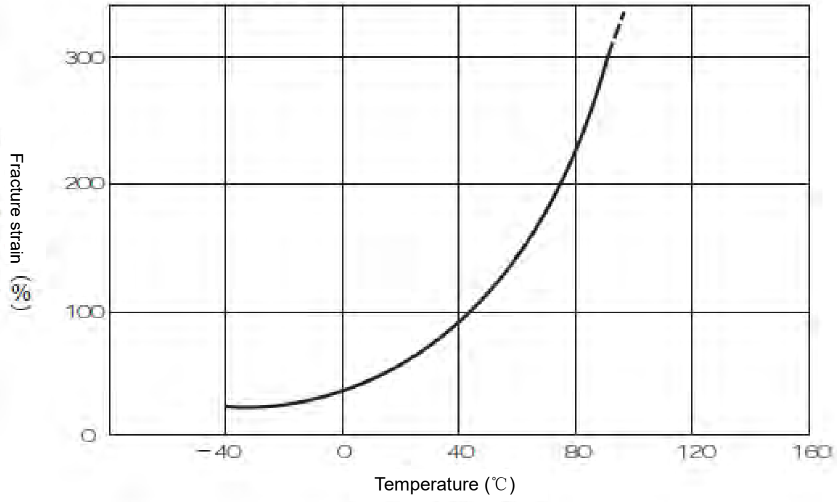


Figure-87 Change of fracture strain with temperature

(1300G)

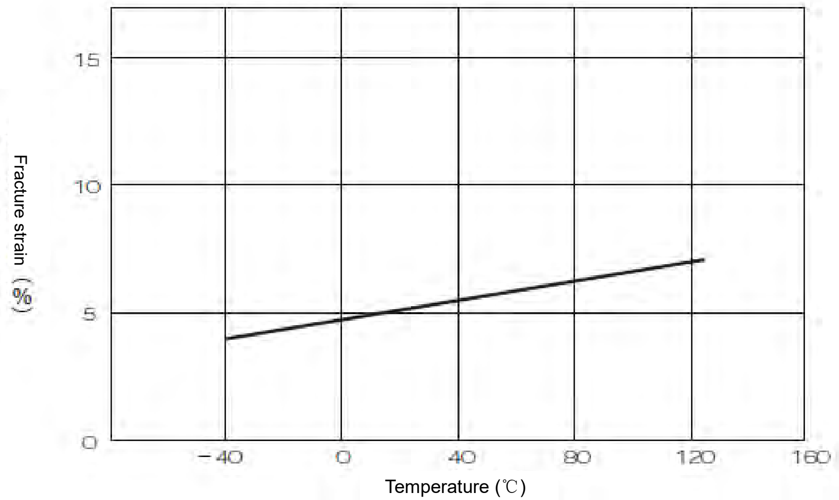
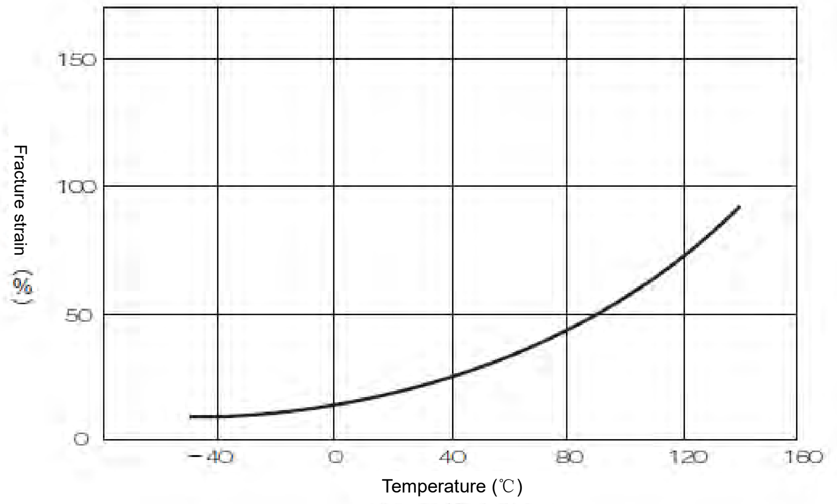


Figure-88 Change of fracture strain with temperature

(FR370)



(3) Flexural modulus

Figure-89 Change of flexural modulus with temperature
(1300S)

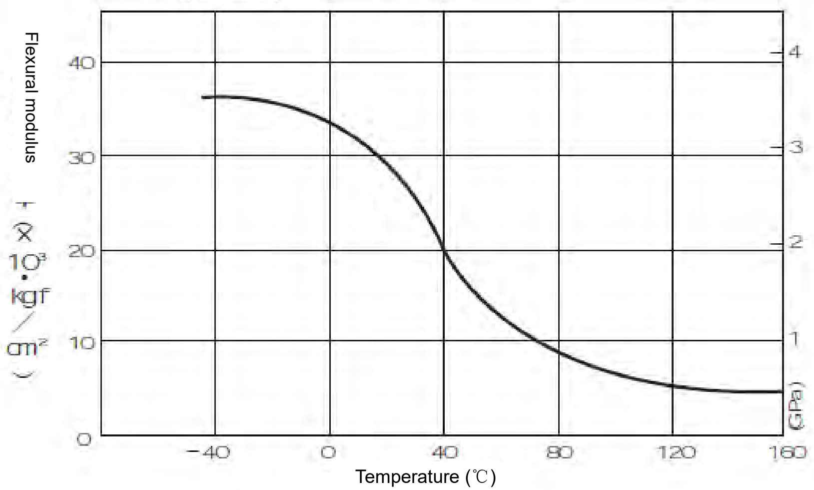


Figure-90 Change of flexural modulus with temperature
(1300G)

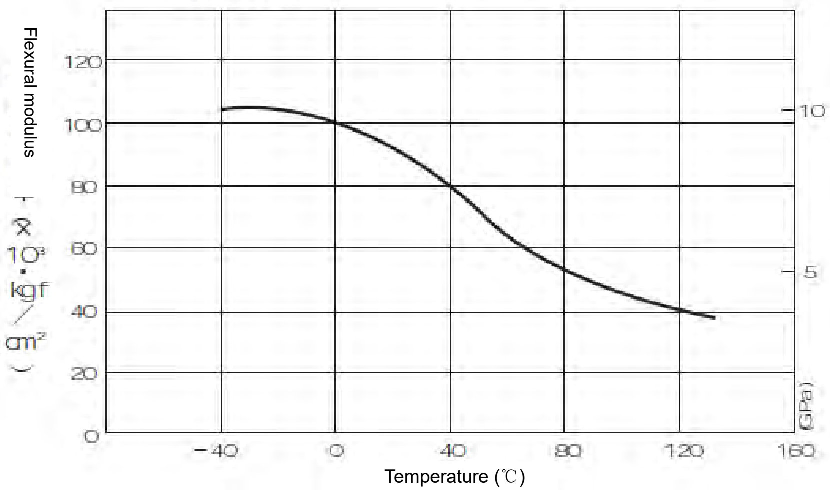
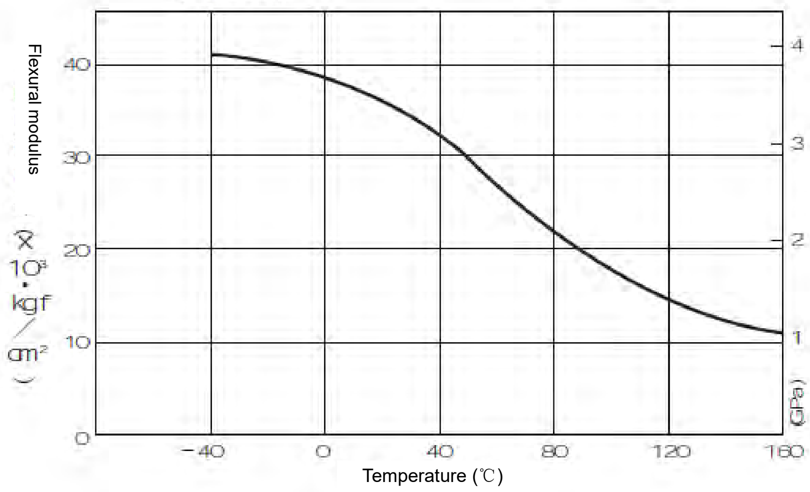


図 91 曲げ弾性率の温度依存性
(F R 370)



LEONA temperature dependency

(4) Izod impact strength

Figure-92 Change of izod impact strength with temperature
(1300S)

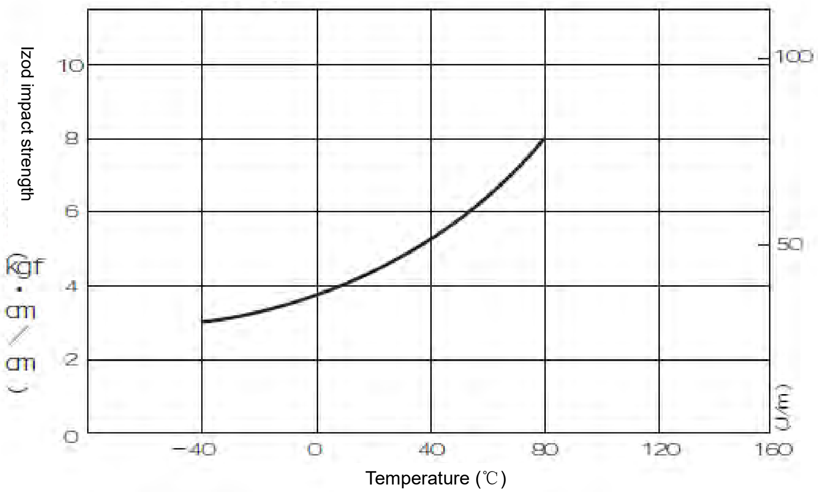


Figure-93 Change of izod impact strength with temperature
(1300G)

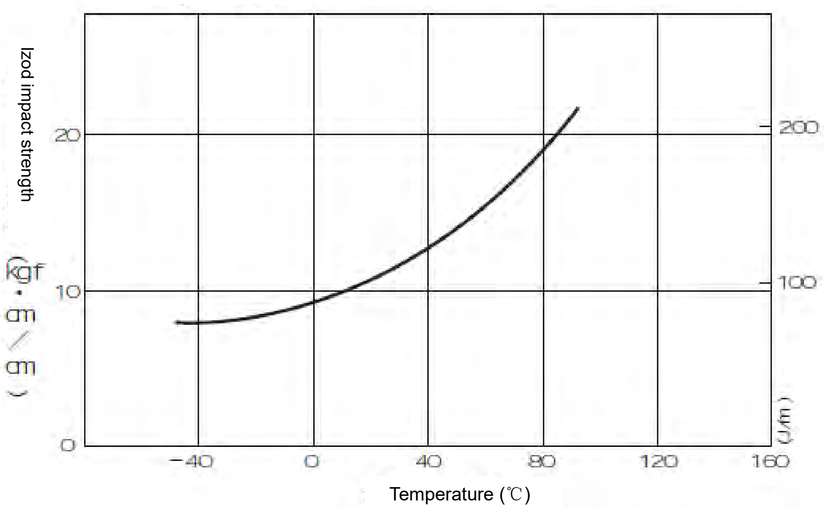
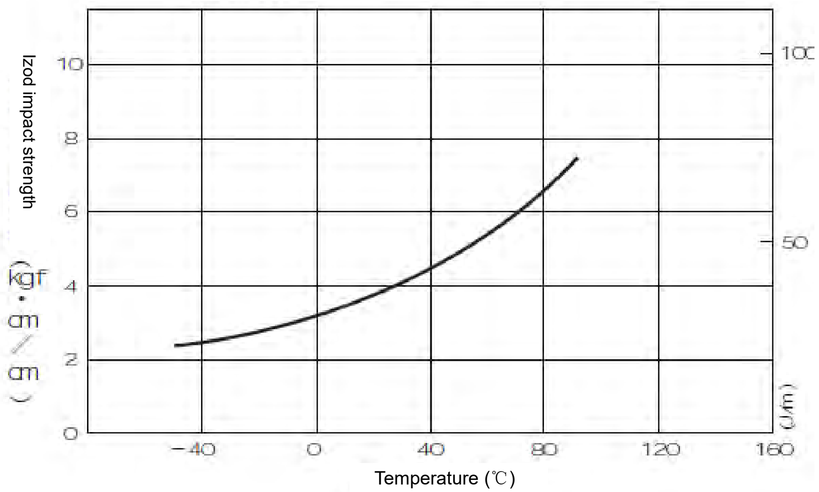


Figure-94 Change of izod impact strength with temperature
(FR370)



General specification
Water absorption characteristics
Moisture dependency
Temperature dependency
Evaluation methods
Specifications and acts
Long-term characteristics
When replacing the metal
Product design
Mold for injection molding
Injection molding technology
Fault cases and countermeasures of molding products

(5) Weld line tensile strength

Figure-95 Change of weld line tensile strength with temperature

(1300S)

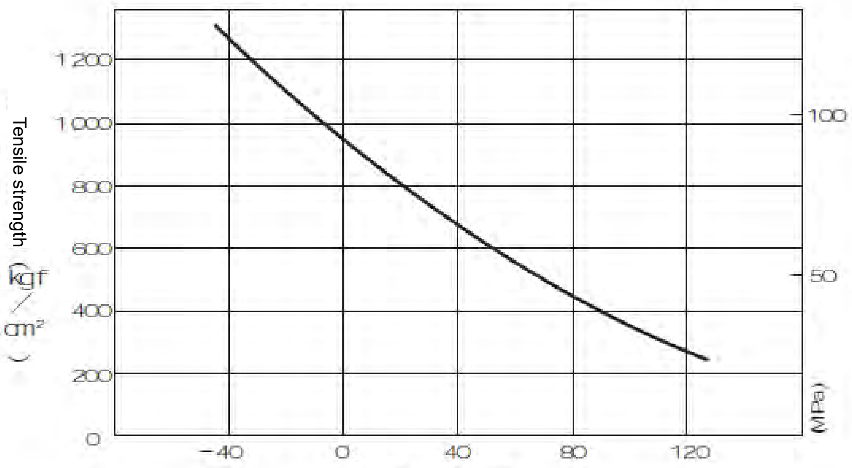


Figure-96 Change of weld line tensile strength with temperature

(1300G)

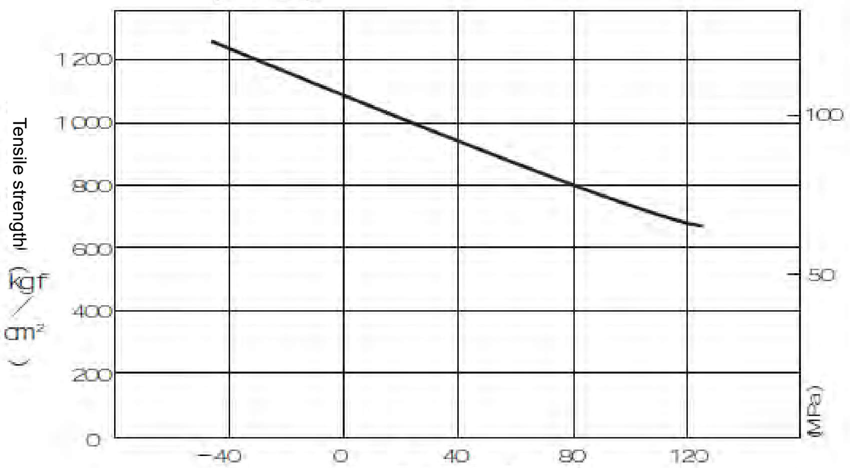
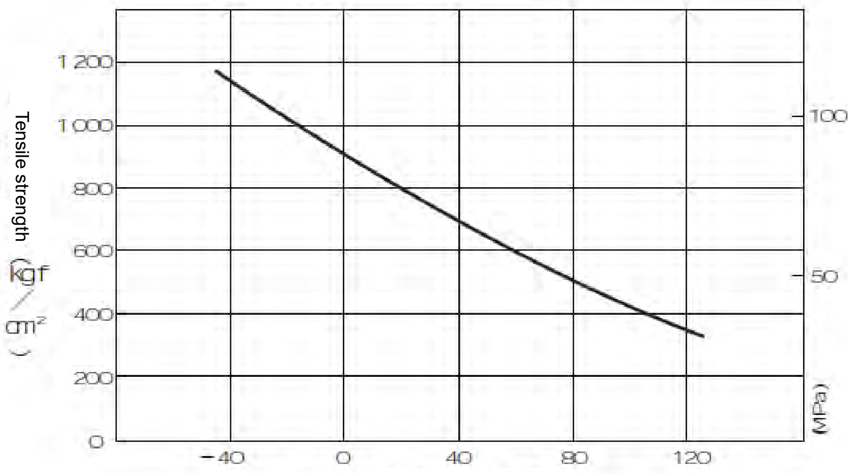


Figure-97 Change of weld line tensile strength with temperature

(FR370)



4-3 Change of electrical characteristics with temperature

(1) Breakdown voltage

Figure-98 Change of breakdown voltage with temperature

(1300S)

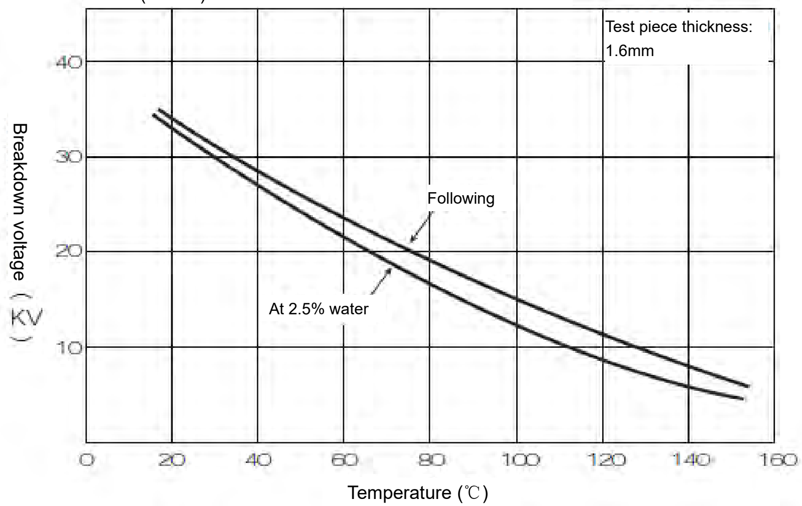


Figure-99 Change of breakdown voltage with temperature

(1300G)

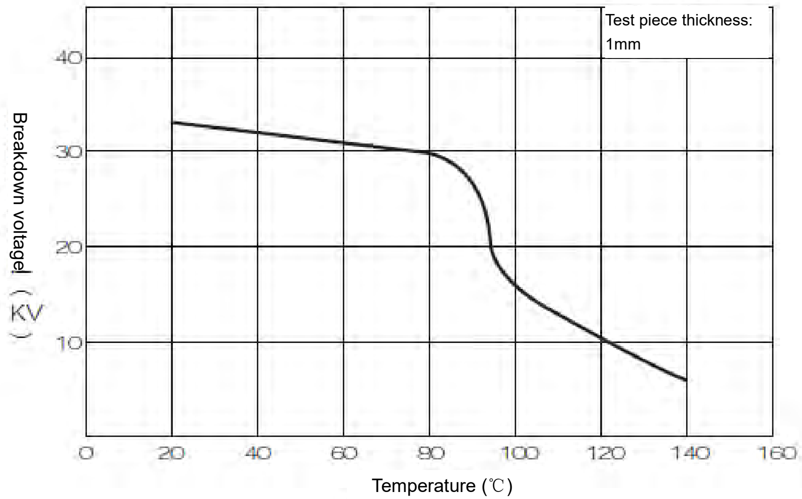
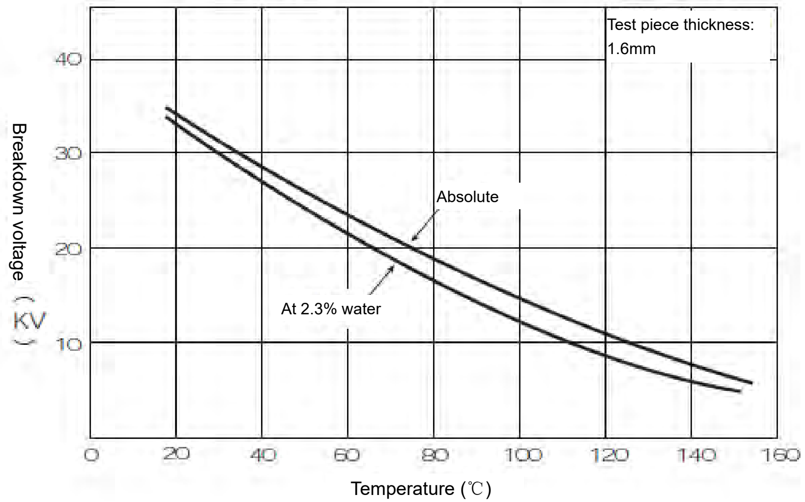


Figure-100 Change of breakdown voltage with temperature

(FR370)



(2) Surface resistivity

Figure-101 Change of surface resistivity with temperature

(1300S)

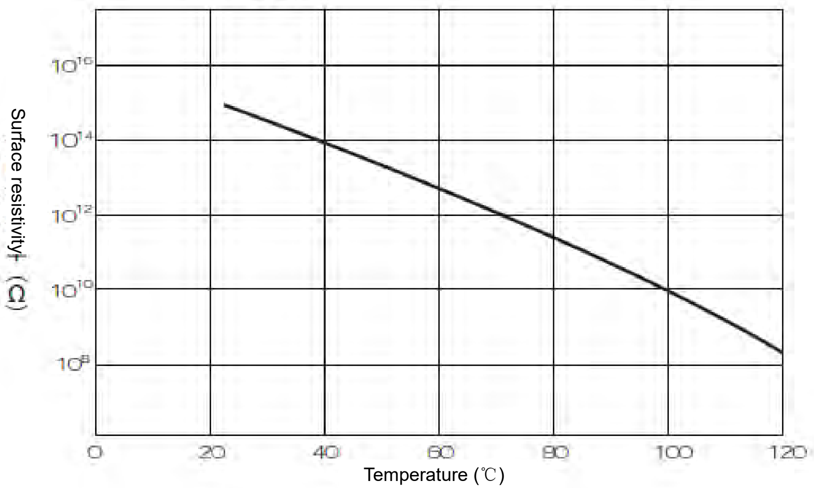


Figure-102 Change of surface resistivity with temperature

(1300G)

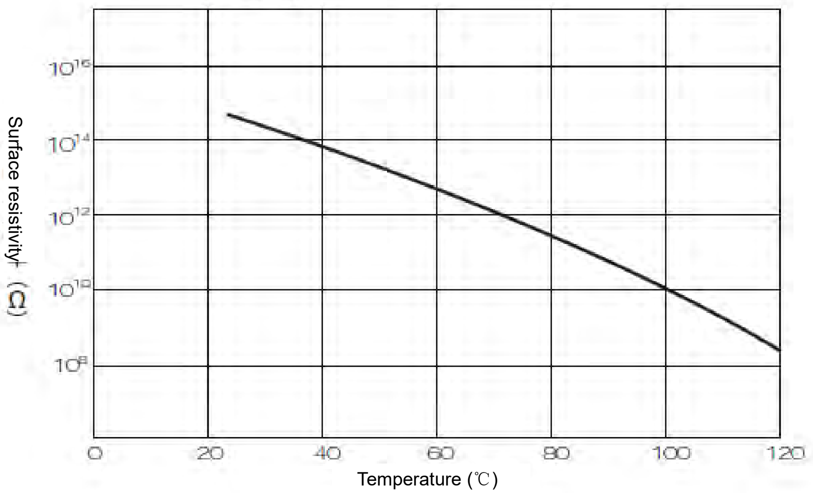
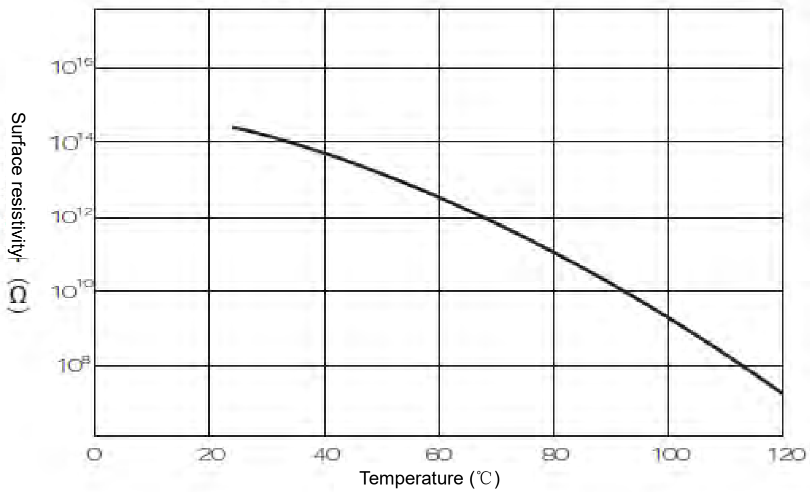


Figure-103 Change of surface resistivity with temperature

(FR370)



(3) Volume resistivity

Figure-104 Change of volume resistivity with temperature

(1300S)

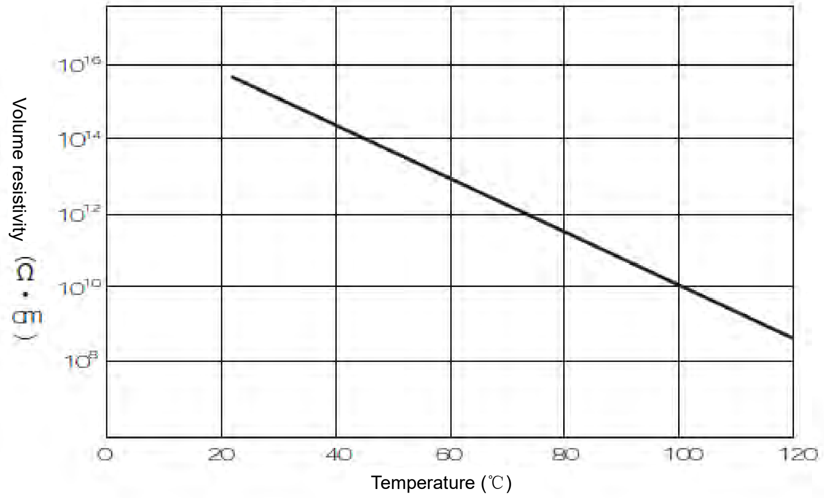


Figure-105 Change of volume resistivity with temperature

(1300G)

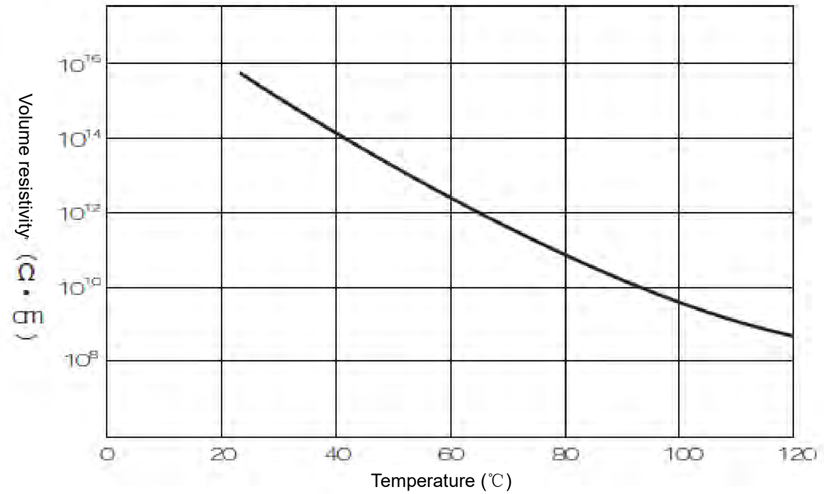
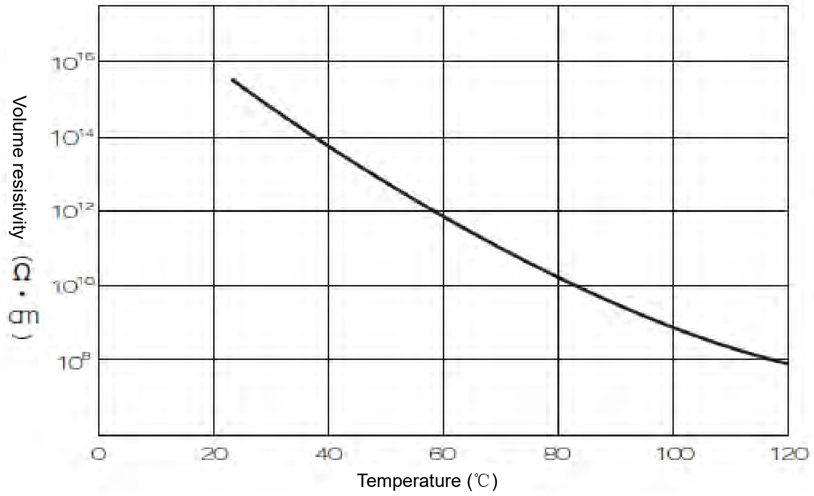


Figure-106 Change of volume resistivity with temperature

(FR370)



(4) Dielectric constant

Figure-107 Change of dielectric constant with temperature

(1300S)

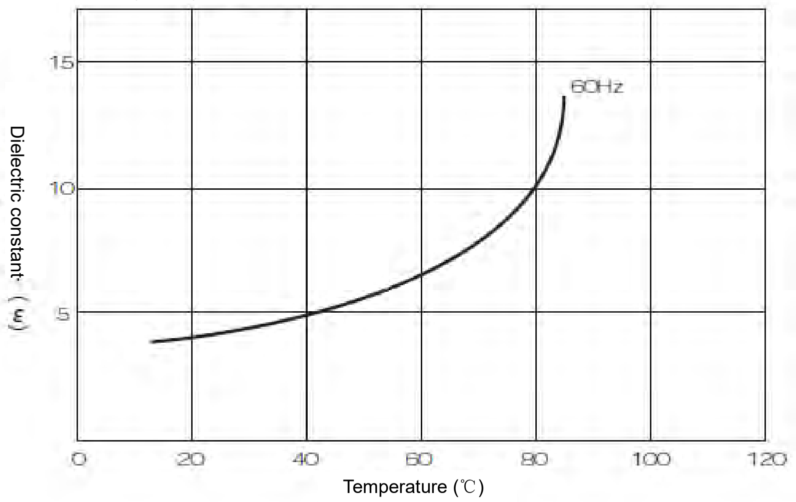


Figure-108 Change of dielectric constant with temperature

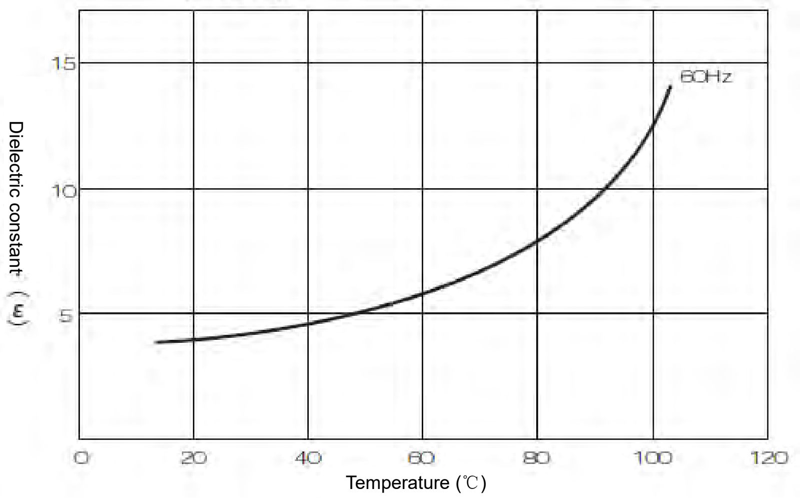
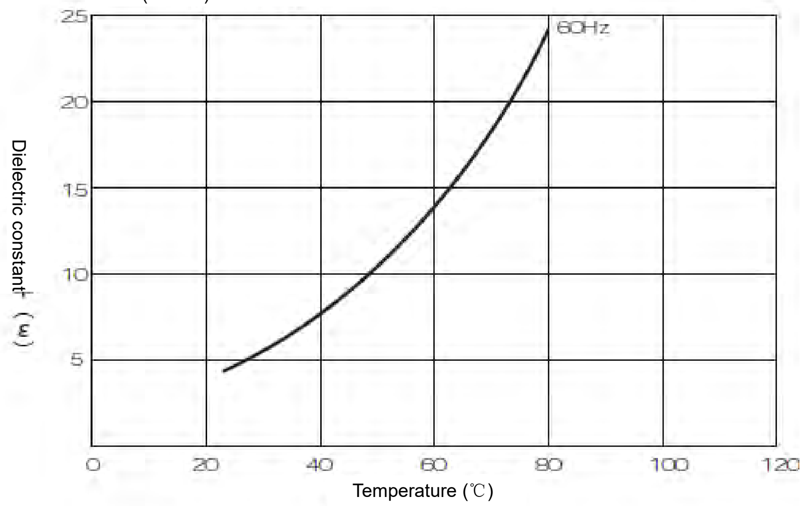


Figure-109 Change of dielectric constant with temperature

(FR370)



(5) Dissipation factor

Figure-110 Change of dissipation factor with temperature

(1300S)

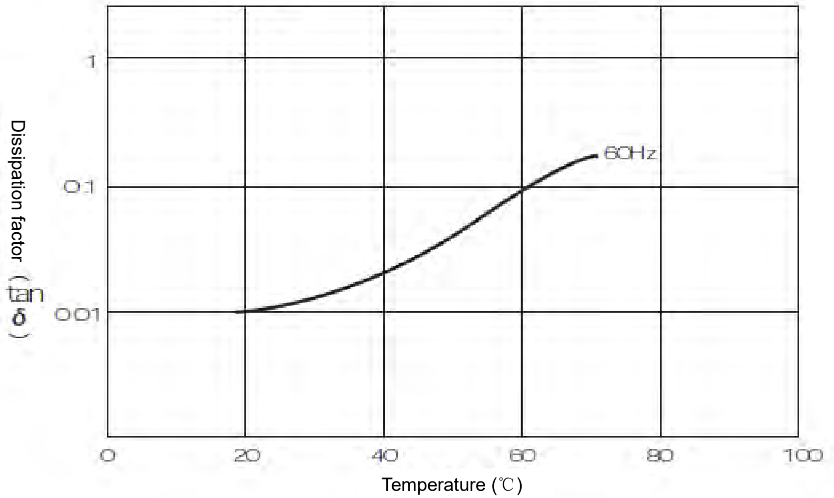


Figure-111 Change of dissipation factor with temperature

(1300G)

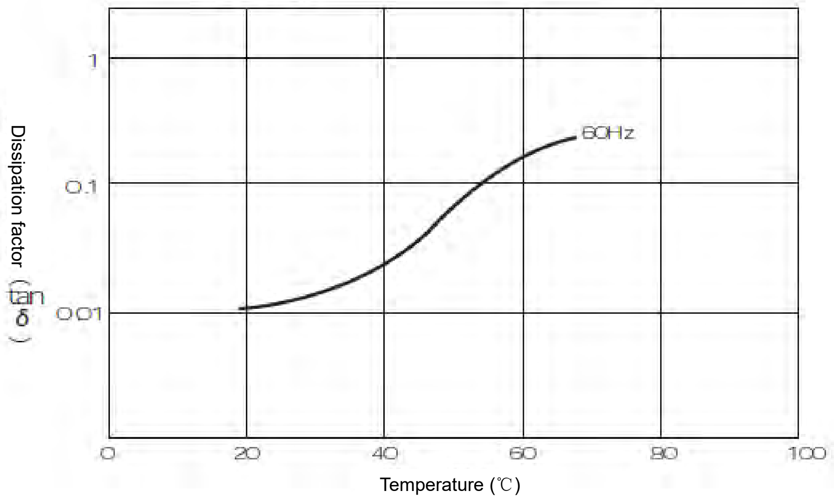
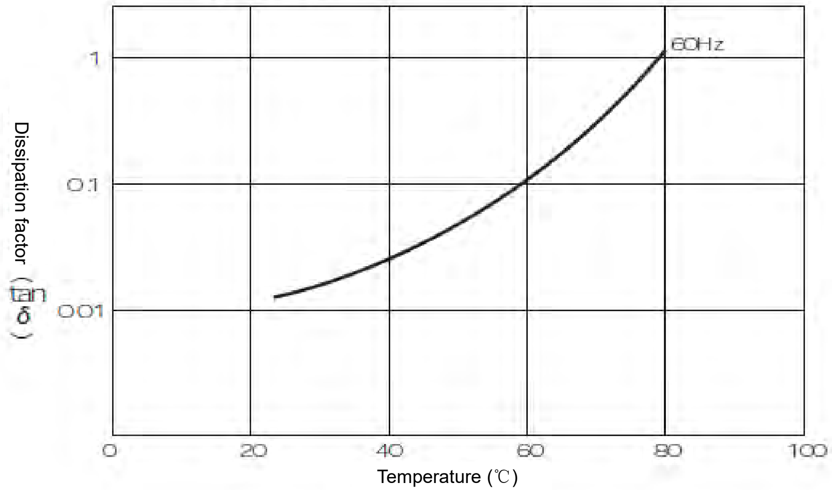


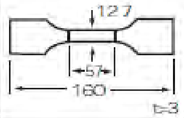
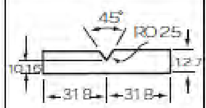
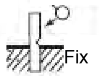
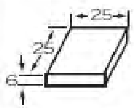
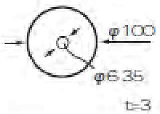
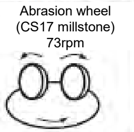
Figure-112 Change of dissipation factor with temperature

(FR370)

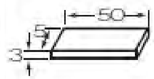
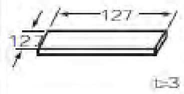
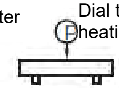
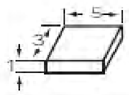
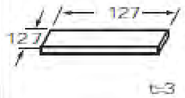
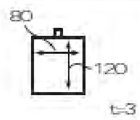
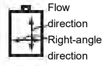


5. LEONA evaluation methods

Table 10: Summary of LEONA evaluation methods

	Physical properties	Test (ASTM)	Test piece (unit: mm)	Tester and test
Mechanical physical properties	Tensile strength	D638		Tensile testing machine Tensile speed 5mm/min
	Fracture strain	D638	The same as	Tensile testing machine (strain between marked lines) Tensile speed 5mm/min, 50.8mm between marked lines
	Bending strength	D790		Tensile compression tester Bending speed 5mm/min, 50.8mm between fulcrums
	Flexural modulus	D790	The same as	The same as
	Izod impact strength (With notch)	D256		Izod impact tester Impact speed 3.4m/sec 
	Rockwell hardness	D785		Rockwell hardness tester R-Scale:12.7mmD steel ball M-Scale:6.350mmD steel ball
	Taber abrasion test	D1044		Taber abrasion tester Load 1000g 1000r 

Summary of LEONA evaluation

	Physical properties	Test methods (ASTM)	Test piece (unit: mm)	Tester and test
Thermal physical properties	Coefficient of linear expansion	D696		Silica dilatometer -30℃~+30℃ 
	Heat deflection temperature 1.82MPa 0.46MPa	D648		Heat deflection Tester Dial test indicator, heating 2℃/min 
General physical properties	Relative density (Density)	D792 D1505		Water buoyancy method (Density gradient tube measuring equipment) 
	Water absorption	—		In constant temperature and humidity room at 23℃ and 50%RH Measure the weight in balanced
	Molding shrinkage (3mmt) Flow direction/ right-angle direction	(Asahi Kasei method)		 Measure after molding (after 40h) Use micrometer

6-1 UL specifications (Underwriters Laboratories Inc.)

UL is an American institution and specifications established privately for product safety tests for the underwriter (Underwrites) to prevent electrical and fire accidents.The basic content of product safety tests include elimination of reasons for product accidents, safety mechanism in case of fault, disaster prevention and fire prevention.The confirmation system for raw materials and semi-finished products that cannot be used as parts and semi-finished products is available in this approval system; the test items required for the parts and finished product can be omitted through maintenance of this system.

1. UL94 Flame retardant test of plastic materials
2. UL746A 〃 Specification of short-term physical property evaluation
3. UL746B 〃 Specification of long-term physical property evaluation
4. UL746C 〃 Specification of electrical equipment usage evaluation
5. UL746D 〃 Specification of assembly parts (molder program)

Figure 113 is the flow chart of flame retardant grades of various materials in UL94 and Figure 11 shows the test methods and criteria of UL94HB and V ratings.The rated temperature and UL PLC are explained in P100~102.

Figure-113 Flame Retardance Summary of Various Materials in UL94

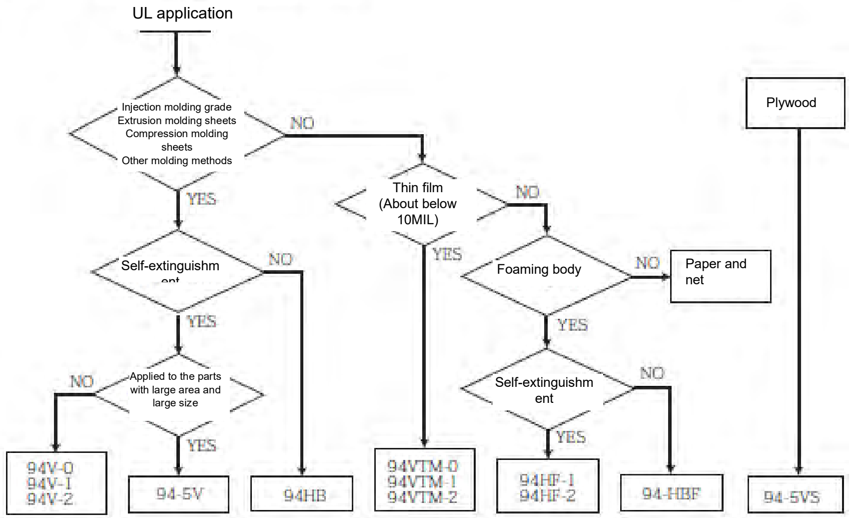


Table 11: Test methods and criteria for 94HB and V rating

Flame retardant / Item	94 HB	94 V-2	94 V-1	94 V-0
Test piece size	A1	A	A	A
Sample pretreatment	I	I&II	I&II	I&II
Sample fixation method	Horizontal	Vertical	Vertical	Vertical
Sample number	n=3	Treatment conditions n=5	The same with the left	The same with the left
Flame length (mm)	1-inch blue flame	3/4-inch blue flame	3/4-inch blue flame	3/4-inch blue flame
Test method	Draw marked lines at 1-inch and 4-inch position at the edge of the sample and measure the burning velocity between 3-inch marked lines in the middle 30s after one end contacts the flame.	Keep the 6-inch flame away from the sample and measure the sample burning time 10s after the lower center of the sample is in contact with the flame. Immediately contact the flame again after flameout and move the flame 10s later. Record the burning time, residual flame time and whether the surgical degreasing cotton placed under 12-inch flame is ignited.		
Criteria	① Flameout of marked line no more than 1inch ② Flameout of marked line no more than 4 inches ③ Below 1.5 inches/min if the sample thickness is 0.120～0.125 inches ④ Below 3.0 inches/min if the sample thickness is no greater than 0.120 inches	Any item of b d g h is met.	Any item of b d e g h is met.	Any item of a c e f h is met.

Test piece size
A1: 5"×1/2"×0.125"±0.005" and if required, minimum thickness no greater than 0.062"
A: 5"×1/2"× minimum thickness
5"×1/2"× maximum thickness (not exceeding 1/2")
5"×1/2"× intermediate thickness (not exceeding 0.125")

Sample pretreatment
Ⅰ: 48hr at 23±2℃ and 50±5%RH
Ⅱ: 168hr at 70±1℃

Criteria
a. Discontinuous combustion for more than 10s after flame application once
b. Discontinuous combustion for more than 30s after flame application once
c. Burning time of 5 samples within 50s after flame application twice on each and total 10 times
d. Burning time of 5 samples within 250s after flame application twice on each and total 10 times
e. Degreasing cotton not burnt 12'' after fire ball drops
f. Residual flame time within 30s after second flame application
g. Residual flame time within 60s after second flame application
h. Pressing plate cannot be burnt

UL94 Burning test methods

Figure-114 HB (horizontal burning method)

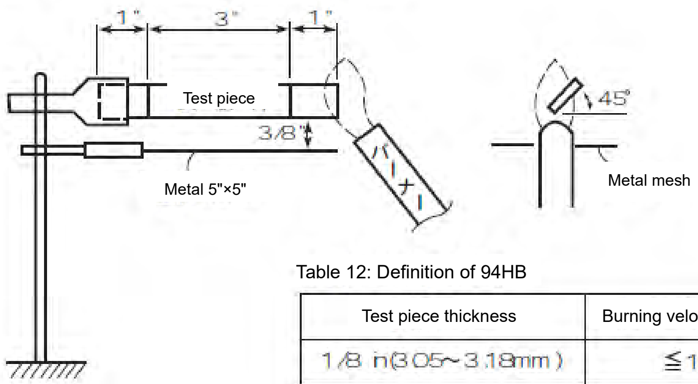


Table 12: Definition of 94HB

Test piece thickness	Burning velocity (in/min)
1/8 in(3.05~3.18mm)	≦1.5
1/6 in(1.47~1.59mm)	≦3.0

Figure-115 VB(vertical burning method)

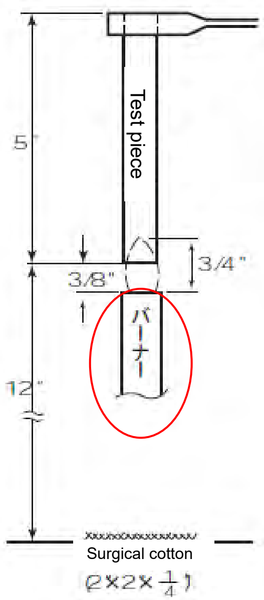


Table 13: Definitions of 94V-0, 1 and

Level	Flame out time (s)		Degreasing cotton on fire caused by molten drops	Residual flame time (s)
	※	Maximum		
94V-0	≦5	≦10	NA	≦30
94V-1	≦25	≦30	NA	≦60
94V-2	≦25	≦30	Available	≦60

(* Each test piece is applied with flame twice for 10s each time

Description of certification table

Table 14: Example: UL certification of 1320S

(Since May 1996)

Color	Thickness (mm)	Rated			Flamma	PLC (PLC*)				
		Electrical characteristics	External			Hot wire ignition	High current arc ignitability	High voltage movement	Arc resistance (D495)	Arc track resistance
			With impact	Without impact						
All colors	0.75	120	95	90	94V-2	4	0	—	—	—
	1.5	120	95	90	94V-2	3	0	—	—	—
	3.18	120	95	100	94V-2	3	0	0	5	0

(UL document No.E48285)

＊PLC: Performance Level Categories

1. Rated temperature (relative temperature index): RTI

Rated temperature refers to the specific temperature when the initial physical values (electrical and mechanical) fall to 50% after exposure to the atmosphere for 100,000hr.

(1) Electrical characteristics: Elec

Applicable to the operating environment not applied with external mechanical force, and judged according to the dielectric breakdown voltage (short time method in the atmpsphere)

(2) External mechanical force (with impact): Mech. with imp

Applicable to the operating environment applied with external dynamic force (impact force, such as blower falling). The thermoplastic plastics is judged according to the tensile impact value (the thermosetting plastic is judged according to the izod impact strength value).

(3) External mechanical force (without impact): Mech. W/O imp

Applicable to the operating environment applied with external static force. The thermoplastic resin is judged according to the tensile strength (the thermosetting plastic is judged according to the bending strength).

6-2 UL PLC (PLC: PerformanceLevelCategories) implemented on February 1, 1985

(1) Hot wire ignition: HWI (imaging that the material is on fire due to overheating)

Table 15: HWI PLC

Range - average ignition time	Corresponding PLC
120≦ignition time (IT)	0
60≦ignition time ＜ 120	1
30≦ignition time ＜ 60	2
15≦ignition time ＜	3
	4
	5

(2) High current arc ignition: HAI (property of material on fire due to arc discharge)

Table 16: PLC of high current arc ignition

Range - average number of arc (NA)	Corresponding PLC
120≦number of arc	0
60≦number of arc＜ 120	1
30≦number of arc＜ 60	2
15≦number of arc＜	3
	4

(3) Arc resistance: (measure the level of difficulty to form conductive paths on the material surface due to arc according to ASTM D495)

Average arc resistance duration	Corresponding PLC
420≦ arc resistance duration (TAR)	0
360≦ arc resistance duration 420	1
300≦ arc resistance duration 360	2
240≦ arc resistance duration 300	3
180≦ arc resistance duration 240	4
120≦ arc resistance duration 180	5
60≦ arc resistance duration 120	6
0≦ arc resistance duration 60	7

4) High voltage arc tracking rate: HVTR

This test is to image high-voltage and low-current arc discharge generated repeatedly on the surface in case of HV power supply fault, so as to measure the difficulty in generating conductive path on the material surface.

Table 18: PLC of high voltage arc tracking rate

Range - tracking rate (mm/min) (TR)	Corresponding PLC
0＜tracking rate≦10	0
10＜tracking rate≦25.4	1
25.4＜tracking rate≦80	2
80＜tracking rate≦150	3
150＜tracking rate	4

High voltage arc tracking rate refers to the rate of formation of conducting channel on the material surface under standard test conditions and is measured by mm/min.

(5) Comparative tracking index: CTI

Minimum voltage to form permanent carbonized conductive path

Table 19: PLC of comparative tracking index

Range - tracking index (voltage V)	Corresponding PLC
600≦tracking index (TI)	0
400≦tracking index ＜600	1
250≦tracking index ＜400	2
175≦tracking index ＜250	3
100≦tracking index ＜175	4
0≦tracking index ＜100	5

6-3 CSA specifications (Canadian Standards Association)

CSA outline

The electrical products, electric apparatuses, wires, electrical parts, materials, gas appliances, oil burning appliances, motorcycle safety helmets and automotive seat belts other than the articles approved by local inspection bureau of the state or CSA are not used or sold considering the personal safety (risk of electric shock in electrical products) and fire safety (fire and other risks caused by short circuit, electric leakage and temperature rise in electrical products) according to the decrees of each state in Canada.

However, the low voltage electrical equipment only with the battery as the power supply is considered as non-dangerous goods and not limited by this provision.Above equipment not approved by the state inspection authorities or CSA is subject to tour investigation by the state or CSA inspectors and, if disclosed, will be withdrawn from the market at the costs of the buyer or punished according to unlawful acts.

CSA specifications

CS specification categories include CIVILENGINEERING of department A to MISCELLANEOUS of department Z, in which, the safety specifications of electrical products classified as PARTIIC22.2 in c electrical department, part of MECHANICAL ENGINEER-ING (such as oil heat appliances) in department B and part of AUTOMOTIVEWORK (such as automotive seat belts and motorcycle safety helmets) in department D are approved according to CSA safety specifications and related to plastics.

The electrical department accounting for the vast majority of above CSA safety approval related specifications is classified as the following PART I～V, and PART II C22.2 in terms of electrical products is directly related to CSA safety specification approval.

Table 20 shows burning test content and Table 21 shows the correspondence between the material test items and UL.

PART I WIRING RULES
PART II SAFETY STANDARDS FOR ELECTRICAL EQUIPMENT
PART Ⅲ OUTSIDE WIRING RULES
PART Ⅳ RADIO INTERFERENCE
PART V MINES

Table 20: Combustibility of plastic materials

CSA specification (C22.2 No.0.6 test content)				
No.	Abbreviated name	Test name	Test content	Corresponding UL specification
01	Test A	127mm burning test	① Flame -127mm ② Sample -100×150mm ③n＝3 ④ (Flame application time 15s - time away from flame 15s ×5 ⑤ Burning after 4 times＜30s ⑥ Burning after 5 times＜60s	NA, strictest burning test in the world
02	B	Burning test of flame retardant materials	①～③ and ⑤⑥ are the same as above.④ (Flame application time 5s - time away from flame 5s) ×5 ⑦ Do the dropping objects cause fire on the degreasing cotton?⑧ Keep the samples in clamping status until non-combustion	B method of UL94-5
03	C	Horizontal/vertical tests of flame retardant materials	Product test (Irrelevant to the material manufacturer)	-
04	D	Horizontal burning test/19mm yellow flame	① 19mm yellow flame ②③ the same as above④ (Flame application time 30s—away from the flame -60s)X2 ⑤Burning time <60s	19mm yellow flame test of portable devices in UL746 C
05	E	Horizontal burning test at 0.6HB level	① 25mm blue flame ② Sample-12.5 ×125mm, consistent with UL94HB	ＵＬ94HB
06	F	Vertical burning test of 0.6V0～V2	①19mm blue flame ② The same as above ③n＝10 ④ Flame application time 10s- away from the flame 10s later) ×2, qualification judgment consistent with UL	UL94V0～V2
07	G	Burning test of expansion surface coating	① Flame -127mm ② Sample-200×200mm ③n＝5 (horizontal and vertical) ④ Burning time 60s after flame application time ＜5s without dropping objects	Burning test of shell of UL 1410 TV set and other products
08	H	Burning test of foam materials	① 38mm blue flame ② Sample-50×150mm ③n＝10 ④ Burning time 60s after flame application time ＜2s (4/5 samples), max＜10s ⑦ The degreasing cotton does not catch fire	UL94HF-1 (strictest in UL)
09	I	Hot wire ignition test (HWI)	It is consistent with HWI of UL746 A, but the sample size is 150 ×13mm (UL is 127×12.7) and a little long.	HWI of UL746A
10	J	Burning test of fire retardant surface coating and liner	Consistent with test A;only test materials are different.	NA

Table 21: Test items of plastic materials

CSA specification (test items of C22. 2 No.0.11)				
	No.	Abbreviated name	Test name	Corresponding UL specification
Mechanical and thermal characteristics	01	TENSL	Tensile strength and elongation at break	UL746A
	02	IZOD	Izod impact strength	UL746A
	03	Drop W	Drop impact strength	–
	04	FLEX	Bending strength	UL746A
	05	DTuL	Heat deflection temperature	UL746A
	06	Vicat	Vicat softening temperature	–
	07	RTI	Relative temperature index	UL746B※
	08	TENSIMPCT	Tensile impact strength	UL746A
Electrical and ignition impedance	09	DIElc	Breakdown strength	UL746A
	10	CTI	Comparative tracking index	UL746A
	11	HAI	High current arc ignitability	UL746A
	12	HVA	High voltage arc ignitability	UL746A (≒ASTM D495)
Identification	13	IR		UL746A
	14	TGA		UL746A
	15	DSC		UL746A

(Remark) ※ is cataloged for the first time and not in the cataloged

6-4 Supervision law on electrical appliances (electrical supervision law)

(1) Purpose

This law stipulates the manufacturing, sales and use provisions for electrical appliances to prevent the fire, electric shock and other risks caused by inferior electrical appliances and to reduce the radio noise.

(2) Definition of electrical appliances

The electrical appliances are classified into class A electrical appliances and class B electrical appliances.Class A electrical appliances refer to the electrical appliances with large possibility of danger or fault in terms of structure or usage methods and the other appliances are class B electrical appliances.The appliances meeting the following circumstances are selected as class A electrical appliances.

Class A electrical appliances

(1) Appliances with great possibility of danger or faults in structure
  a. Appliances generating high voltage in the equipment
  b. Appliances causing much fire in the equipment utilizing heat
  c. Appliances hindering electromagnetic wave

(2) Suppliers with large possibility of danger and fault in terms of usage methods and other usage conditions
  1) Generally used in humid environment
  2) Used during sleep time
  3) Used outdoors
  4) Mostly used by children
  5) Used in different places

(3) Technical standards

The manufacturers and importers of the electrical appliances shall perform the obligations for making the manufactured and imported electrical appliances comply with the technical standards, especially the standards related to engineering plastics, including "ball pressure temperature" and "upper limit of operating temperature".

Hot ball pressure temperature

(1) The equipment body material is required to withstand the temperature under general working conditions.Withstanding the temperature refers to the circumstance that the diameter of the concavity hole is less than 2mm after a steel ball with the diameter of 5mm is used to apply 2kgf static load for 1h at the temperature of 20℃ higher than the reached temperature when the material of the supporting shell or electrical insulator is thermoplastic.

The temperature obtained through the steel ball is called hot ball pressure temperature.

This test method is summarized as follows.

a) Test piece

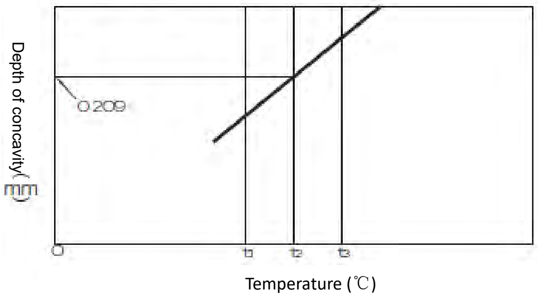
20mm×20mm×3mmt

Pretreatment for 100h in an air oven at 70℃

b) Steps

Press with a load bar after reaching the set temperature, preheat for 30min, apply 2kgf load for 1h, take out the test piece and immediately cool in 25℃ water for 30min.

Measure the depth of concavity, make the following chart, obtain the temperature corresponding to the depth of concavity of 0.209mm and take it as the hot ball pressure temperature.



t1, t3: test temperature

t2: Hot ball pressure temperature

※ Equivalent to the depth of concavity with the concavity hole diameter of 2mm

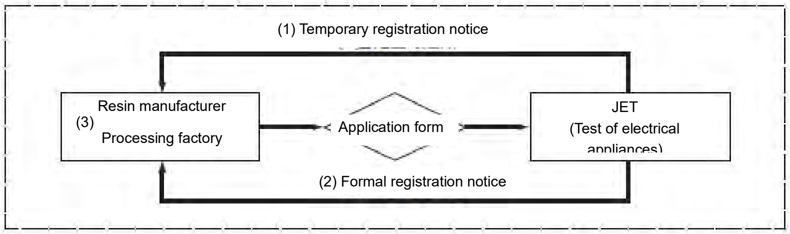
Upper limit of operating temperature

MITI Decree stipulates that "When approaching a temperature, the electrical insulator and thermal insulator shall be able to fully withstand......" and the materials may not be used under the temperature conditions exceeding the upper limit of the operating temperature.

This temperature, including inferred heat aging temperature (it is inferred that the dielectric breakdown pressure, tensile strength, impact resistance and other characteristics are not below 50% of the initial valve after 40,000hr), has been confirmed and tested and registered in Japanese electrical appliances institute and is equivalent to the registered upper limit of operating temperature.(Detailed material classification of each grade) Moreover, the upper limit of the operating temperature in MITI Decree schedule is the value under macrotaxonomy of the resins and the value of each grade cannot be obtained.

The registered upper limit of operating temperature is described below.

The temporarily registered value and formally registered value are available.The following figure is the flow chart from application to registration.



(1) Temporary registration refers to the remedial measure taken for the insulating materials with actual use performance till test completion,
The upper limit of operating temperature is temporarily affirmed when either of the following two items is met.

1) The experimental results of the principal are added as additional data for insulators and in the results, the upper limit of operating temperature exceeds the temperature 1 in the column of upper limit of operating temperature in MITI Decree schedule of the stipulated technical standards for electrical appliances and is within the range below the temperature 2 (refer to Table 23).
2) The formulas of the material submitted are subject to necessary chemical analysis and physical measurement and the results show that the material is the insulator meeting temporary registration conditions.

(2) When the following validation test is passed in the formal registration, the upper limit of the operating temperature will be approved and registered.

- Validation test
  - Basic material test
    - Chemical analysis and physical measurement
    - Thermal aging property test (calculate thermal aging and infer the temperature)
    - Three items in bending strength, impact strength, tensile impact strength, tensile strength, elongation at break and dielectric breakdown voltage (dielectric strength)
    - Only one item of dielectric breakdown voltage for the insulators not subject to external mechanical force
    - Dielectric breakdown voltage +2 items for the insulators subject to external mechanical force
  - Test material of the same series Simplified test

Table 22: Example: Organic materials (thermoplastic plastics)

Type (Material name)	Class (Reinforcer)	Upper limit of operating temperature 1	2
Isobutylene resin	—	50	90
Cellulose acetate resin	—		60
Cellulose acetate resin Butyrate resin	—		
Polystyrene	—	50	85
Polyamide	—	90	120
	Glass fiber	120	130
Polyamide mixture (for wires)	—	90	—

(4) Representation of table

Example: Upper limit of operating temperature of 1402S

Black color
Test piece thickness
130℃ of GF reinforced polyamide is MAX temperature
External mechanical force refers to external dynamic force

(Since July 1988)

Color	Thick (mm)	Upper limit of operating temperature (℃) Electrical and thermal insulators Position not subject to external mechanical force	Registration No. Unstamped / Temporary registration No. Ⓩ
Black	1.6	120	031 GNC 0350
Black	0.4	120	Ⓩ 031 GNC 0080 001

Code number of validation test dependent
Material class symbol
Registration number of material of the same series
Registration No.
Temporary registration symbol

Example: Hot ball pressure temperature of 1402S

(Since July 1988)

Registered	Registered	Registration	Remark
Temporary	145℃	TB 0284	Including

Material class symbol
Registration No.
The temporarily registered values of Polyamide 66 are mostly 145℃
The formal registration system was used from 1987 and the temporary registration system was used in 5 years

> Remark
> Comply with the provisions of relevant authorities when using these specifications and decrees

General specification | Water absorption characteristics | Moisture dependency | Temperature dependency | Evaluation methods | Specifications and acts | Long-term characteristics | When replacing the metal | Product design | Mold for injection molding | Injection molding technology | Fault cases and countermeasures of molding

6-5 Certification list

(1) UL certification

Table 24: UL certification list

＊Refer to the following URL for latest values.
http://data.ul.com/ULiQ_Link/

E 48285 (M)

Mtl Dsg (Grade)	Col	Min Thk mm	UL94 Flame Class	RTI			HWI	HAI	HVTR	D495	CTI
				Elec	Mech With Imp	Mech W/o Imp					
Polyamide (PA66), Type 66 nylon designated "Leona" furnished in the form of pellets.											
1300S	All	0.70	V−2	105	75	85	4	0	—	—	—
		1.5	V−2	105	75	85	4	0	—	—	—
		3.0	V−2	105	75	85	3	0	0	6	0
1402S	All	0.71	V−2	130	105	105	4	0	—	—	—
		1.5	V−2	130	105	105	3	0	—	—	—
		3.0	V−2	130	105	105	3	0	0	6	1
1402SH	All	0.69	V−2	120	95	100	4	0	—	—	—
		1.5	V−2	120	95	100	3	0	—	—	—
		3.0	V−2	120	95	100	2	0	0	6	1
13G15	All	0.75	HB	125	110	115	4	0	—	—	—
		1.5	HB	125	110	120	3	0	—	—	—
		3.0	HB	125	110	120	2	0	0	5	0
13G25	All	0.75	HB	125	110	115	4	0	—	—	—
		1.5	HB	125	110	120	3	0	—	—	—
		3.0	HB	125	110	120	3	0	1	5	0
1300G	All	0.75	HB	125	105	110	4	0	—	—	—
		1.5	HB	125	105	110	4	0	—	—	—
		3.0	HB	125	110	120	4	0	1	5	1
13G43	All	0.75	HB	110	110	115	4	0	—	—	—
		1.5	HB	110	110	120	2	0	—	—	—
		3.0	HB	110	110	120	3	0	1	5	0
14G15	All	0.75	HB	130	110	115	4	0	—	—	—
		1.5	HB	130	110	120	3	0	—	—	—
		3.0	HB	130	110	120	3	0	—	—	—
1402G	All	0.71	HB	120	90	110	4	0	—	—	—
		1.5	HB	120	90	120	3	0	—	—	—
		3.0	HB	120	100	125	0	0	1	6	1
14G25 14G33	All	0.75	HB	140	65	65	3	0	—	—	—
		1.5	HB	140	125	140	3	0	—	—	—
		3.0	HB	140	125	140	3	0	0	6	1
14G50	All	0.75	HB	140	65	65	3	0	—	—	—
		1.5	HB	140	125	140	0	0	—	—	—
		3.0	HB	140	125	140	0	0	0	5	0
90G33	All	1.5	HB	65	65	65	—	—	—	—	—
		3.0	HB	65	65	65	—	—	—	—	—
90G50	All	1.5	HB	65	65	65	2	0	—	—	—
		3.0	HB	65	65	65	0	0	0	5	0

E 48285 (M)

Mtl Dsg (Grade)	Col	Min Thk mm	UL94 Flame Class	RTI			HWI	HAI	HVTR	D495	CTI
				Elec	Mech With Imp	Mech W/o Imp					
Polyamide (PA66), Type 66 nylon designated "Leona" furnished in the form of pellets.											
93G33	All	1.5	HB	65	65	65	3	0	—	—	—
		3.0	HB	65	65	65	0	0	0	5	0
54G33	All	0.75	HB	125	90	120	3	0	—	—	—
		1.5	HB	125	90	120	2	0	—	—	—
		3.0	HB	125	90	120	0	0	1	6	1
54G43	All	0.80	HB	65	65	65	—	—	—	—	—
1330G	All	0.75	HB	125	105	105	4	0	—	—	—
		1.5	HB	125	105	115	1	0	—	—	—
		3.0	HB	125	105	120	0	0	1	5	0
MR001	All	0.71	HB	105	75	75	4	0	—	—	—
		1.5	HB	105	75	75	3	0	—	—	—
		3.0	HB	105	75	85	3	0	0	6	0
FR200	All	0.71	V−0	105	65	65	3	0	—	—	—
		1.5	V−0	105	65	65	3	0	—	—	—
		3.0	V−0	105	65	65	2	0	0	5	0
FR370	All	0.38	V−0	95	—	95	—	—	—	—	—
		0.75	V−0	130	90	105	4	1	—	—	—
		1.5	V−0	130	105	105	3	0	—	—	—
		3.0	V−0	130	105	105	2	0	0	5	0
FG170	BK	0.4	V−0	65	65	65	—	—	—	—	—
	All	0.75	V−0	105	105	105	0	0	—	—	—
		1.5	V−0	105	105	105	0	0	—	—	—
		3.0	V−0	105	105	105	0	0	1	6	3
FG172	NC	0.41	V−0	65	—	65	—	—	—	—	—
		0.50	V−0	130	—	65	0	0	—	—	—
	All	0.75	V−0	130	115	120	0	0	—	—	—
		1.5	V−0, 5VA	130	115	120	0	0	—	—	—
		3.0	V−0	130	115	120	0	0	1	6	2
FG171	NC	0.50	V−0	130	—	—	1	0	—	—	—
	All	0.75	V−0	130	—	120	0	0	—	—	—
		1.5	V−0	130	115	120	0	0	—	—	—
		3.0	V−0	130	115	120	0	0	1	6	2
FG173	NC	0.50	V−0	65	65	65	0	0	—	—	—
		0.72	V−0	65	65	65	0	0	—	—	—
	All	0.75	V−0	130	110	110	0	0	—	—	—
		1.5	V−0	130	120	120	0	0	—	—	—
		3.0	V−0	130	120	120	0	0	3	7	2
FH772	All	0.70	V−0	65	65	65	—	—	—	—	—
		0.75	V−0	65	65	65	0	0	—	—	—
		3.0	V−0	65	65	65	—	—	2	5	0

E 66823 (M)

Concentrate Dsg		LetDown Col		Min Thk mm	Max LetDown Ratio	UL94 Flame Class
LC020		All		0.75	1:10	HB
Color concentrate, furnished in the form of pellets or powder, for use in Recognizes Polyamide 66 (PA66) resins designated "Leona" covered in File E48285 for Asahi Kasei Corp.						
Concentrate Dsg	Base Resin Mfr	Mtl Dsg	LD Col	Min Thk mm	Max LetDown Ratio	UL94 Flame Class
Color concentrate, furnished in the form of pellets, for use in specific recognized Type66 nylons shown.						
LC020	Asahi Kasei corp.	1300S	All	0.71	1:10	V–2
		1302S	All	0.71	1:10	V–2
		1402S	All	0.71	1:10	V–2
		1402SH	All	0.69	1:20	V–2
		FR200	All	0.71	1:20	V–0
		FR370	All	0.75	1:20	V–0
		FG170	All	0.75	1:20	V–0
		FG172	All	0.75	1:20	V–0
		FG173	All	0.75	1:20	V–0

Table 24: List of upper limits of operating temperature

Trademark	Color	Thickness (mm)	Upper limit of operating temperature (℃): Motor insulator – Position subject to external mechanical force without impact	Motor insulator – Position not subject to external mechanical force	Thermal insulator – Position subject to external mechanical force without impact	Formal temperature (without seal) Temporary registration (Z) Designation
LEONA 1300S	All colors	1.6		135		031GNC 0422
	All colors	0.83		140		031GNC 0194
	All colors	0.4		135		031GNC 042–001
LEONA 1302S	All colors	1.6		120		(Z)031GNC 0457–002
	All colors	0.4		115		(Z)031GNC 0457–003
LEONA 1402S	All colors	1.6	115	125	115	(Z)031GNC 0457
	All colors	0.4		120		(Z)031GNC 0457–001
LEONA 1402G	All colors	1.6		125		031GND 0351
LEONA MR001	All colors	1.6	110	140	110	031GND 0406
	All colors	0.78		145		031GNC 0195
LEONA FR200	All colors	0.4		130		031GNC 0212
LEONA FR370	All colors	0.4		130		031GNC 0293
LEONA FG170	All colors	0.78		130		031GNC 0497
LEONA FG171	All colors	0.78		130		031GND 0351–001
LEONA FG172	All colors	0.78		130		031GND 0633

Table 25: Hot ball pressure temperature registration list

Trade name	Trademark	Color	Registered temperature (℃)	Registration No.
LEONA	1300S、1500 1700Q、1302S、1402S	All colors	160	B0985
LEONA	FR370	All colors	160	B0986
LEONA	1300G、1402G	All colors	160	B09875
LEONA	13G43、14G43	All colors	160	B0988
LEONA	FG171	All colors	160	B0989
LEONA	FG172	All colors	160	B0989
LEONA	FG170	All colors	160	B0993
LEONA	MR001	All colors	160	B0990
LEONA	1330G	All colors	160	B0991
LEONA	FR200	All colors	160	B0994

Table 26: Horizontal burning registration list

Trade name and trademark		Color	Thickness (mm)	Burning velocity	Registration
LEONA	MR001	All colors	2.0	40	H−0158
LEONA	MR001	All colors	1.0	75	HS−0059
LEONA	FG170,FG173,FG172, FG171	All colors	0.8	40	H−0294
LEONA	CR302	All colors	2.0	40	H−0295
LEONA	CR302	All colors	1.0	75	HS−0109
LEONA	1300S,1200S,1302S、1402S	All colors	0.9	40	H−0840
LEONA	13G15	All colors	0.9	40	H−0842
LEONA	1700S	All colors	1.7	40	H−0841
LEONA	1700S	All colors	0.9	75	HS−0345
LEONA	FR200	All colors	0.9	40	H−1054
LEONA	FR370	All colors	0.9	40	H−1057
LEONA	13G43,1300G,14G15 1402G,14G43	All colors	1.7	40	H−1058
LEONA	13G43,1300G,14G15 1402G,14G43	All colors	1.0	75	HS−0432
LEONA	CR301	All colors	1.7	40	H−1402
LEONA	CR301	All colors	0.8	75	HS−0561
LEONA	CR700	Black	1.4	40	H−0297
LEONA	CR700	Black	1.0	75	HS−0111
LEONA	5300G	Black	2.1	40	H−0298
LEONA	5300G	Black	1.0	75	HS−0112
LEONA	1402SH	All colors	1.7	40	H−1055
LEONA	1402SH	All colors	0.9	75	HS−0430
LEONA	1330G	All colors	2.0	40	H−1056
LEONA	1330G	All colors	1.0	75	HS−0431

Table 24: CSA certification list

CSA Component Acceptance Plastics Recognition CAS FILE No LS65020

Product Type	Product ID	Flame Test	Tests Colour	MM	CSA/UL Rating	IEC Rating	ISO Rating	Electrical and Mechanical Tests: Test	Electrical and Mechanical Tests: Rating
PA	FG170	F	NC	0 76	V 0	FV0	V0	CTI	250 V
		I	NC	1 50	HW I60			HAI	200 Cycles
PA	FG171	F	NC	0 71	V 0	FV0	V0	CTI	275 V
		I	NC	1 49	HW I60			HAI	200 Cycles
PA	FG172	F	NC	0 76	V 0			CTI	250 V
		I	NC	1 50	HW I60			HAI	200 Cycles
PA	FR200	F	All	0 69	V 0	FV0	V0	D E Ic	25 kV/mm AR
		I	BK	0 75	HW I60			CTI	600 V
		I	NC	0 76	HW I15			CTI	600 V
		I	NC	1 46	HW I60			HAI	200 cycles
		I	RD	0 76	HW I60			HAI	200 cycles
		I	YL	0 75	HW I15			ARCR	121 cycles 3 11mm
		RTI	NC	0 80	65	65	105	TENSLIMP	810 kJ/m² 00kJ/m²
		RTI	NC	1 60	65	65	105	TENSL-YL	57 kPa 5 04k%
		RTI	NC	3 20	65	65	105	DtuL1820	91 0 ℃ 1820kPa
								DtuL455	209 0 ℃ 455kPa
PA	FR370	F	All	0 69	V 0	FV0	V0	D E Ic	24 kV/mm AR
		I	BK	0 75	HW I60			CTI	550 V
		I	NC	1 49	HW I60			CTI	600 V
		I	WT	0 75	HW I15			HAI	200 cycles
		I	YL	0 75	HW I60			HAI	200 cycles
		RTI	NC	0 80	75	80	105	ARCR	98 cycles 3 12mm
		RTI	NC	1 60	75	80	105	TENSLIMP	860 kJJ/m² 00kJ/m²
		RTI	NC	3 20	75	80	105	TENSL-YL	74 kPa 5 94k%
								DtuL1820	128 5 ℃ 1820kPa
								DtuL455	239 0 ℃ 455kPa

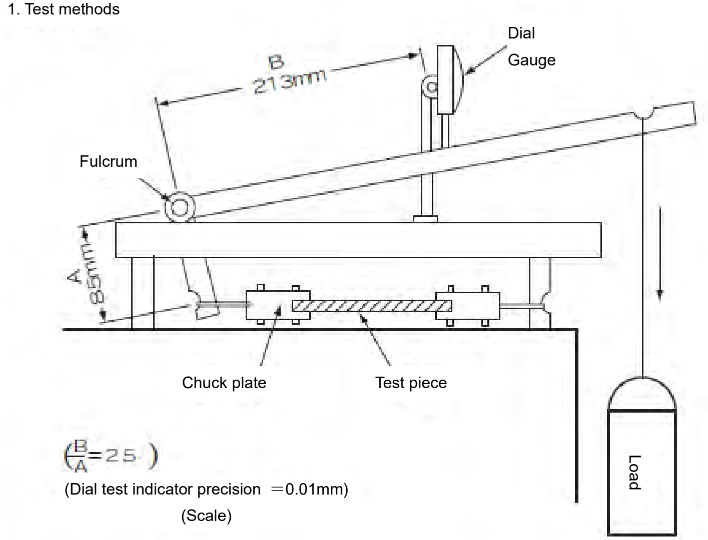
Product Type	Product ID	Flame Test	Tests Colour	MM	CSA/UL Rating	IEC Rating	ISO Rating	Electrical and Mechanical Tests: Test	Electrical and Mechanical Tests: Rating
PA	1300S	F	All	0 66	V 2	FV2	V2	D E Ic	29 kV/mm AR
		I	BK	0 75	HW I60			CTI	600 V
		I	NC	0 76	HW I60			CTI	600 V
		I	NC	1 48	HW I60			HAI	200 cycles
		I	RD	0 76	HW I15			HAI	200 cycles
		I	YL	0 75	HW I15			ARCR	125 cycles 3 11mm
		RTI	NC	0 80	75	85	105	TENSLIMP	1490 kJ/m² 00kJ/m²
		RTI	NC	1 60	75	85	105	TENSL-YL	64 kPa 6 02%
								DtuL1820	96 5 ℃ 1820kPa
								DtuL455	225 5 ℃ 455kPa
PA	1302S	F	All	0 67	V 2	FV2	V2	D E Ic	25 kV/mm AR
		I	NC	0 76	HW I60			CTI	600 V
		I	RD	0 75	HW I15			HAI	200 cycles
		I	WT	0 75	HW I18			ARCR	102 cycles 3 10mm
		I	YL	0 75	HW I16			TENSLIMP	1940 kJ/m² 00kJ/m²
		RTI	NC	0 80	85	90	120	TENSL-YL	64 kPa 5 96%
		RTI	NC	1 60	85	90	120	DtuL1820	89 5 ℃ 1820kPa
		RTI	NC	3 20	85	90	120	DtuL455	221 5 ℃ 455kPa
PA	1402S	F	All	0 68	V 2	FV2	V2	D E Ic	27 kV/mm AR
		I	NC	0 75	HW I60			CTI	500 V
		I	NC	1 48	HW I29			CTI	580 V
		I	RD	0 76	HW I60			HAI	200 cycles
		I	YL	0 75	HW I60			HAI	200 cycles
		RTI	NC	0 80	105	105	105	ARCR	73 cycles 3 11mm
		RTI	NC	1 60	105	105	105	TENSLIMP	2050 kJ/m² 00kJ/m²
								TENSL-YL	65 kPa 6 32%
								DtuL1820	94 5 ℃ 1820kPa
								DtuL455	220 5 ℃ 455kPa

7-1 Creep properties

(1) Tensile creep

Figure-116 Outline of test methods

1. Test methods

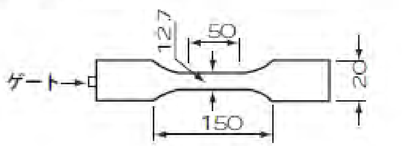


$\left(\frac{B}{A}=2.5\right)$

(Dial test indicator precision =0.01mm)

(Scale)

2. Test piece (unit: mm)



(Thickness: 3mm)

3. Calculation of bending stress

Tensile $\sigma = \frac{P}{t \times w}$

Strain $\varepsilon(\%) = \frac{l}{L} \times 100$

Here, P: load (kgf)

t: Test piece thickness (cm)

w: Test piece width (cm)

l: Deformation (cm)

L: Spacing between clamps (cm)

Figure-117 Tensile creep (1300S)
(Stress IOOkgf/cm², DRY)

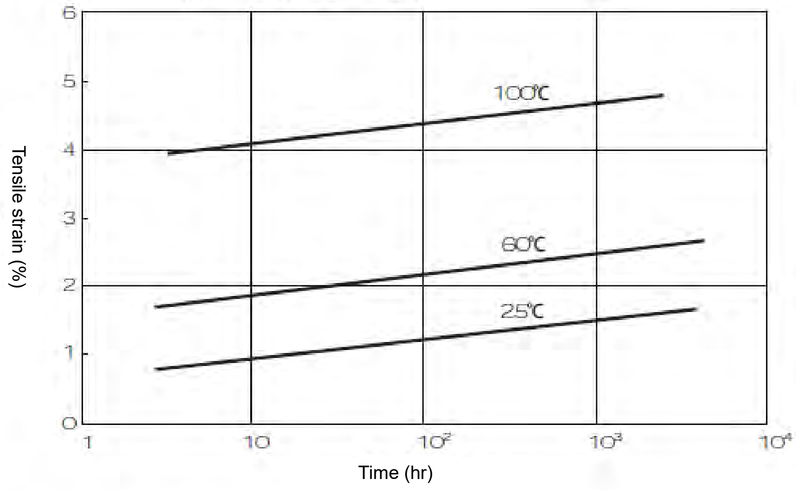
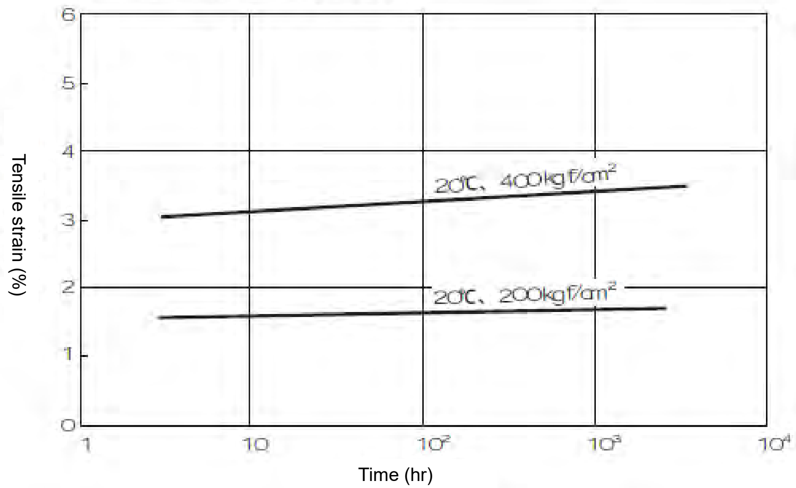


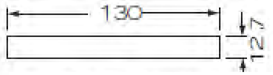
Figure-118 Tensile creep (1300G)



(2) Bending creep

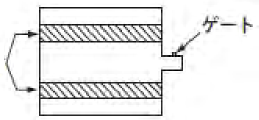
Figure-119 Outline of test methods

1. Test piece (unit: mm)

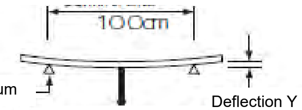


(Thickness: 3mm)

Cut above test piece from 130×110×3 (mm) slab after injection molding.



2. Test methods



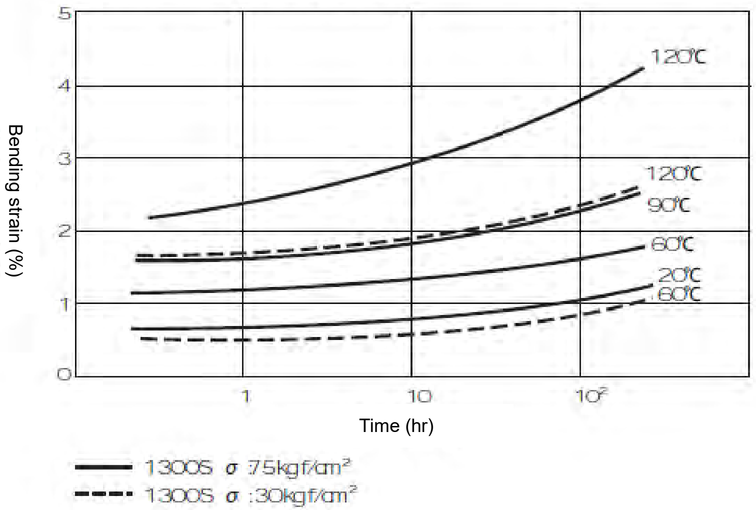
3. Calculation of bending stress and strain

Bending strain $\sigma = \frac{3PL}{2bd^2}$ (kgf/cm²)

Strain $\varepsilon\ (\%) = \frac{6dY}{L^2} \times 100$

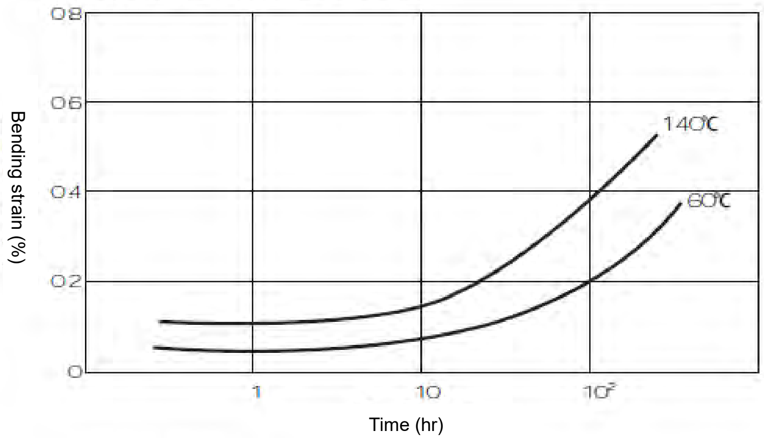
P: load (kgf)
L: Distance between the fulcrums (cm)
b: Test piece width (cm)
d: Test piece thickness (cm)
Y: Deflection (cm)

Figure-120 Bending creep (1300S)



(Remark) σ: Bending stress

Figure-121 Bending creep (1300G)



σ (Bending stress): 75kgf/cm²

(3) Compression creep

Figure-122 Outline of test methods

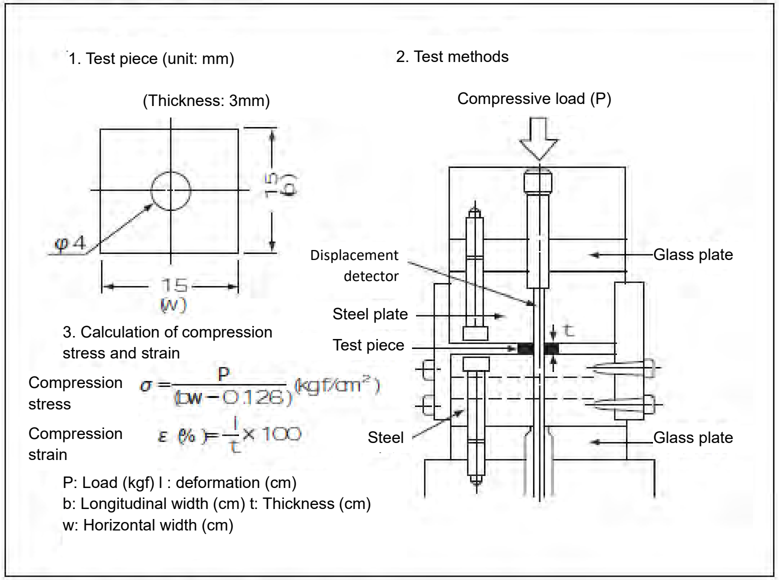
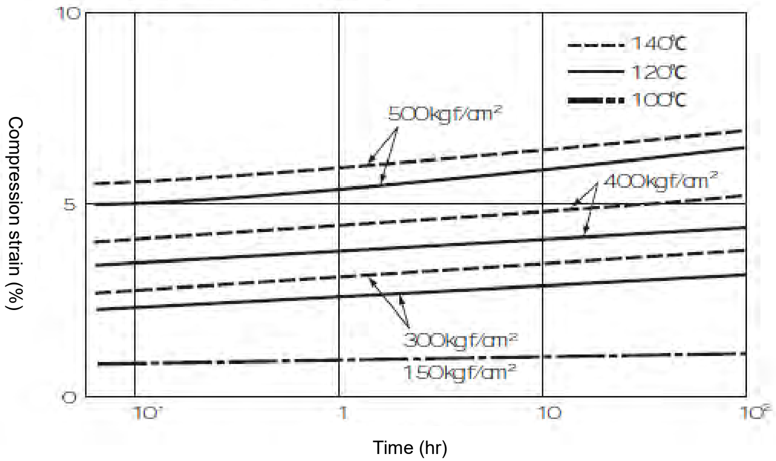


Figure-123 Compression creep (1300G)



7-2 Relieve stress

Figure-124 Outline of test methods

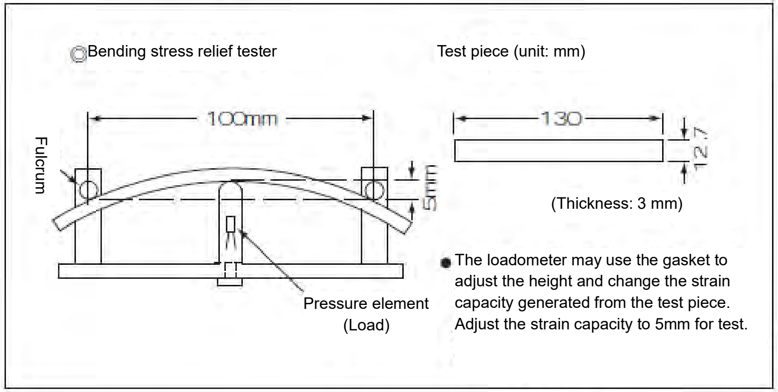
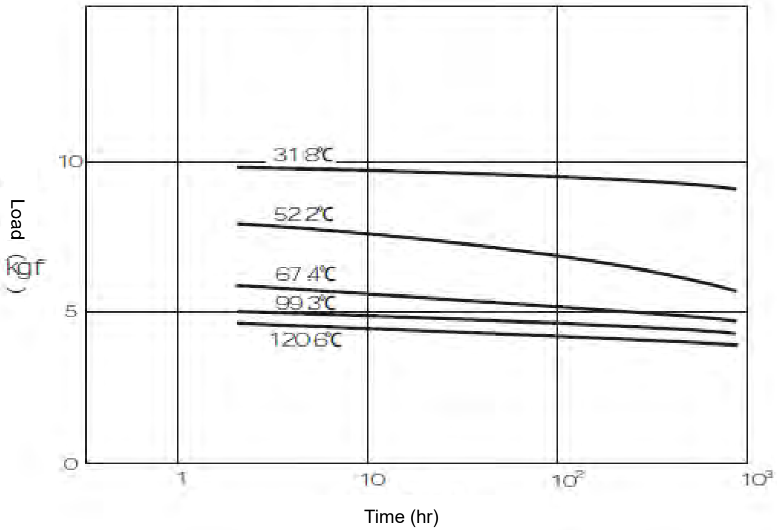


Figure-125 Bending stress relief (1300G)



7-3 Vibration fatigue characteristics

(1) Bending vibration fatigue S/N

Test methods

① Test specification ASTM D671

② Vibration fatigue machine Constant-stress repeated vibration fatigue machine (manufactured by TOYOSEIKI)

③ Test conditions

Environment temperature 20, 80, 120, 140℃

Test stress range 150～950（kgf/cm^2）

Test speed 1,800 ±4cpm (times/min)

Maximum vibration frequency 10^7 times

④ Relationship between test piece thickness and load

$$P=\frac{\sigma \cdot b_0 \cdot d^2}{6\ell}$$

(Ex $$P=\frac{\sigma \times 1.91 \times d^2}{6 \times 5.72}$$

σ :Bending stress Set target stress (kgf/cm^2)

b_0 :Fixed width of cantilever (test piece width) (cm)

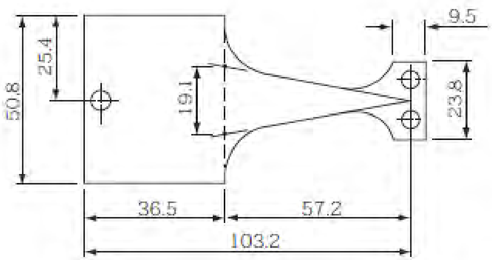
d :Test piece thickness (mm)

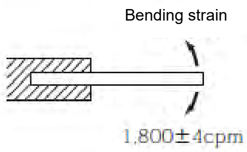
ℓ :Length of load points from fixed part of cantilever to free end (cm)

P :Load (kgf)

⑤ Test piece (unit: mm)

Tybe B





(Thickness: 3 mm)

Figure-126 Vibration fatigue characteristics (1300S)
(Test conditions 23℃, 50% humidity)

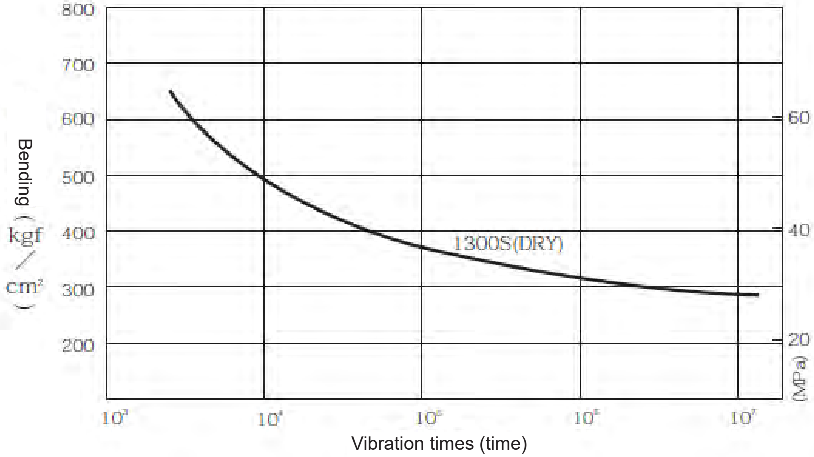


Figure-127 Change of vibration fatigue characteristics with water absorption (1300G)
(Test conditions 23℃, 50% humidity)

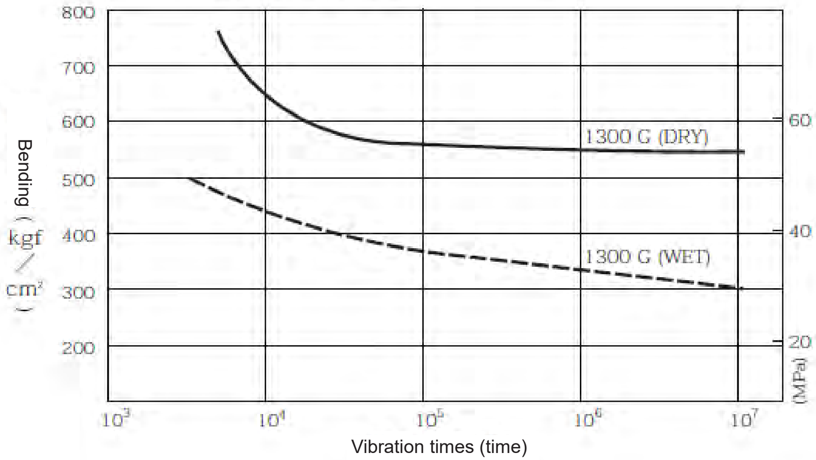


Figure-128 Vibration fatigue characteristics (1300S)
(Test conditions 50% humidity)

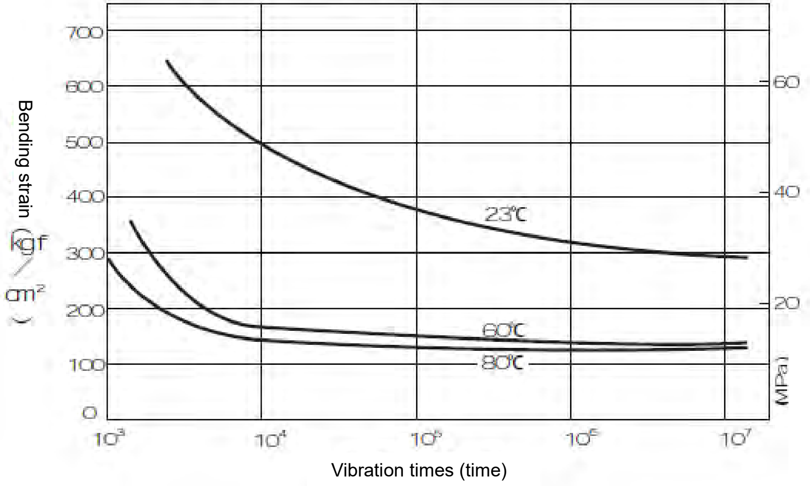


Figure-129 Vibration fatigue characteristics (1300G)
(Test conditions 50% humidity)

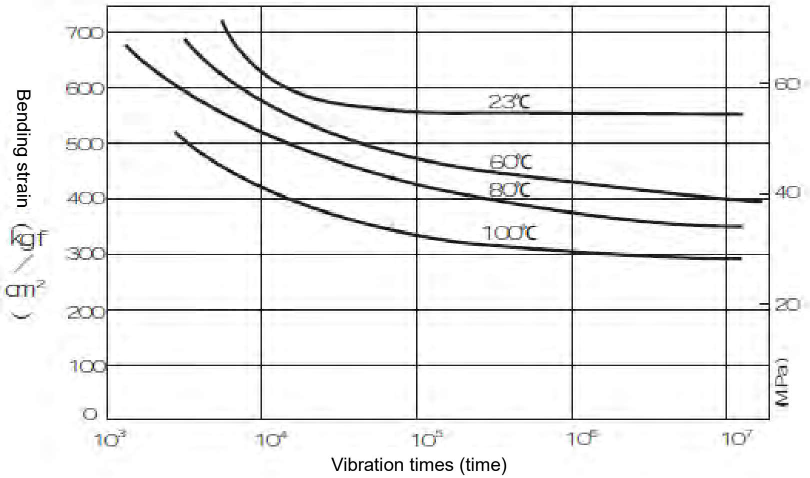
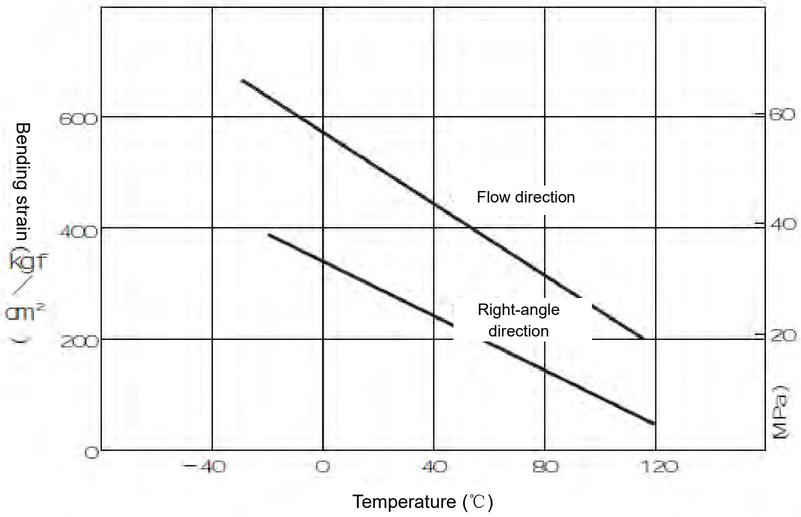


Figure-130 Vibration fatigue characteristics (1300G)
(Vibration times 10^7 times)



Test piece (unit: mm)
(Thickness: 3 mm)

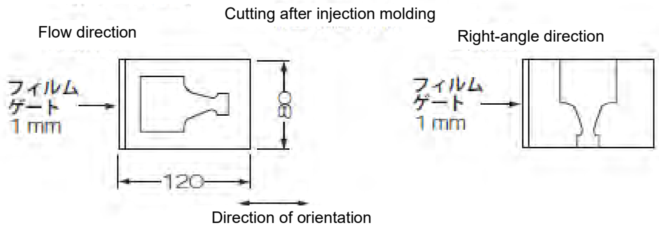


Figure-131 Vibration fatigue characteristics (1300G)

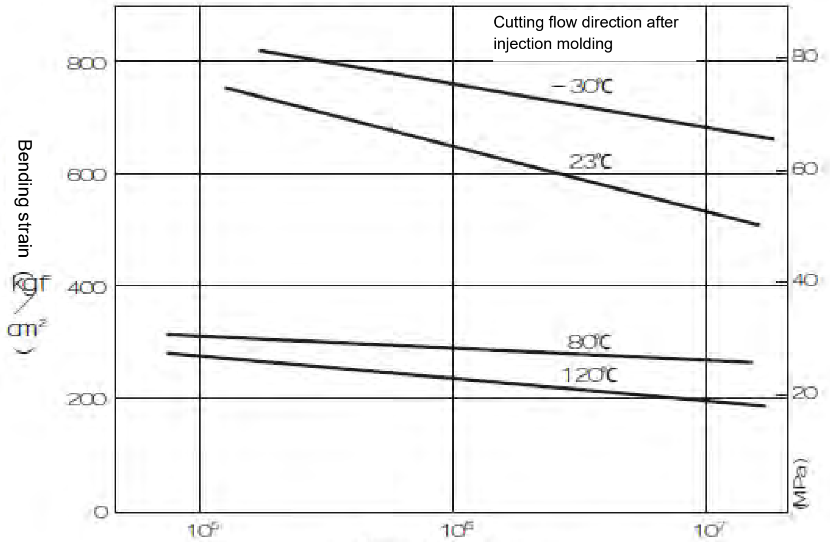
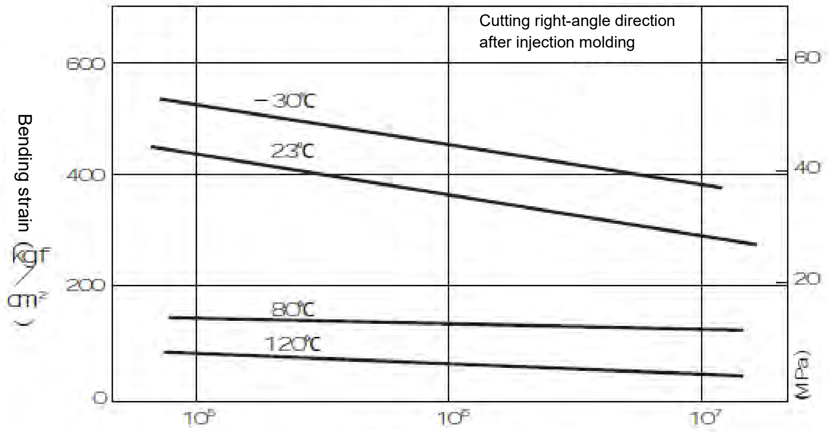


Figure-132 Vibration fatigue characteristics (1300G)



(2) Load-controlled tensile vibration fatigue S/N (source: Resin fatigue research society)
Test piece: 1402G (PA66GF33%), ASTM-D1822 Tensile impact dumbbell TypeS
Fatigue conditions: Tensile - tensile, minimum load 5kg, sin wave

Figure-133 Change of fatigue S/N curve with environment temperature (f=20Hz)

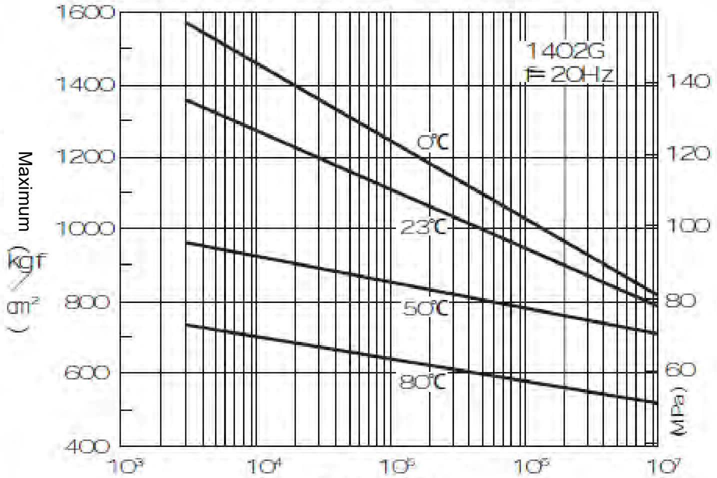
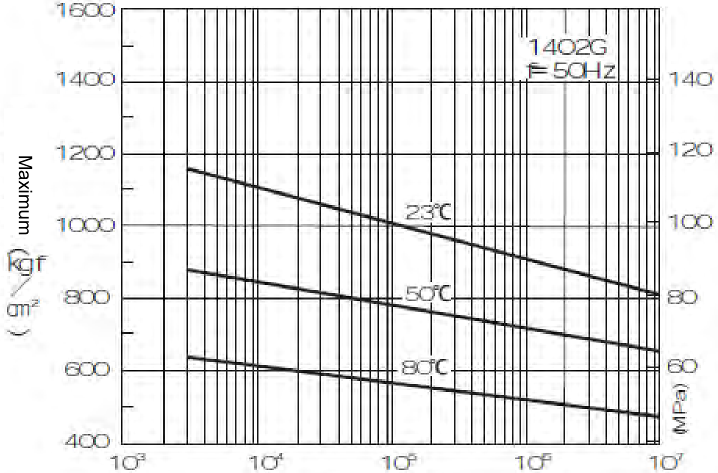


Figure-134 Change of fatigue S/N curve with environment temperature (f=20Hz)



7-4 Friction and wear characteristics

(1) Friction characteristics

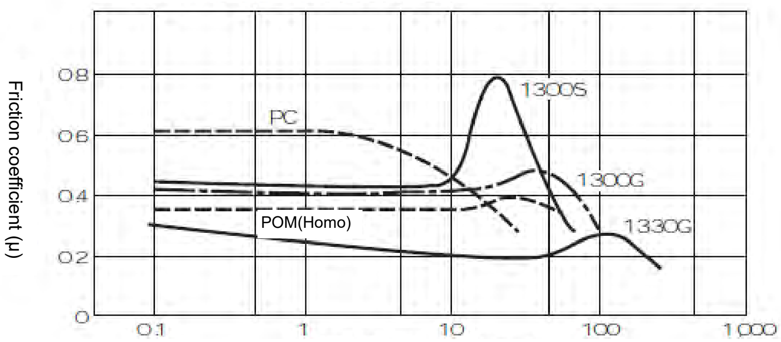
Each grade of LEONA has self-lubrication property, so the friction and wear characteristics are good.The friction and wear characteristics of 1330G are further improved.

Table 28: Friction and wear characteristics of resins

Resin name	*1 Friction coefficient	*2 Boundary PV value (kgf/cm²)(cm/sec)	*3 Coefficient of wear (×10⁻¹⁰cm³/kgf·cm)
LEONA 1300S	0.45	650	1
〃 1300G	0.44	900	8
〃 1330G	0.21	1800	0.2
〃 CF150	0.48	600	0.46
POM (Homo)	0.35	600	1
PC	0.61	<390	220

Measurement conditions: pin-on-disc friction and wear tester Material against wear: S45C steel
*1. Surface pressure 10kgf/cm^2 *3. Surface pressure 1.5kgf/cm^2 Linear velocity 60cm/sec
*2. Surface pressure lOkgf/cm2, value in melt status Coefficient of wear＝wear loss/load × slide distance
(Remark) Measurement of test piece under absolute dry conditions (cm^3) (kgf)(cm)

Figure-135 Friction coefficient and linear velocity of

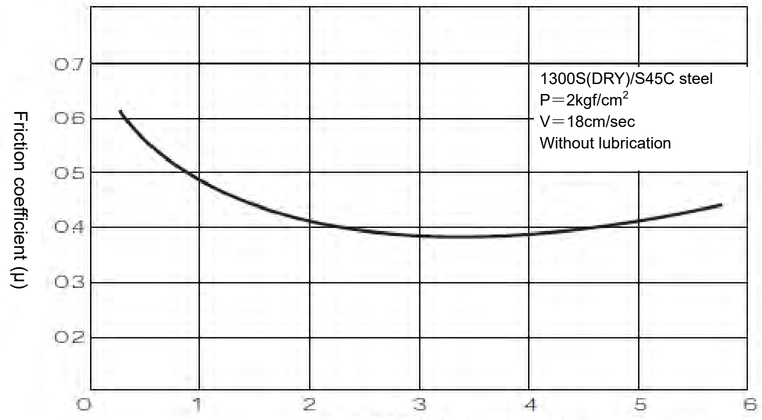


Linear velocity (cm/sec)

Measurement conditions: Sliding wear tester Material against wear: S45C steel Surface pressure: 10kgf/cm^2

(Remark) Measurement of test piece under absolute dry conditions Measuring temperature: 20℃

Figure-136 Surface roughness and friction coefficient of materials against wear

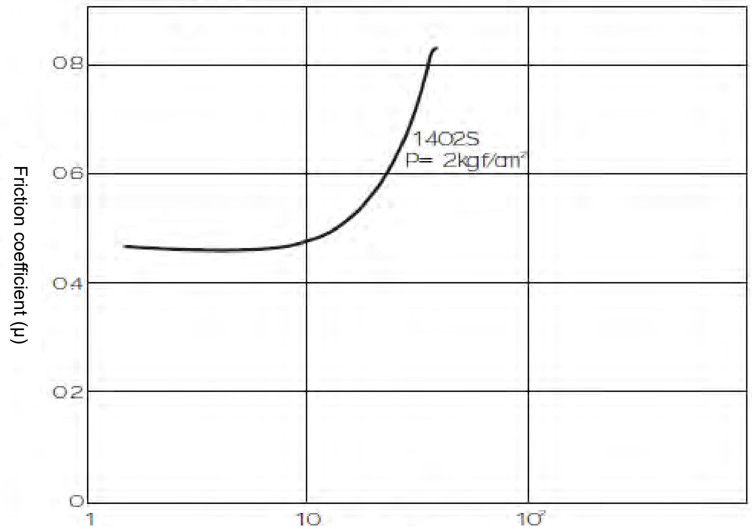


Surface roughness of materials against wear Ra (μm)

(Ra: Centerline average roughness)

Figure-137 Friction characteristics of 1402S

(Without lubrication)



Linear velocity (cm/sec)

(Remark) Use S45C steel as the material against wear and measure with the sliding friction tester

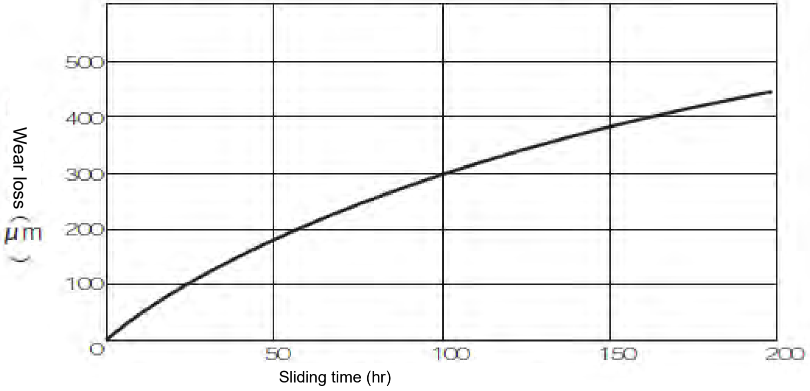
※ Measure after aging for 190hr in 170℃ rotatable oven

General specification
Water absorption characteristics
Moisture dependency
Temperature dependency
Evaluation methods
Specifications and acts
Long-term characteristics
When replacing the metal
Product design
Mold for injection molding
Injection molding technology
Fault cases and countermeasures of molding products

(2) Wear characteristics

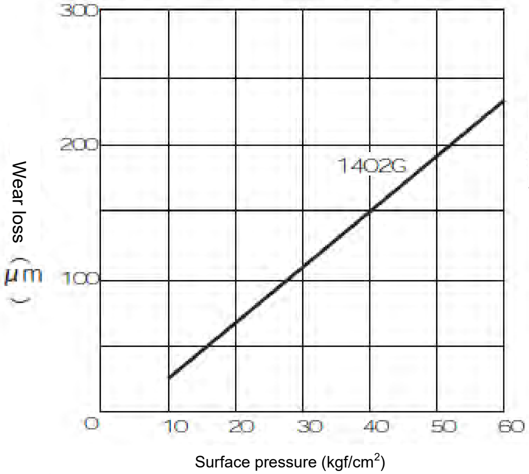
Figure-138 Wear characteristics of LEONA (1)(1402S)

(Use sliding friction and wear tester Surface pressure 2kgf/cm^2, linear velocity 18cm/sec, material against wear S45C steel)



(Remark) Measurement of test piece under absolute dry conditions

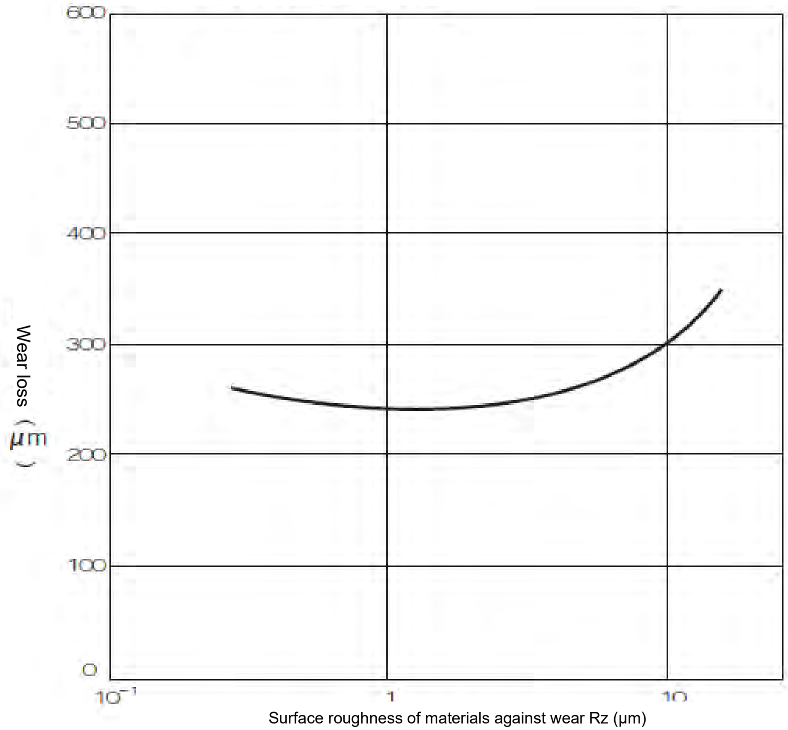
Figure-139 Wear characteristics of LEONA (2)(1402G)



Material against wear: S45C steel
Contact area: 1 cm^2
Linear velocity: 30cm/sec
Slide distance: 2.16km
Tester: sliding wear tester

(Remark) Measurement of test piece under absolute dry conditions

Figure-140 Surface roughness and wear loss of materials against wear



○Sample 1402G (roughness 20.6μmRz)

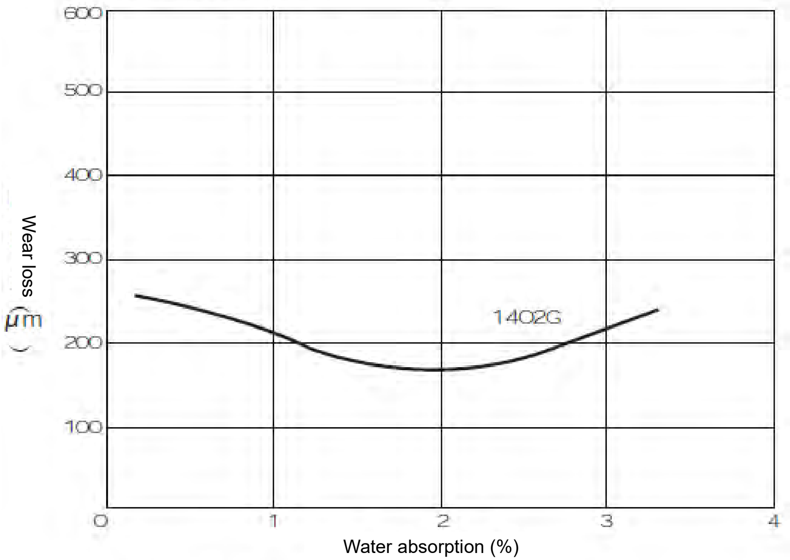
○Material against wear
S45C steel
Surface roughness

0.2 μmRz
1.2 μmRz
15 μmRz

○Test
Contact area 1 cm^2
Slide distance 2.16km
Linear velocity 30cm/sec
Surface pressure 60kgf/cm^2

○Rz Average roughness of 10 points

Figure-141 Influence of water absorption



○ Sample 1402G

○ Material against wear S45C steel (Surface roughness 1.2μmRz)

○ Test conditions Contact area $1cm^2$

Slide distance: 2.16km

Linear velocity: 30cm/sec

Surface pressure $60kgf/cm^2$

7-5 Drug resistance

(1) Drug resistance ① (Judgment of outstanding, good and acceptable)

Polyamide 66 resin has weak acid resistance generally but has very strong resistance to other chemicals, organic solvents and lubricating oil.

Table 29 Drug resistance of LEONA ① (Judgment of outstanding, good and acceptable)

Drug name	Level	Drug name	Level	Drug name	Level
Water ・Ethanol class Water Methanol Ethyl alcohol Propanol Butanol Ethylene glycol Glycerin Benzyl alcohol	Good Outstanding Good Good Good Outstanding Outstanding Good	Toluene Xylene Cyclohexane	Outstanding Outstanding Outstanding	Acetic acid 40% Benzoic acid	Unacceptable Unacceptable
		Halide Dichloromethane Trichloromethane Trichloro ethylene Perchloroethylene Carbon tetrachloride	Good Good Outstanding Outstanding Outstanding	Inorganic acetic acid Hydrochloric acid 2% Sulfuric acid 2% Nitric acid 2% Chromic acid 10%	Unacceptable Unacceptable Unacceptable Unacceptable
Acetaldehyde and ketone Formaldehyde Acetaldehyde Benzaldehyde Acetone Methyl ethyl ketone	Good Good Good Outstanding Outstanding	Phenol Phenol Resorcinol	Unacceptable Unacceptable	Inorganic salts Sodium hydroxide 50% Ammonia water 10% Potassium hydroxide 50%	Good Good Good
		Esters Ethyl acetate	Outstanding	Inorganic matters Sodium carbonate 10% Sodium chloride 10%	Outstanding Outstanding
Hydrocarbon Paraffin Benzene	Outstanding Outstanding	Organic acids Formic acid 85%	Unacceptable	Oils Gasoline	Outstanding

Description of levels
Excellent: almost no change in dimensions and weight
Good: Change in dimensions and weight
Acceptable: slightly corroded
Unacceptable: corroded and dissolved

At 20℃

(2) Drug resistance ②(qualitative changes of physical properties)

a) Description of symbols

The arrow symbols in the form of physical property change rates have the following significances.

Symbol	Significance
→	● The physical property is not changed in the test process.
⌐→ ∟→	● The physical property is increased (⌐→) or decreased (∟→) at the start of the test and then not changed.
↗ ↘	● The physical property is constantly increased (↗) or decreased (↘) in the whole test period.
—↗ —↘	● The physical property is not changed within a period of time after start of the test.The physical property has the trend of increase (—↗) or decrease (—↘) at the end of the test
↘↗	● The physical property is reduced at the start of the test and then constantly increased from a point subsequently.

b) Consider water absorption

LEONA absorbs water or dehydrates according to the moisture concentration in the environment until the balanced water absorption status,so the changes in the weight, dimensions and physical properties of LEONA immersed in the drug are the general performance of water absorption change and drug influence of LEONA.

The values in the brackets in the row recording "Consider dehydration" in the test data sheet only consider the change rate affected by the drug.

The drug impregnation test under the water absorption status will be affected by the physical property changes and the drug after water absorption.

a. Measure the water absorption of the samples impregnated in the drug.
b. Speculate the weight and various physical property values of a water absorption.
c. Subtract the measured value of the weight and various physical property values after drug impregnation by the value obtained in second item above.

Table 30: Drug resistance of LEONA ②(qualitative changes of physical properties-1)

No.	Drug types	Test: Temperature (℃)	Test: Period (Day)	Grade	Status of test piece before start of test
1	Sodium chloride water (saturated, pH=7.9)	30	90	1402S	Water absorption 3.1%
2	Calcium chloride water (saturated, pH=5.5)	30	90	1402S	Water absorption 3.1%
3	Magnesium chloride water (saturated, pH=7.2)	30	90	1402S	Water absorption 3.1%
4	Zinc chloride water (saturated, pH=0.2)	30	1	1402S	Water absorption 3.1%
5	Methanol	30	20	1402S	Absolute dry condition
6	Methanol	30	90	1402S	Water absorption 3.1%
7	Ethyl alcohol	30	20	1402S	Absolute dry condition
8	Ethylene glycol	30	90	1402S	Water absorption 3.1%
9	Propylene glycol	30	20	1402S	Absolute dry condition
10	Brake fluid (JIS B2401) {Diethylene glycol Ethylene glycol diethyl ester Ethylene glycol diethyl ester	120	21	1402G	Absolute dry condition
11	Brake fluid (the same as above)	120	21	MR001	Absolute dry condition
12	Iso-octane/toluene 5/5	20	42	1402G	Absolute dry condition
13	Iso-octane/toluene 5/5	20	42	MR001	Absolute dry condition
14	Iso-octane/toluene 4/6	30	90	1402S	Water absorption 3.1%
15	Gasoline (ENEOS silver, Nippon Oil Corp)	30	90	1402S	Water absorption 3.1%
16	Gasoline (ENEOS gold, Nippon Oil Corp)	30	90	1402S	Water absorption 3.1%
17	Gasoline (smoke-free high octane; Shell)	60	21	1402S	Absolute dry condition
18	Gasoline (synthesis: iso-octane 1 + toluene 1)	60	21	1402S	Absolute dry condition
19	Gasohol [(iso-octane 1 + toluene 1) + ethyl alcohol 20%]	60	21	1402S	Absolute dry condition
20	Gasohol [(iso-octane 1 + toluene 1) + methanol 15%]	60	21	1402S	Absolute dry condition
21	Diluent (for coating, Daeshin)	30	30	1300G	Water absorption 1.9% (Consider dehydration)
22	White kerosene (Nippon Oil Corp)	30	30	1300G	Water absorption 1.9% (Consider dehydration)
23	Milling oil (#1, Nippon Oil Corp)	80	24	1300G	Absolute dry condition
24	Milling oil (the same as above)	80	30	1300G	Water absorption 1.9% (Consider dehydration)
25	Motor oil (Chima 300, Mobil)	120	42	1402G	Absolute dry condition
26	Engine oil (#120)	80	30	1300G	Water absorption 1.9% (Consider dehydration)

* Izod impact strength (with notch)

Weight Change rate (%)	Dimensions Change rate (%)	Bending strength change rate (%)	Bending elastic modulus change rate (%)	Tensile strength Change rate (%)	Breaking strain Change rate (%)	Impact strength Change rate * (%)	Appearance	No.
↗ 1.3	↗ 0.4			↘ −15	↗ 13		Unchanged	1
↳ −0.4	↳ −0.2			→ −4	→ 0		Unchanged	2
↗ 2.2	↗ 0.6			↘ −24	→ 0		Unchanged	3
↗ 1.0	↗ 0.4			↘ −41	↘ −97		Cracks	4
↗ 2.4	↗ 3.8						Turn yellow	5
↱ 5~6	↱ 2.5~3			−30	→ 0			6
↗ 10	↱ 0.7						Unchanged	7
↗ 0.6	↳ −0.1			↳ 13	→ 0			8
↗ 0.7	↱ 0.2						Turn brown	9
↗ Above	↗ 3.8	↘ −56	↘ −62	↱			Cracks	10
↗ 5.0	↗ 3.8	↘ −73	↘ −77				The same as above	11
↗ 0.3	↱ 0.1	↘ −6	→ −4				Unchanged	12
↗ 0.3	→ 0.0	↘ −10	→ −4				Unchanged	13
↳ −0.3	↳ −0.3			→ −3	→ 0		Unchanged	14
↳ −0.4	↳ −0.2			→ 0	→ 0		Unchanged	15
↳ −0.4	↳ −0.3			→ 0	→ 0		Unchanged	16
→ 0.2	→ 0.0			→ 2	↗ 15	→ 6	Rockwell hardness 94	17
→ 0.2	→ 0.0			→ 3	↗ 12	↗ 30	〃 R94	18
→ 3.9	→ 0.9			↗ 33	↗ >600	↗ 1800	〃 R83	19
↗ 8.4	→ 3.5			↗ 60	↗ >600	↗ 430	〃 R71	20
→ 0.0 (0.0)	↳ −0.1			→ −1 (−1)	↗ 21 (21)	↘ −13 (−13)	Unchanged	21
↳ −0.1 (0.0)	↳ −0.1			→ −1 (0)	↱ 25 (25)	↱ 16 (16)	Unchanged	22
↗ 0.2	↳ −0.1			→ 0	→ 2	→ −4		23
↘ −1.2 (0.0)	↘ −0.7			↗ 19 (−3)	↘ −5 (4)	↘ −41 (−14)		24
↱ 0.1	→ 0.0	→ −1	↳ −5				Slightly discolored	25
↘ −1.0 (0.0)	↘ −0.6			↗ 13 (−3)	→ 3 (8)	↘ −37 (−16)		26

Long-term characteristics of LEONA

Drug resistance of LEONA ②(qualitative changes of physical

* Izod impact strength (with notch)

No.	Drug types	Test Temperature (℃)	Test Period (Day)	Level	Status of test piece before start of test	Weight Change rate (%)	Dimensions Change rate (%)	Bending strength change rate (%)	Bending elastic modulus change rate (%)	Tensile strength Change rate (%)	Breaking strain Change rate (%)	Impact strength Change rate * (%)	Appearance	No.
27	Cutting oil	80	30	1300G	Water absorption 1.9% (Consider dehydration)	↘ −1.2 (0.0)	↘ −0.7			↗ 18 (−1)	→ −3 (6)	↘ −39 (−18)		27
28	Industrial oil (shell telluss27, Shell)	120	42	1402G	Absolute dry condition	↱ 0.1	↳ −0.4	⤵ −22	→ −3				Turn dark green	28
29	Industrial oil (the same as above)	120	42	MR001	Absolute dry condition	↱ 0.1	↳ −0.3	⤵ −18	↱ 5				Turn dark green	29
30	Anti-rust oil (P5600, LUBE TECH)	80	30	1300G	Absolute dry condition	→ 0.0	↘ −0.2			→ 4	→ 4	→ −1		30
31	Anti-rust oil (the same as above)	80	30	1300G	Water absorption 1.9% (Consider dehydration)	↘ −0.7 (0.4)	↘ −0.4			→ 2 (−17)	↗ 13 (20)	↘ −40 (−19)		31
32	Anti-rust oil (P5850, LUBE TECH)	80	30	1300G	Absolute dry condition	→ 0.0	↘ −0.2			→ 3	→ 2	→ −2	Unchanged	32
33	Anti-rust oil (the same as above)	80	30	1300G	Water absorption 1.9% (Consider dehydration)	↘ −0.5 (0.2)	↘ −0.5			↗ 9 (0)	→ −2 (3)	↘ −32 (−16)		33
34	Lubricating oil (Alumix TN02, KYODO YUSHI)	30	90	1402S	Water absorption 3.1%	↳ −0.6	↳ −0.5			→ −1	→ 0		Unchanged	34
35	Lubricating oil (MARUTENPU TA, KYODO YUSHI)	30	90	1402S	Water absorption 3.1%	↳ −0.3	↳ −0.3			→ 0	→ 0		Unchanged	35
36	Lubricating oil (MARUTENPU PSN0.2, KYODO YUSHI)	80	30	1300G	Absolute dry condition	↱ 0.1	↘ −0.2			→ −1	→ 0	→ 5		36
37	Lubricating oil (the same as above)	80	30	1300G	Water absorption 1.9% (Consider dehydration)	↘ −1.0 (0.0)	↘ −0.6			↗ 23 (9)	↘ −7 (−1)	↘ −37 (−18)		37
38	Lubricating oil (KONIRU-PU N0.0 0, KYODO YUSHI)	80	30	1300G	Absolute dry condition	↱ 0.2	↳ −0.2			→ −1	→ 0	→ −4		38
39	Lubricating oil (the same as above)	80	30	1300G	Water absorption 1.9% (Consider dehydration)	↳ −0.2 (0.1)	↳ −0.3			↱ 7 (4)	↱ 16 (18)	↳ −28 (−24)		39
40	Lubricating oil (Molub Alloy,Imperial & Grease Co.)	80	30	1300G	Water absorption 1.9% (Consider dehydration)	⤻ −0.3 (0.7)	↳ −0.4			↗ 27 (11)	↘ −10 (−3)	↘ −35 (−14)		40
41	Lubricating oil (G30M, ShinEtsu)	120	42	1402G	Absolute dry condition	→ 0.0	↳ −0.1	→ 3	↳ −5				Slightly discolored	41
42	Lubricating oil (the same as above)	120	42	MR001	Absolute dry condition	→ 0.0	↳ −0.1	⤴ 5	→ −1				Slightly discolored	42
43	Castor oil	30	20	1402S	Absolute dry condition	↗ 0.2	→ 0.0							43
44	Colza oil	80	30	1300G	Water absorption 1.9%	↘ −1.4	↘ −0.7			↗ 23	↘ −6	↘ −41	Unchanged	44
45	Margarine (Snow Brand Milk Products)	120	42	1402G	Absolute dry condition	↗ 4.0	↱ 0.9	↳ −45	↳ −36				Turn brown	45
46	Margarine (the same as above)	120	42	MR001	Absolute dry condition	↱ 3.0	↱ 0.9	↳ −50	↳ −50				Turn brown	46
47	Butter (Snow Brand Milk Products)	120	42	1402G	Absolute dry condition	↗ 5以上	↗ 1.3	↘ −58	↳ −39				Turn brown	47
48	Butter (the same as above)	120	42	MR001	Absolute dry condition	↗ 3.6	↗ 1.2	↘ −73	↘ −57				Turn brown Cracks	48

(3) Drug resistance ③ (quantitative changes of physical properties)

a) Oil resistance (gasoline, engine oil, gear oil, brake oil and lubricating oil)

- Gasoline and engine oil are sold in the market and tested in a closed high pressure vessel.
- The gear oil is made by adding general anti-wear reagent at extreme pressure (anti-sintering agent of gear, i.e. organic compound containing sulfur, phosphorus, chlorine and other elements), dibenzyl disulfide and 5% tricresyl phosphate in the engine oil.
- The brake oil is made by adding antirust agent and other additives in the main component ethylene glycol.Due to volatile components, the oil resistance test is conducted in a closed high pressure vessel.
- MARUTENPU PSNo.2 of KYODO YUSHI is used as the lubricating oil.

b) Liquid resistance (LLC, window cleaning solution)

c) Acid resistance (hydrochloric acid, sulfuric acid and nitric acid)

d) Resistance to other drugs

e) Ozone resistance

f) Long-term characteristics of 1402S

a) Oil resistance (gasoline, engine oil, gear oil, brake oil and lubricating oil)

Figure-142 Gasoline resistance of 1402G
(With activated carbon at 135℃)

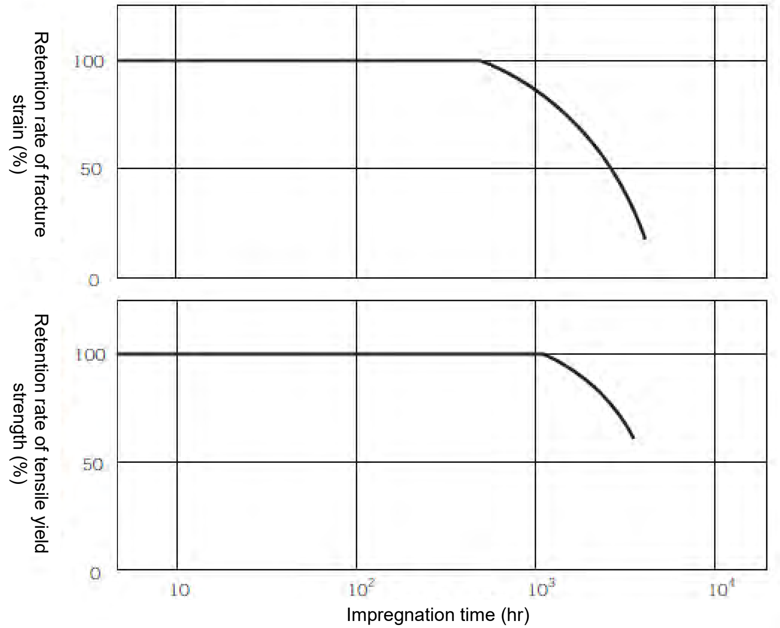


Figure-143 Gasoline resistance of 1402G
(With activated carbon at 23℃)

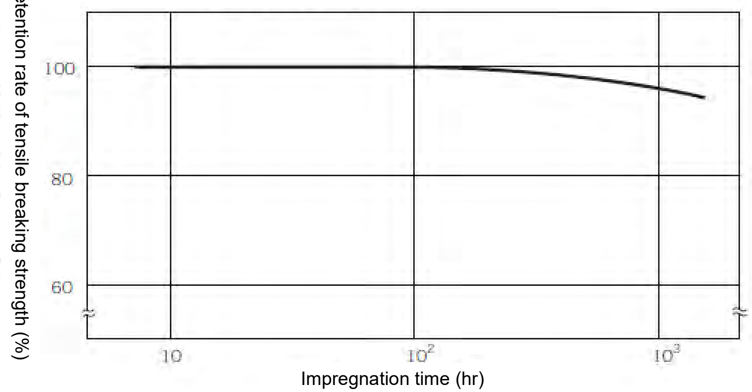


Figure-144 Oil resistance of 1402S

(Impregnated in engine oil)

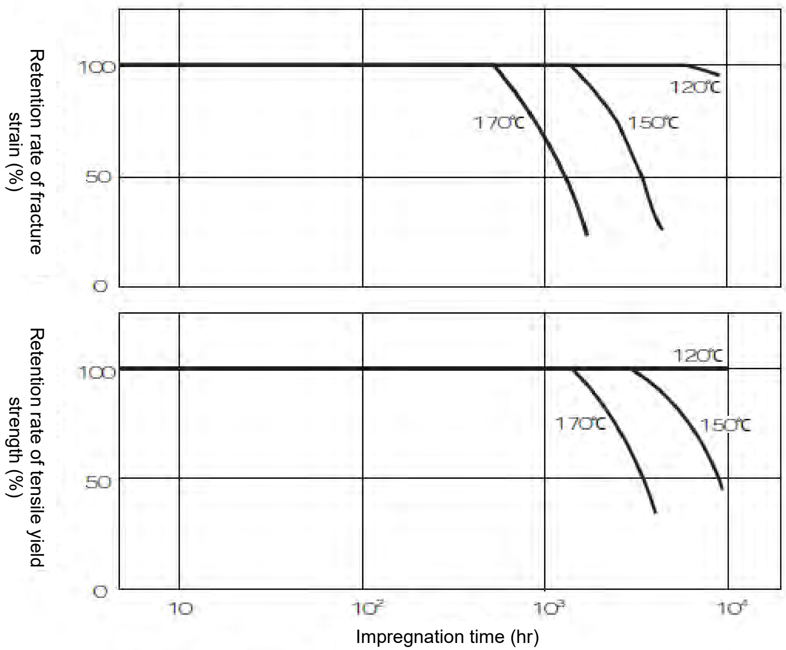


Figure-145 Oil resistance of 1402G

(Impregnated in engine oil)

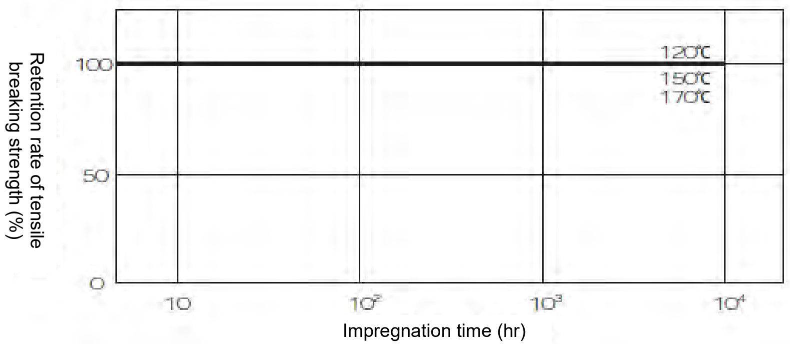


Figure-146 Oil resistance of LEONA

(Change rate of weight and dimensions in engine oil
Difference of change rates up to 0.2% at 120, 150 and)

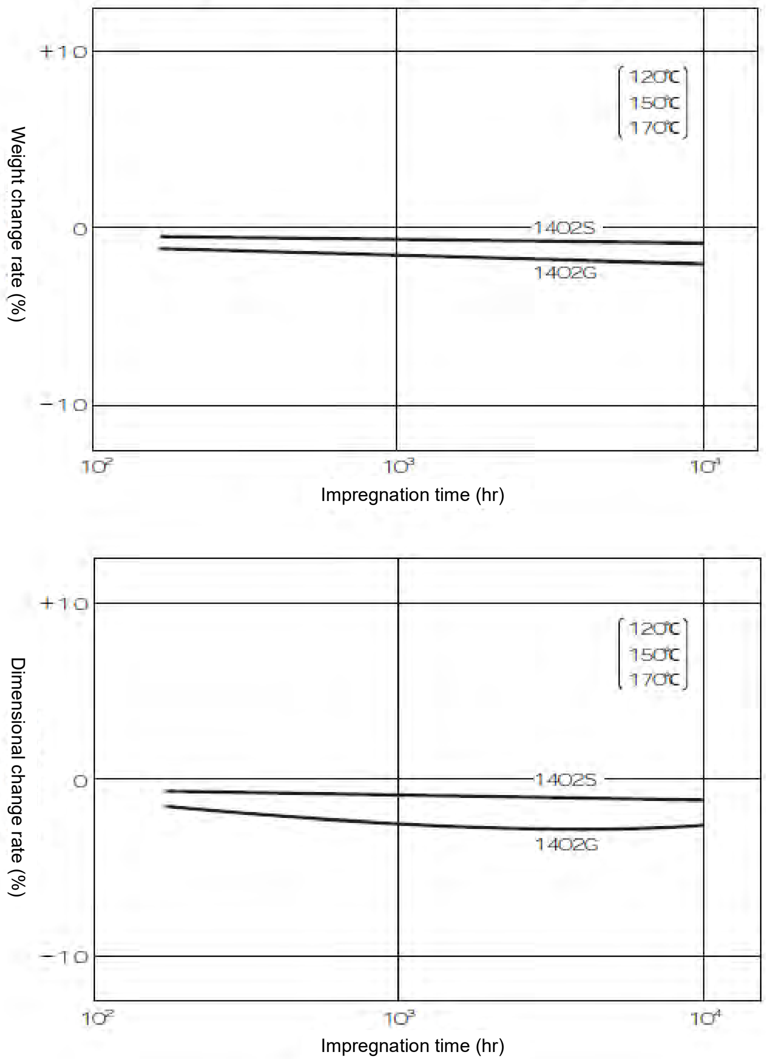


Figure-147 Life characteristic of 1402S in engine oil
(Relationship between time and temperature when the retention rate of fracture strain and tensile yield strength reaches 50% in the air environment and in the engine oil)

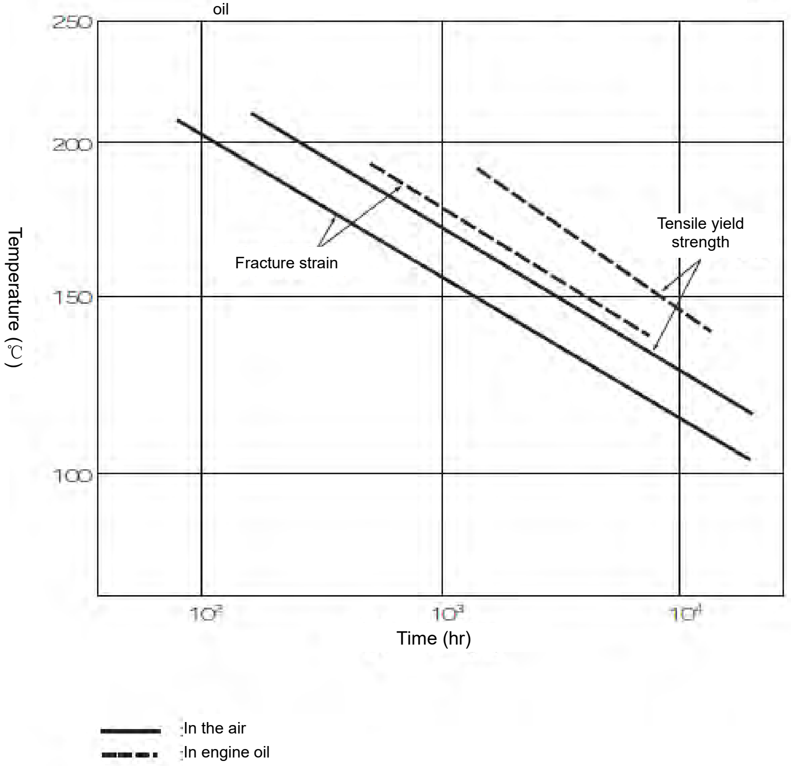


Figure-148 Oil resistance of 1402S
(In gear oil)

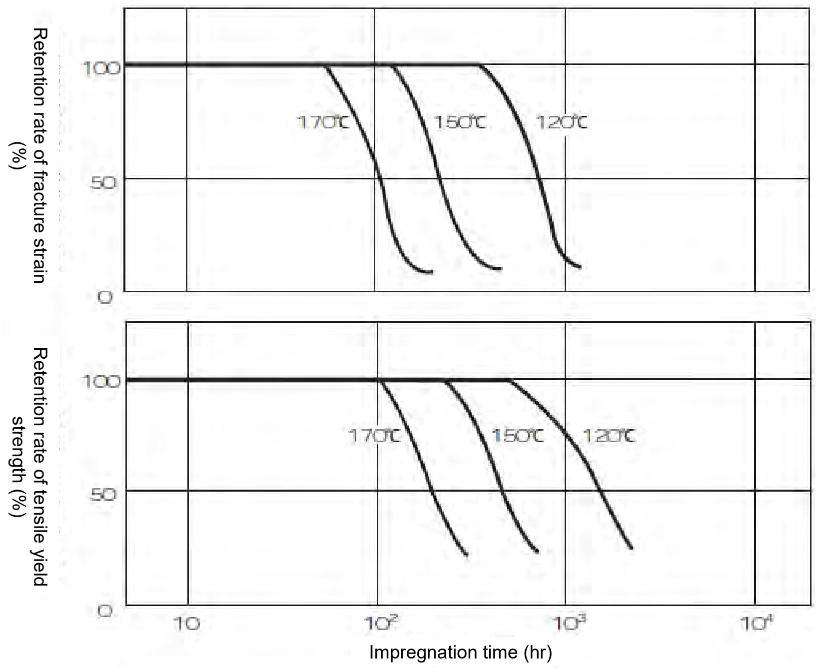


Figure-149 Oil resistance of 1402G
(In gear oil)

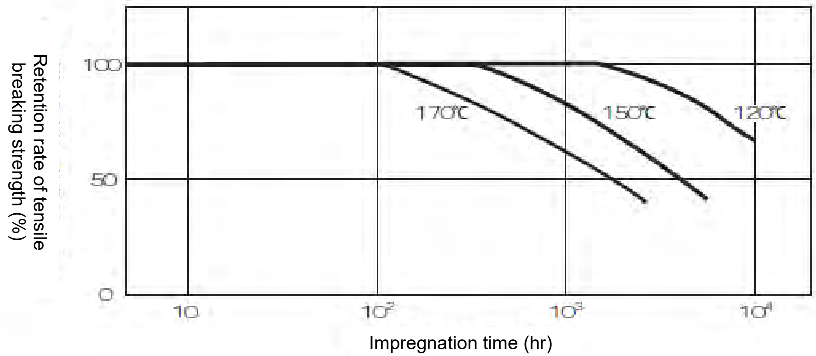


Figure-150 Oil resistance (gear oil) of LEONA

(Difference of change rates up to 0.2% at 120, 150 and 170℃)

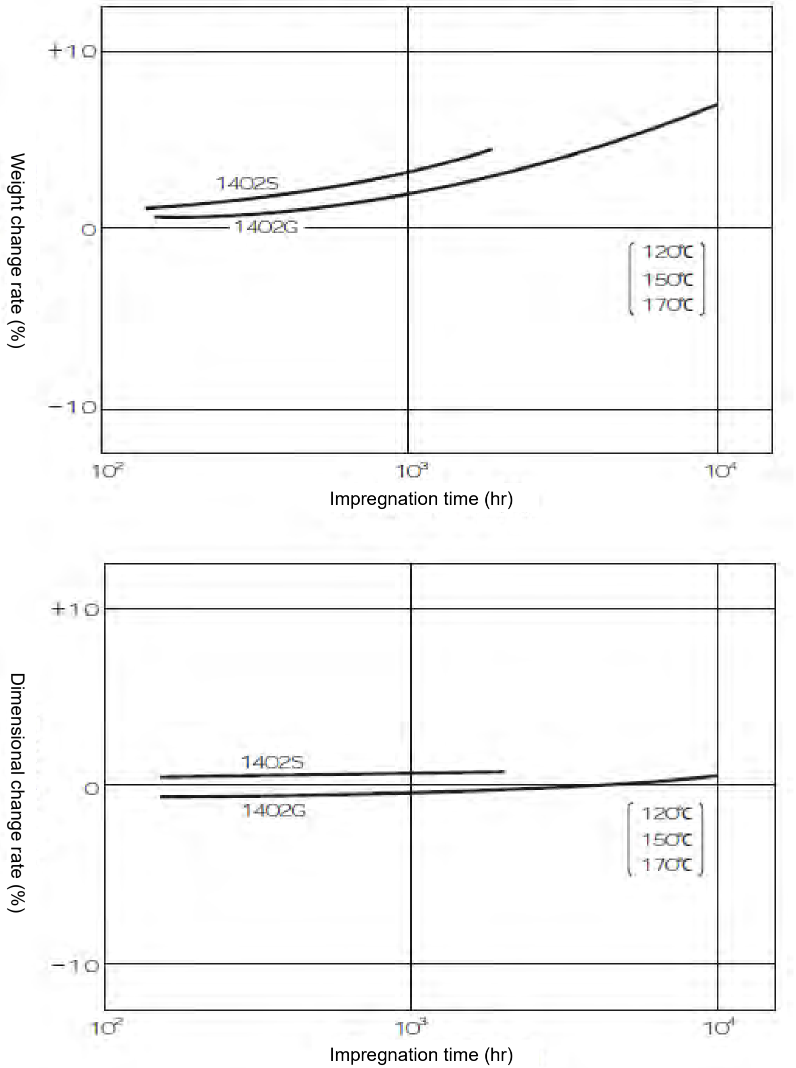
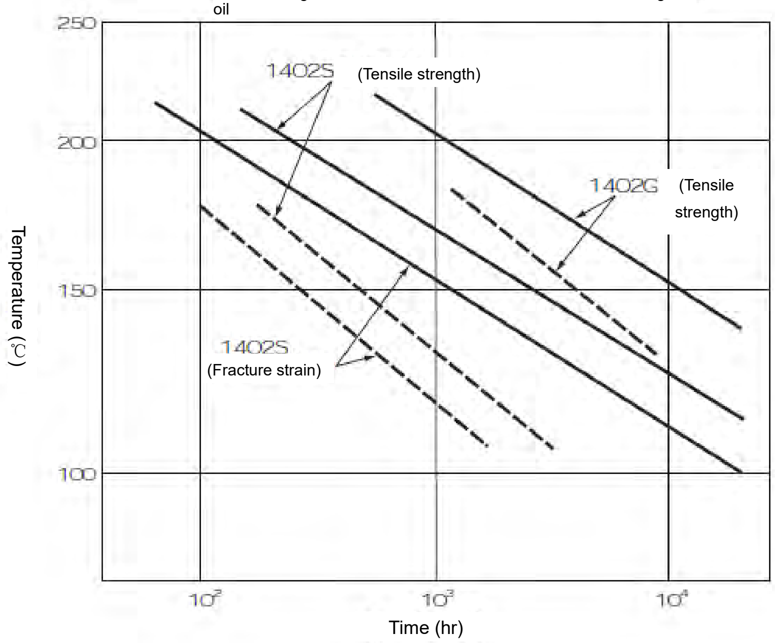


Figure-151 Life characteristic of 1402S and 1402G in engine oil

(Relationship between time and temperature when the retention rate of fracture strain and tensile strength reaches 50% in the air environment and in the gear oil)



:In the air

:In gear oil

Figure-152 Oil resistance (brake oil) of LEONA

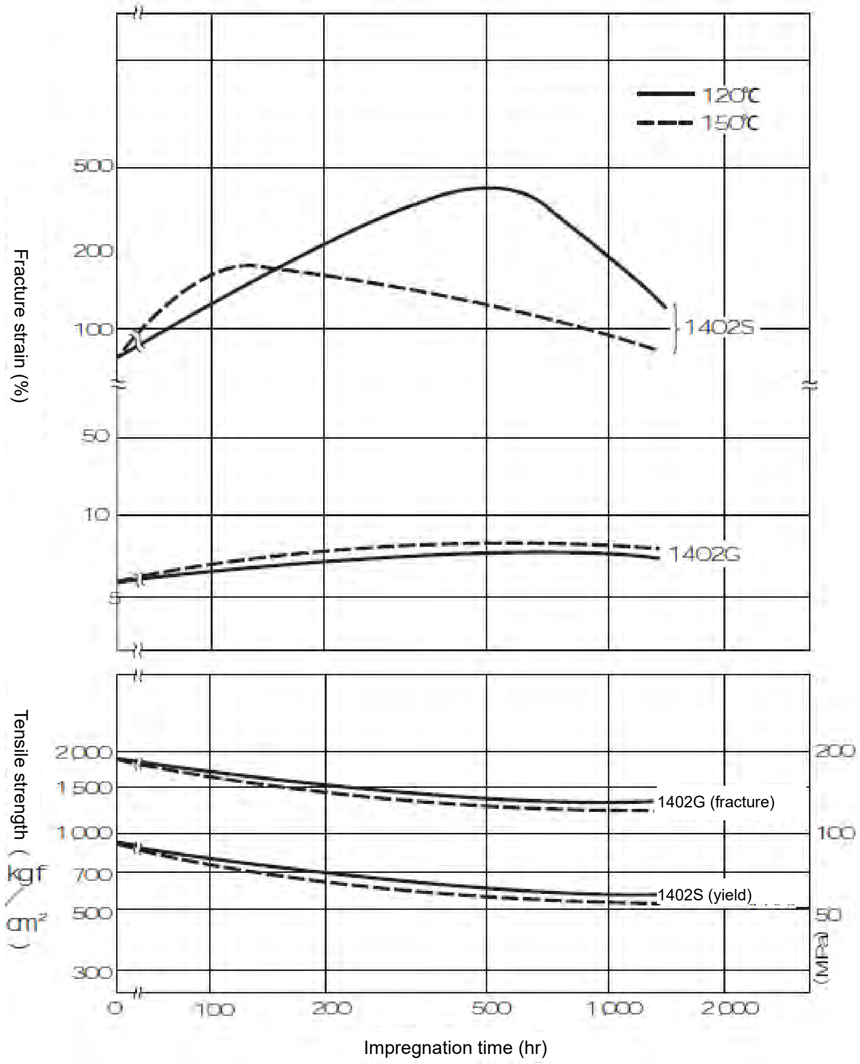
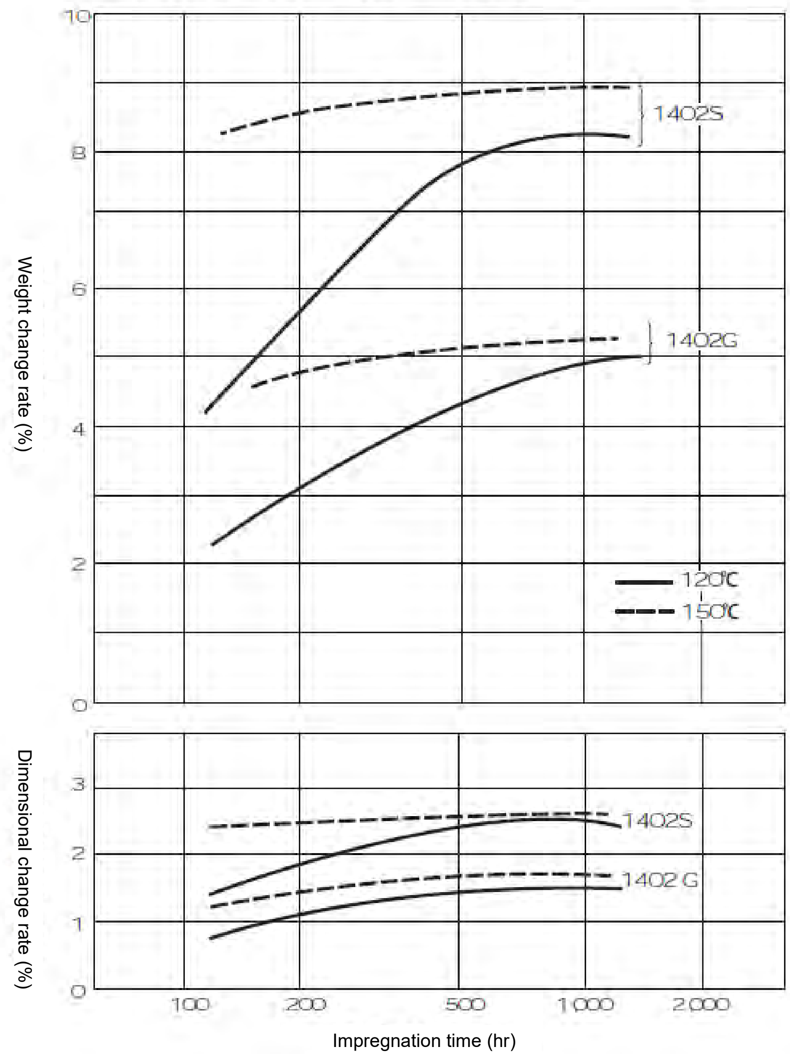


Figure-153 Oil resistance (brake oil) of LEONA



Long-term characteristics of LEONA

Figure-154 Failure characteristics of 14G43 (120℃)

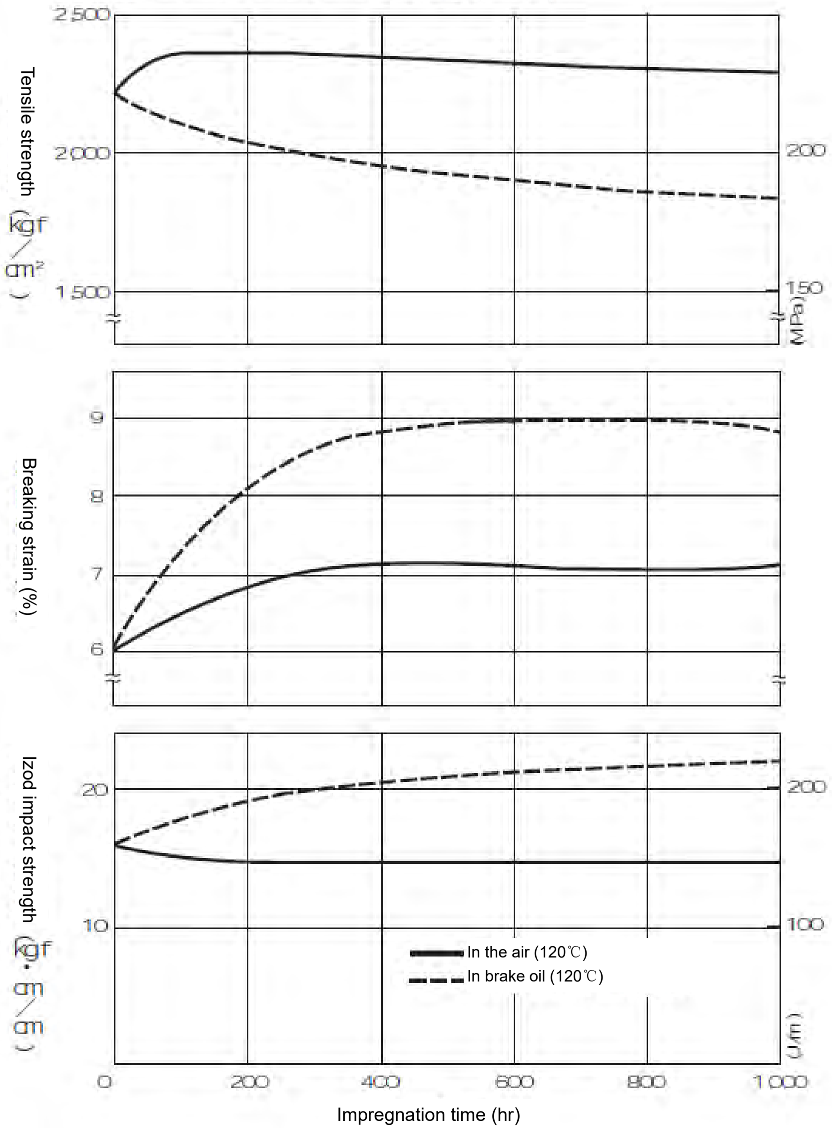
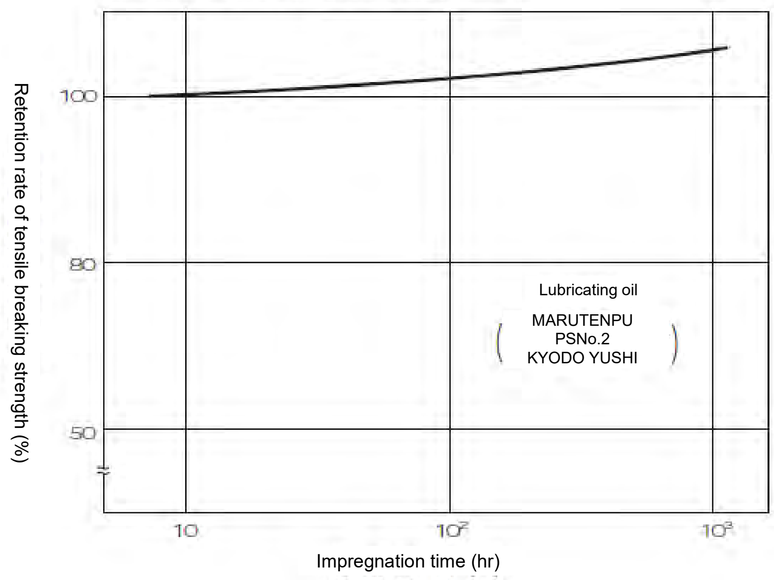


Figure-155 Lubricating oil resistance of 1402G (120℃)



b) Liquid resistance (LLC, window cleaning solution)

Figure-156 LLC resistance of LEONA

(Room temperature, LLC 50% aqueous solution)

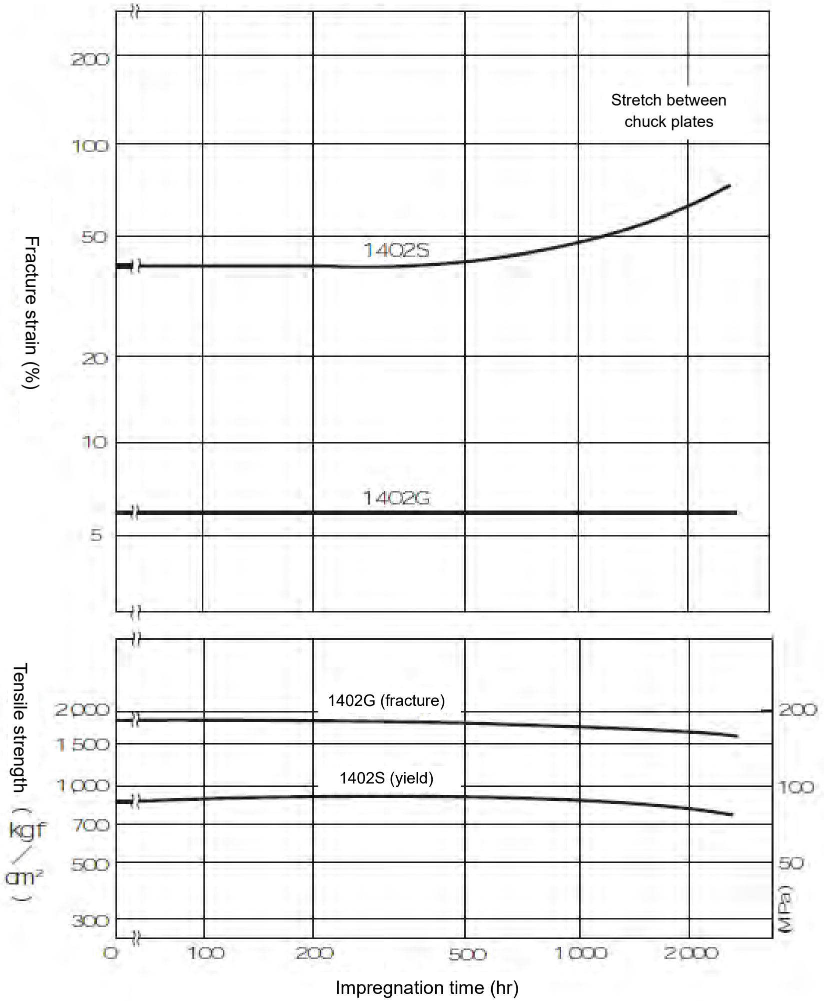
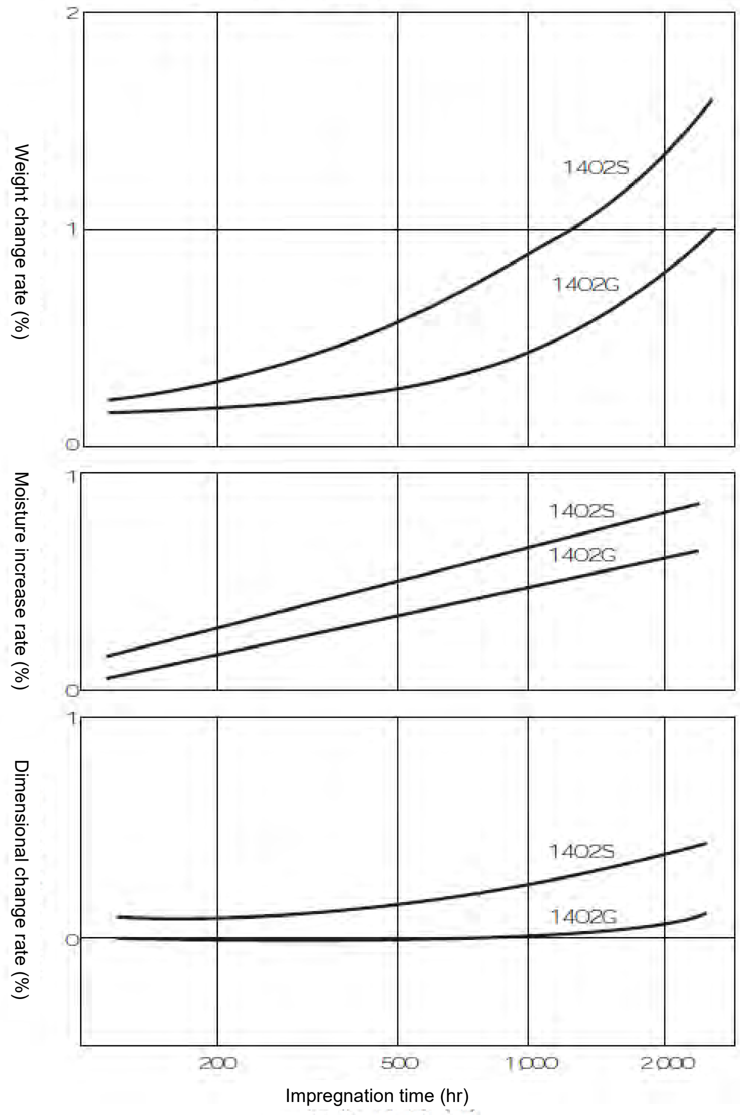


Figure-157 LLC resistance of LEONA

(Room temperature, LLC 50% aqueous solution)



Long-term characteristics of LEONA

Figure-158 LLC resistance of 1300G
(Tensile strength/Impregnation time)

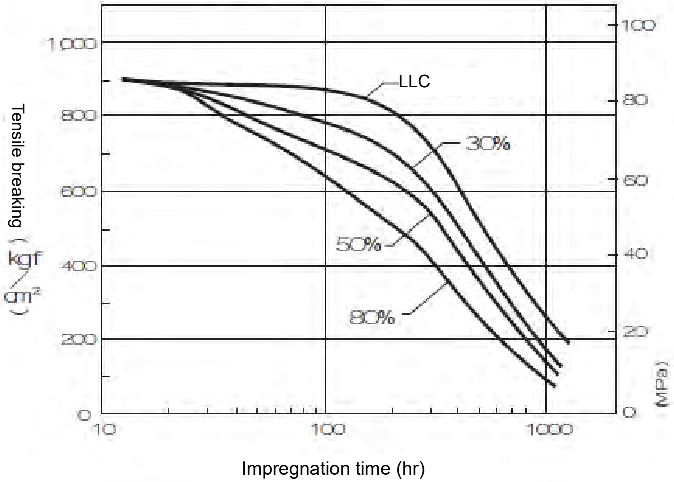


Figure-158 LLC resistance of 1300G
(Weight and dimensional changes/impregnation time)

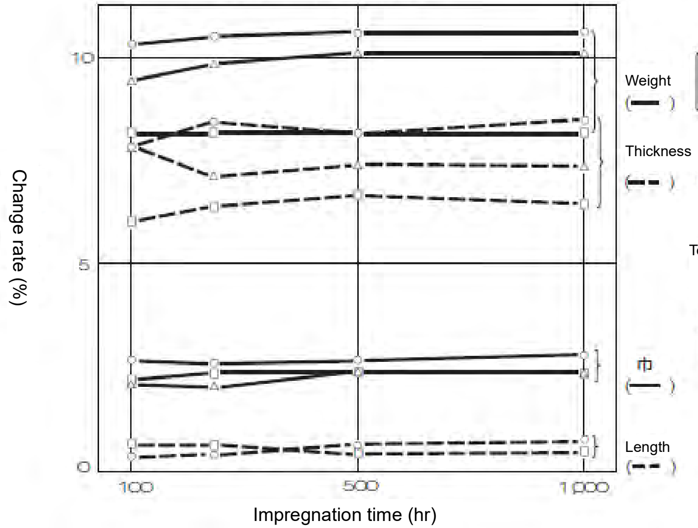


Figure-160 LLC resistance of 1300G (140℃)
(LLC 50% aqueous solution)

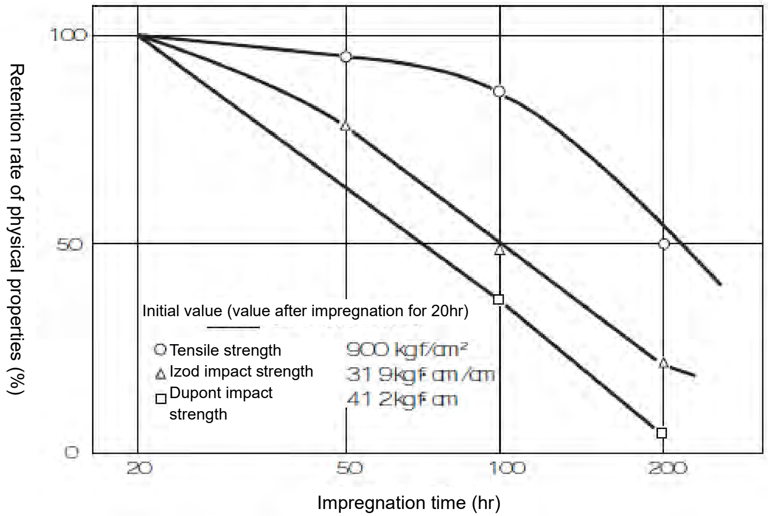


Figure-161 LLC resistance of 1300G (23℃ and 120℃)
(LLC 50% aqueous solution)

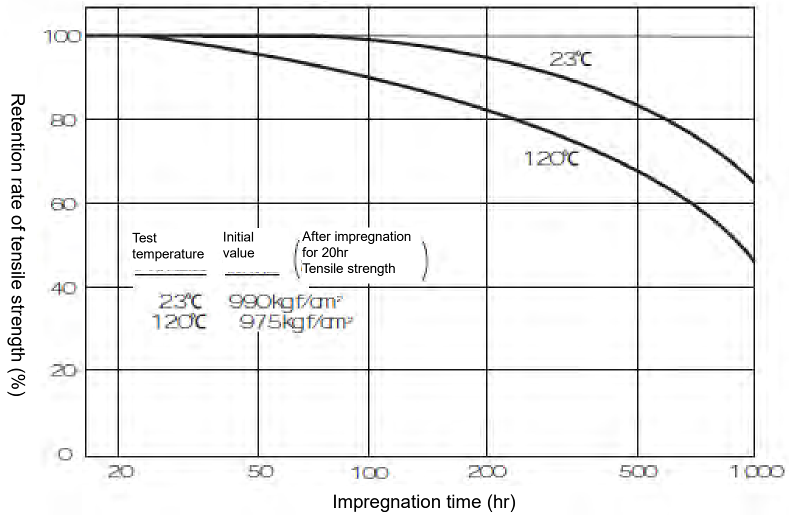


Figure-162 LLC resistance of 130G

(Tensile strength/LLC temperature)

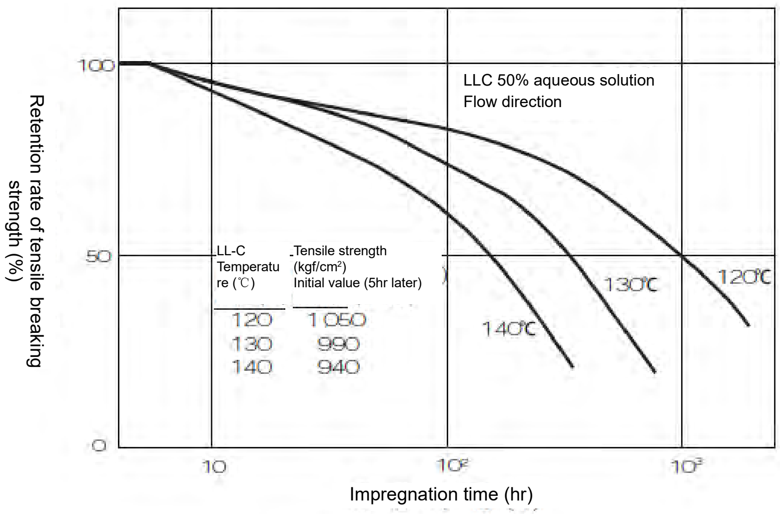


Figure-163 LLC resistance of 1300G

(Tensile strain/LLC temperature)

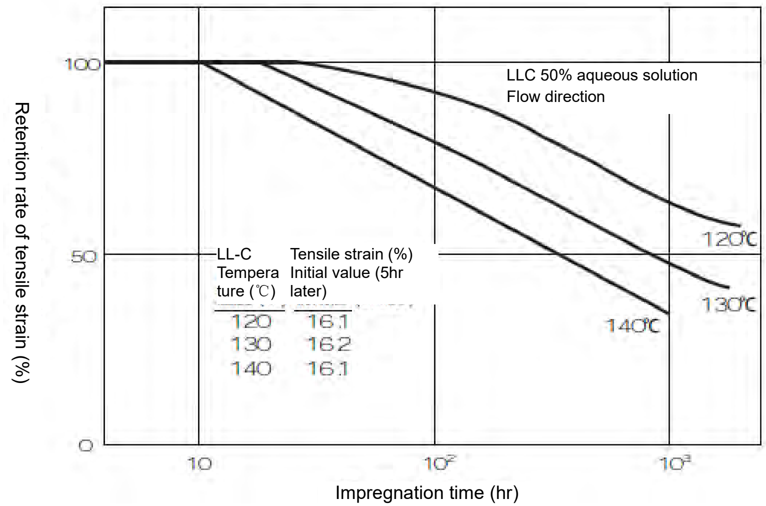


Figure-164 LLC resistance of 1300G

(Tensile strength/LLC temperature)

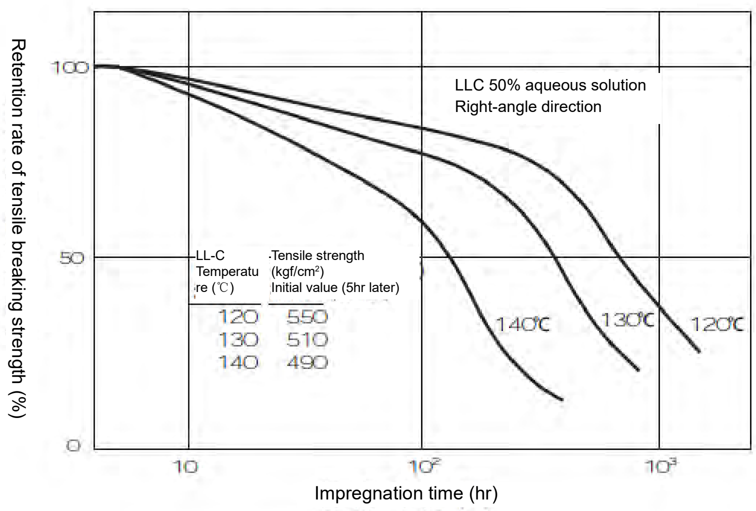


Figure-165 LLC resistance of 1300G

(Tensile strain/LLC temperature)

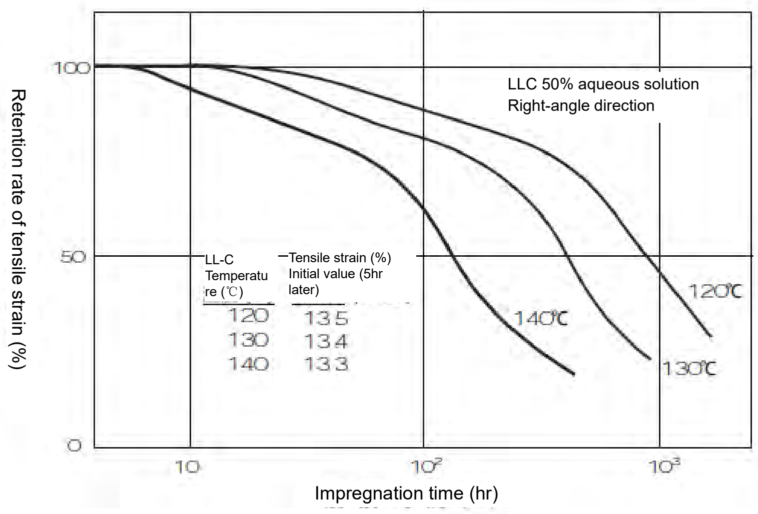


Figure-166 LLC resistance of 1300G (flow direction)

(Tensile strength/test piece thickness)

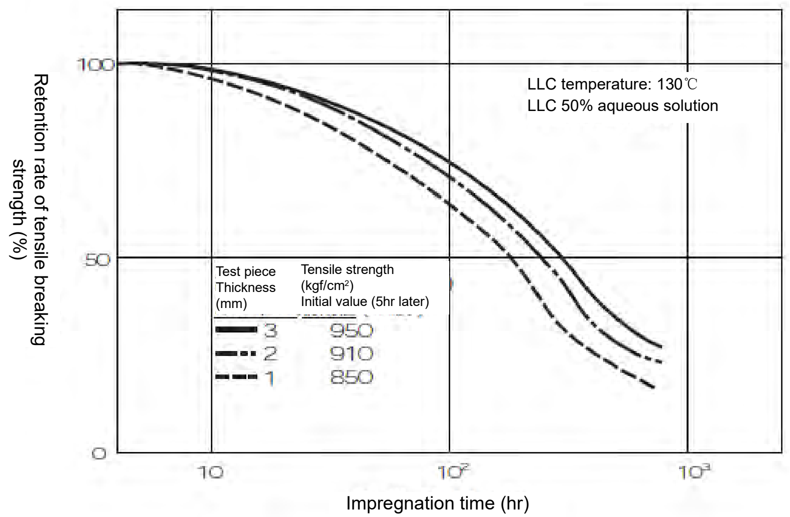


Figure-167 LLC resistance of 1300G (flow direction)

(Tensile strain/test piece thickness)

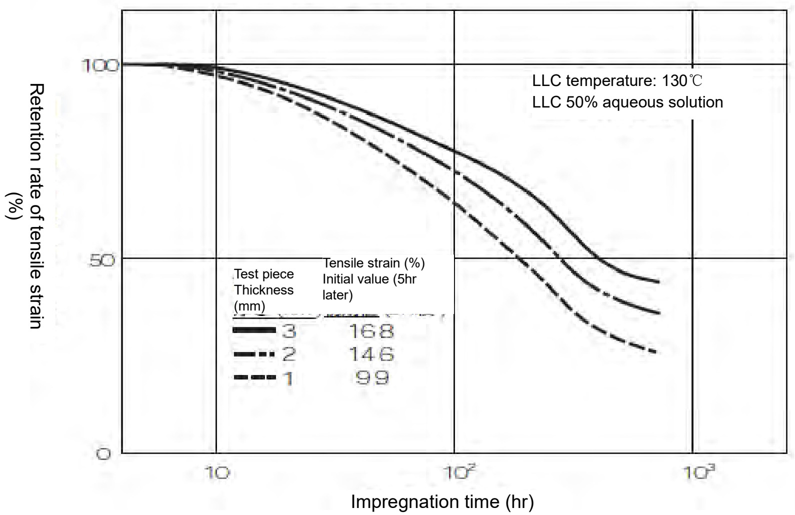


Figure-168 LLC resistance of 1300G (right-angle direction)

(Tensile strength/test piece thickness)

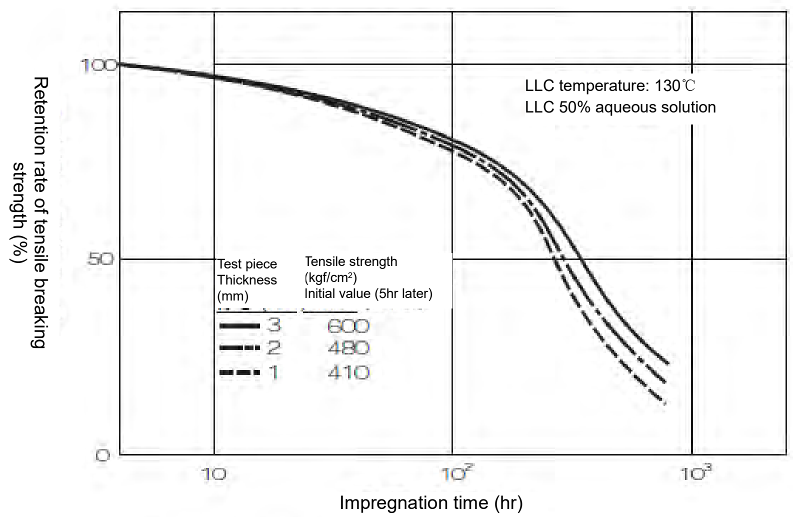


Figure-169 LLC resistance of 1300G (right-angle direction)

(Tensile strain/test piece thickness)

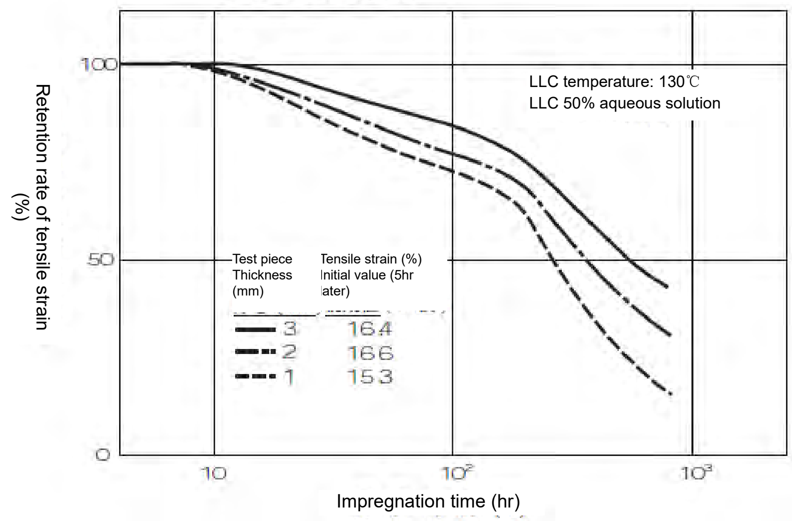


Figure-170 LLC resistance of 1300G

(Bending strength/molding cycle)

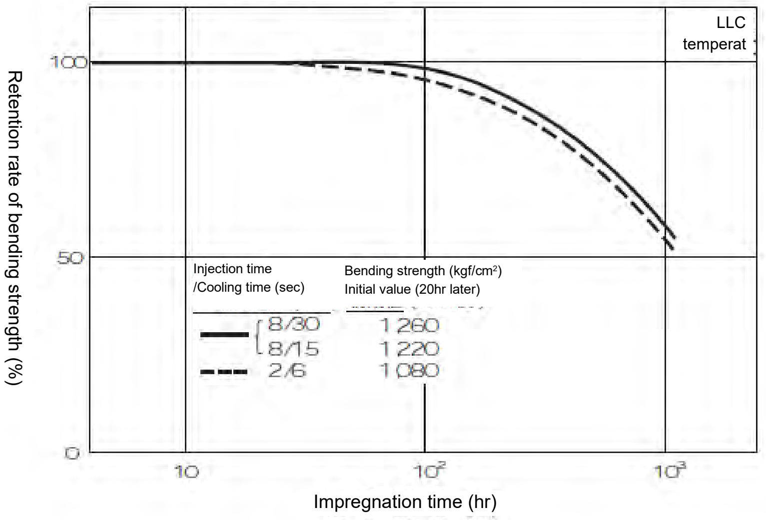


Figure-171 LLC resistance of 1300G

(Izod impact strength/molding cycle)

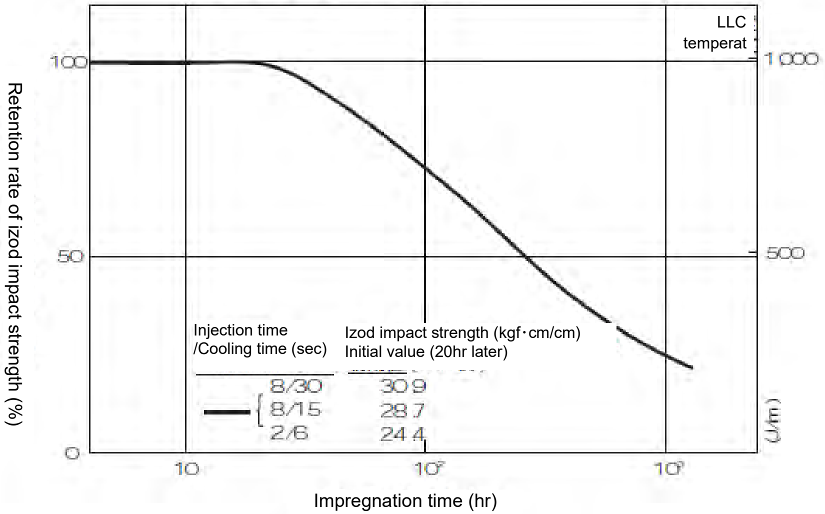


Figure-172 Window cleaning solution resistance of LEONA

(Normal temperature)

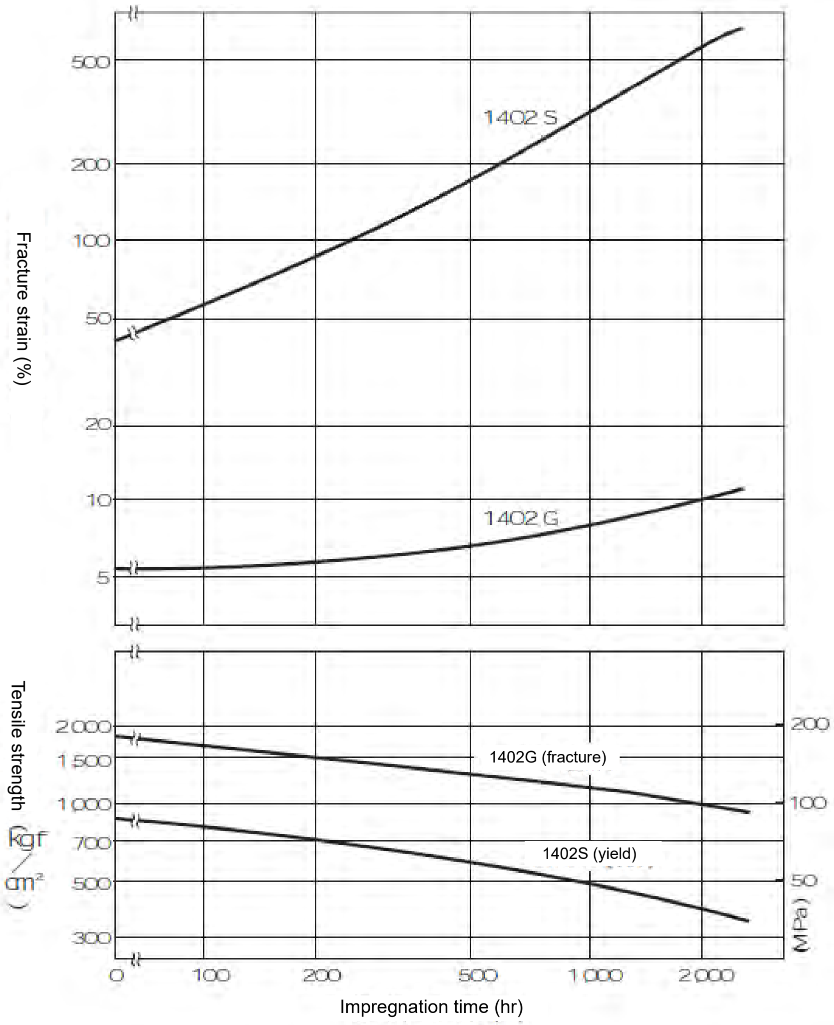


Figure-173 Window cleaning solution resistance of LEONA

(Normal temperature)

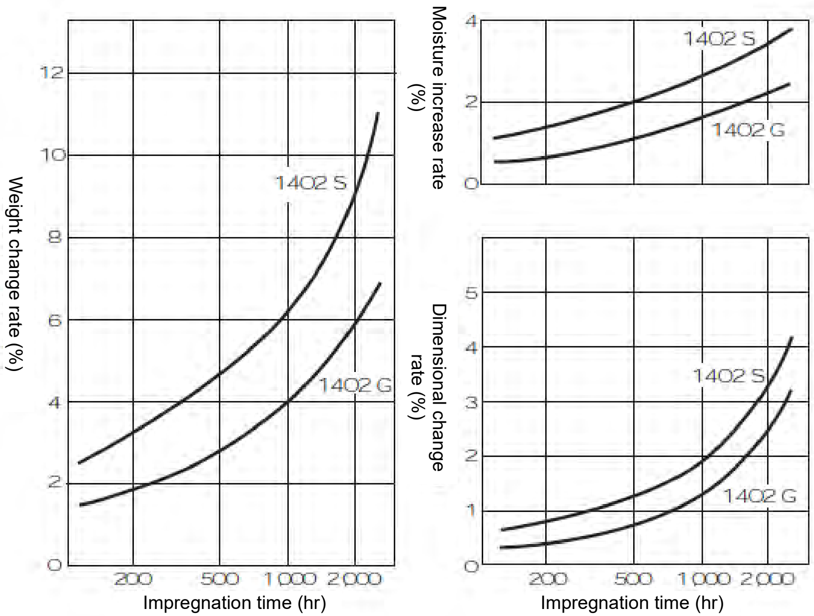
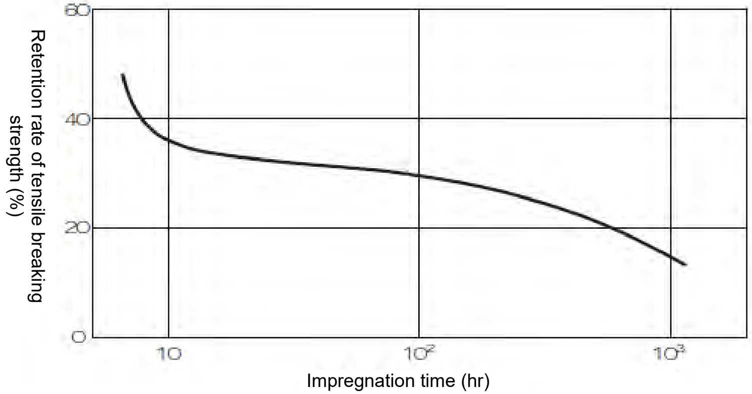


Figure-174 Window cleaning solution resistance of 1402G

(120℃)



c) Acid resistance (hydrochloric acid, sulfuric acid and nitric acid)

Figure-175 Hydrochloric acid resistance of 1402G (liquid temperature 20℃)

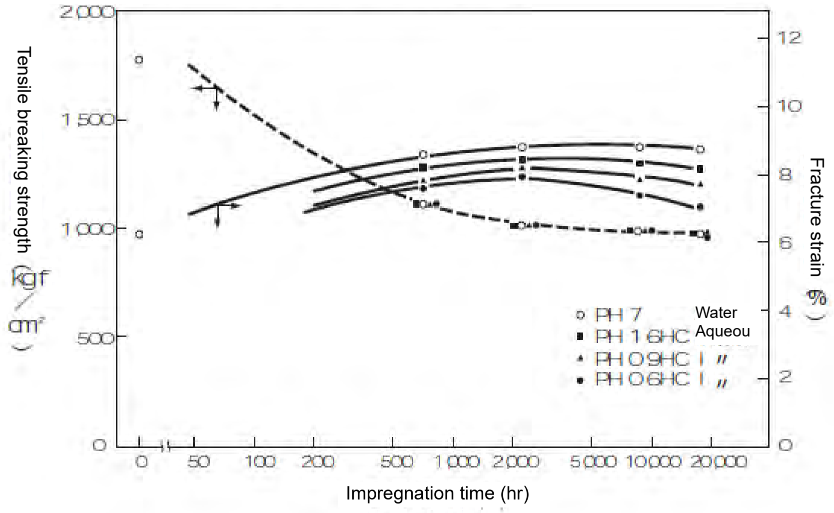


Figure-176 Hydrochloric acid resistance of 1402G (liquid temperature 20℃)

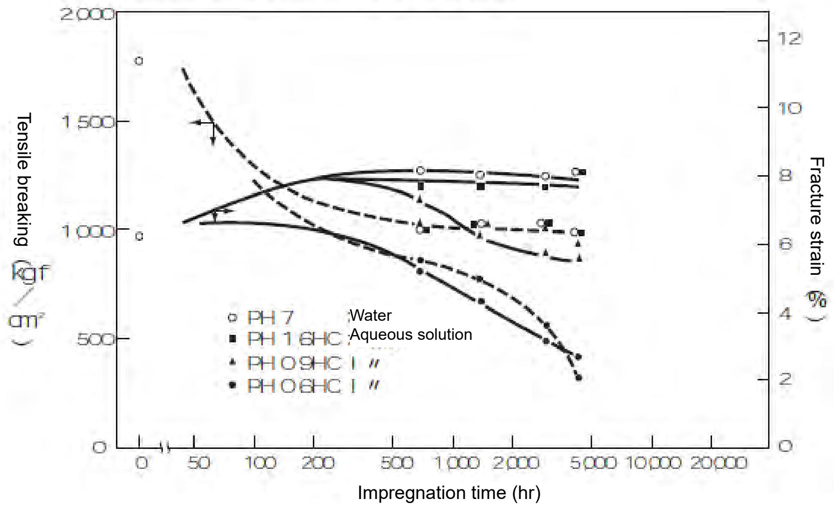


Figure-177 Sulfuric acid resistance of 1402G (liquid temperature 20℃)

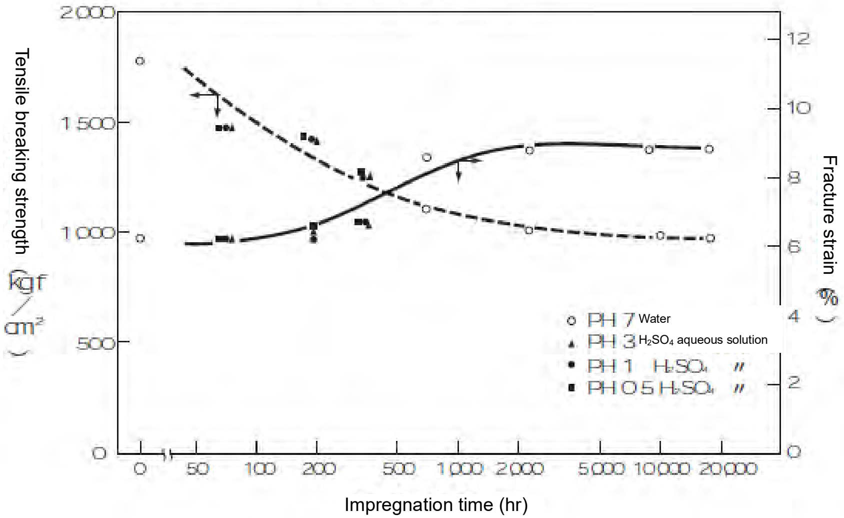


Figure-178 Sulfuric acid resistance of 1402G (liquid temperature 80℃)

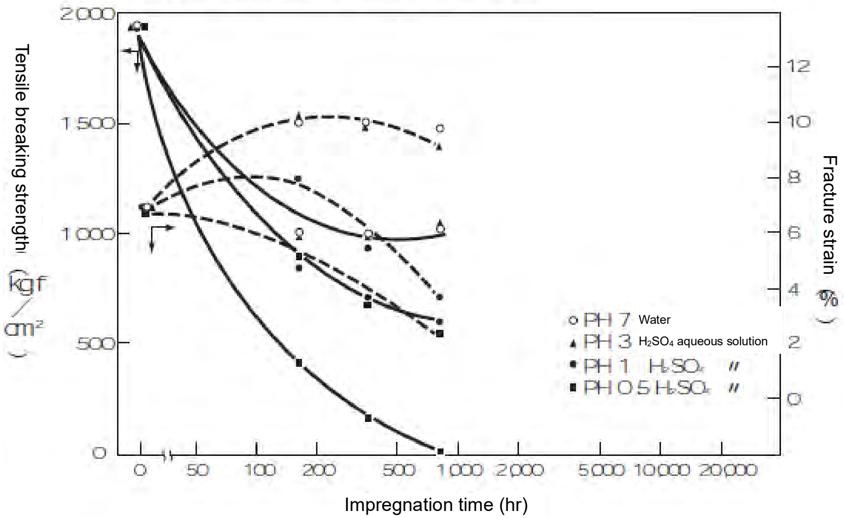


Figure-179 Sulfuric acid resistance of 1402G (liquid temperature 20℃)

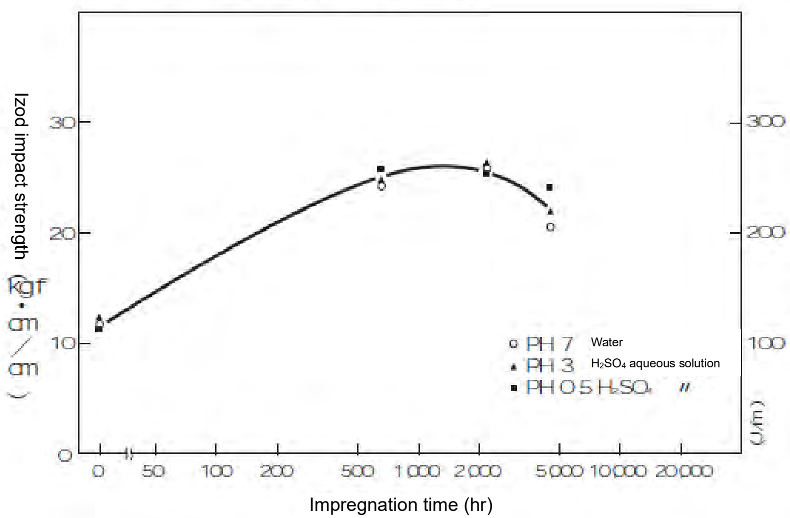
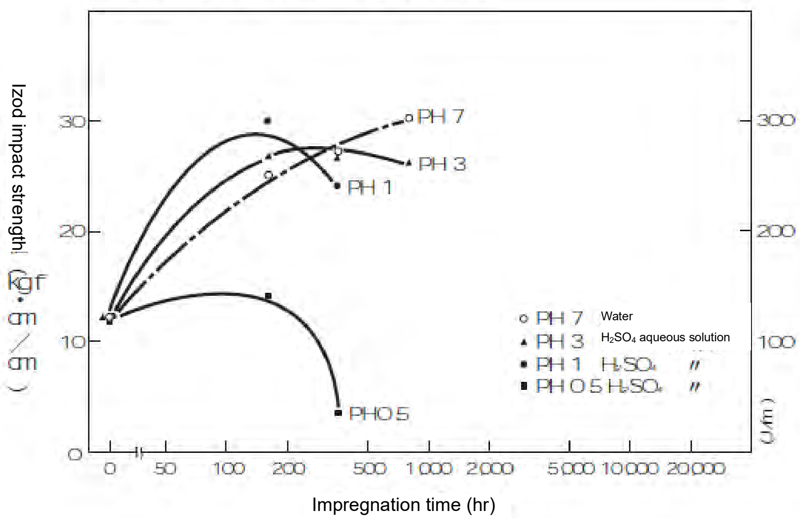


Figure-180 Sulfuric acid resistance of 1402G (liquid temperature 80℃)



General specification
Water absorption characteristics
Moisture dependency
Temperature dependency
Evaluation methods
Specifications and acts
Long-term characteristics
When replacing the metal
Product design
Mold for injection molding
Injection molding technology
Fault cases and countermeasures of molding products

Figure-181 Nitric acid resistance of 1402G (liquid temperature 20℃)

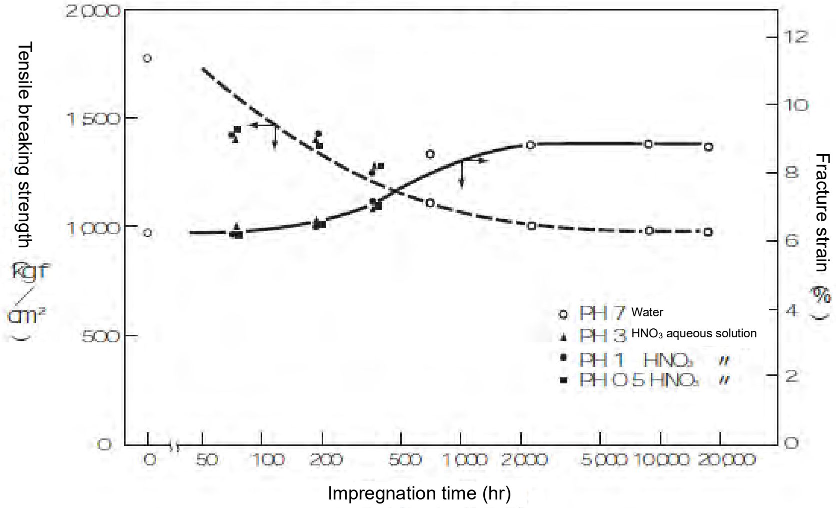


Figure-182 Nitric acid resistance of 1402G (liquid temperature 80℃)

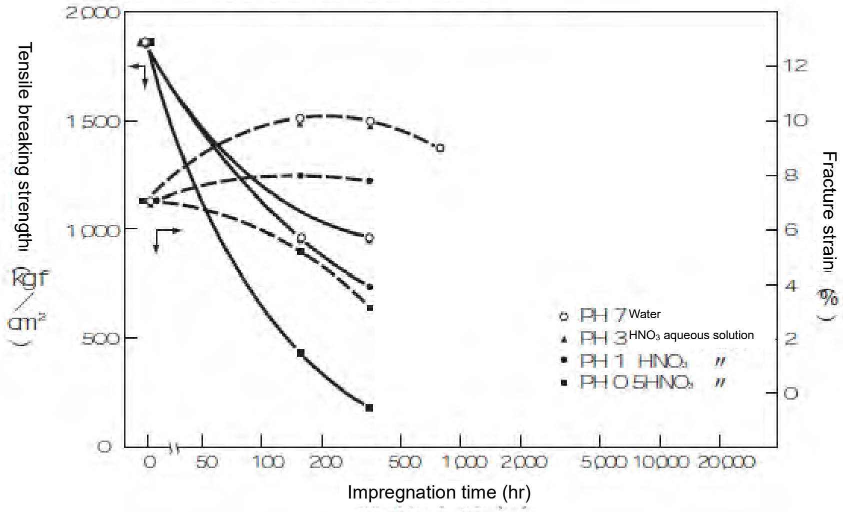


Figure-183 Nitric acid resistance of 1402G (liquid temperature 20℃)

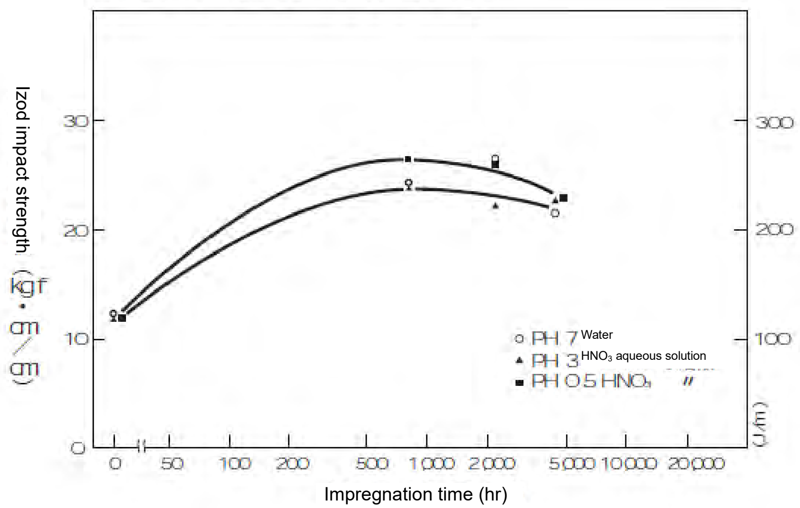
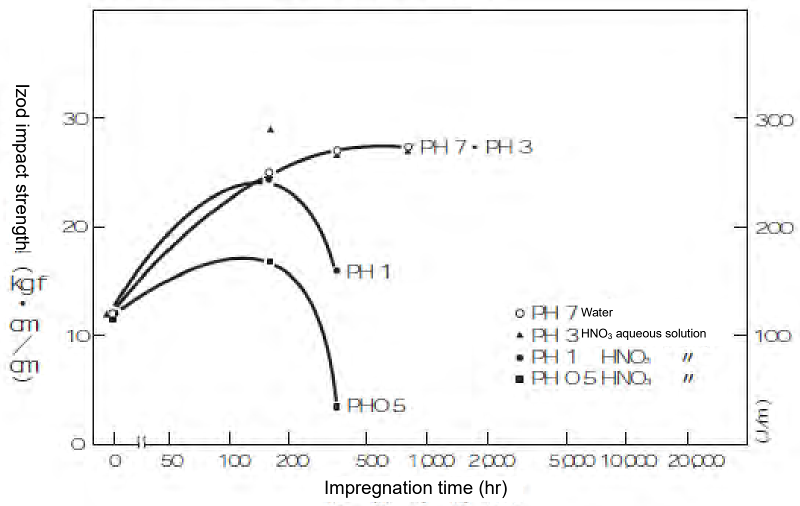


Figure-184 Nitric acid resistance of 1402G (liquid temperature 80℃)



d) Resistance to other drugs

1

(1) Materials: 1300S and 1300G

(2) Drugs ①NaCl(salt/sodium chloride) 0.873g/l aq. (0.087%)

② H_2SO_4 (sulfuric acid) 0.52 g/l aq. (0.0053N)

③$Ca(NO_3)2 \cdot 4H_2O$(calcium nitrate) 0.029g/l aq. (0.0001Mol/l)

④HCHO(formaldehyde) 0.004g/l aq. (0.00013Mol/l)

(Remark) * aq: aqueous solution

(3) Temperature 90℃

(4) Time 50hr and 250hr

2

⑴ Material 14G43(non-contact with liquid level...exposed in steam)

(2) Drugs ① Saint-paul (toilet detergent and hydrochloric acid 9.5%)

② Vinegar

(3) Temperature 23℃

(4) Time l25hr, 250hr and 500hr

1 (sodium chloride, sulfuric acid, calcium nitrate and formaldehyde)

Figure-185 Drug resistance of 1300S (90℃)

The figure in () is the change rate according to the standard of water (100)

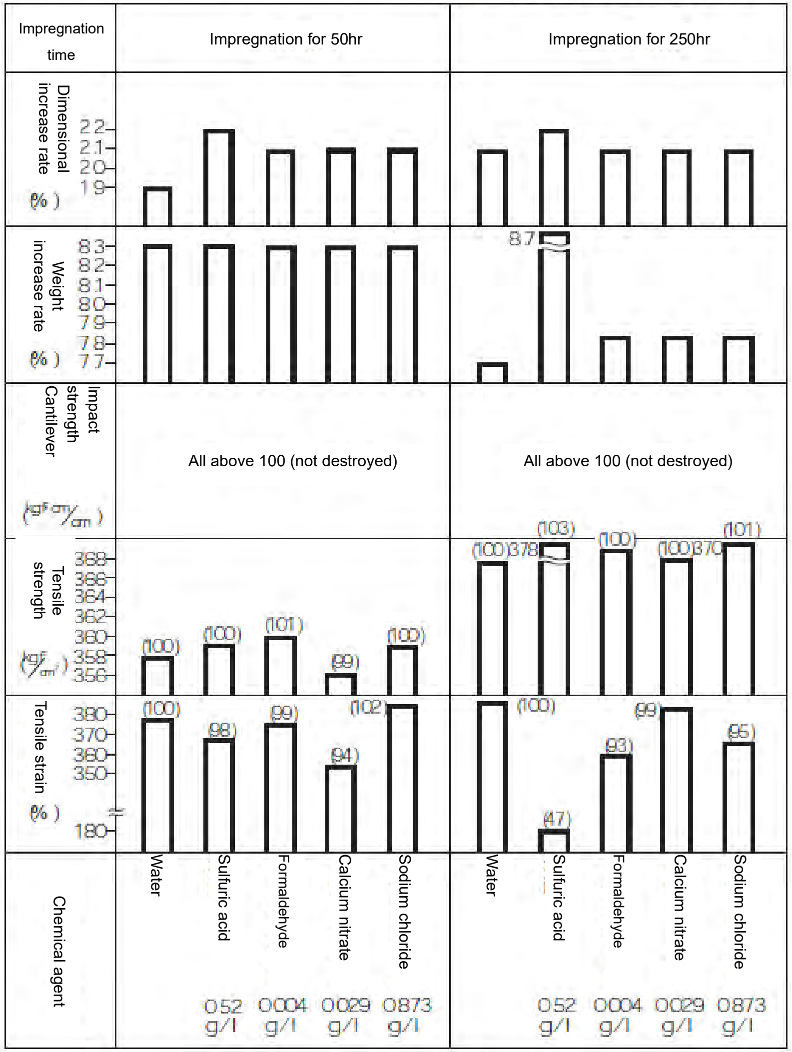
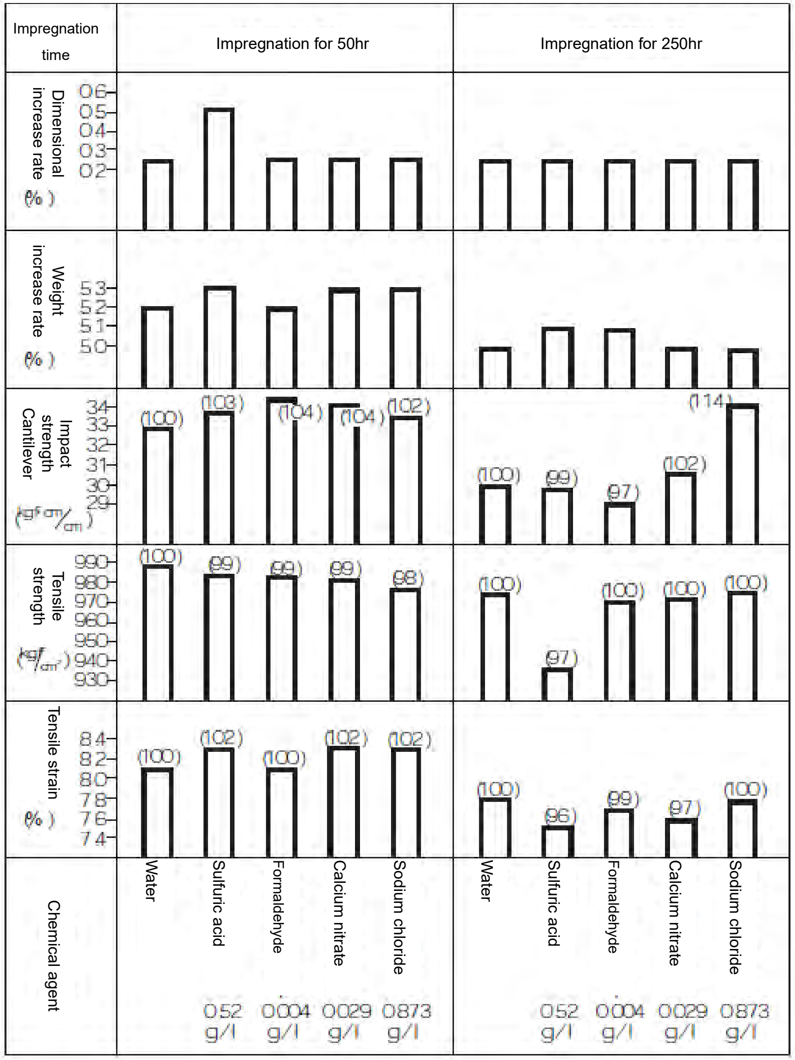


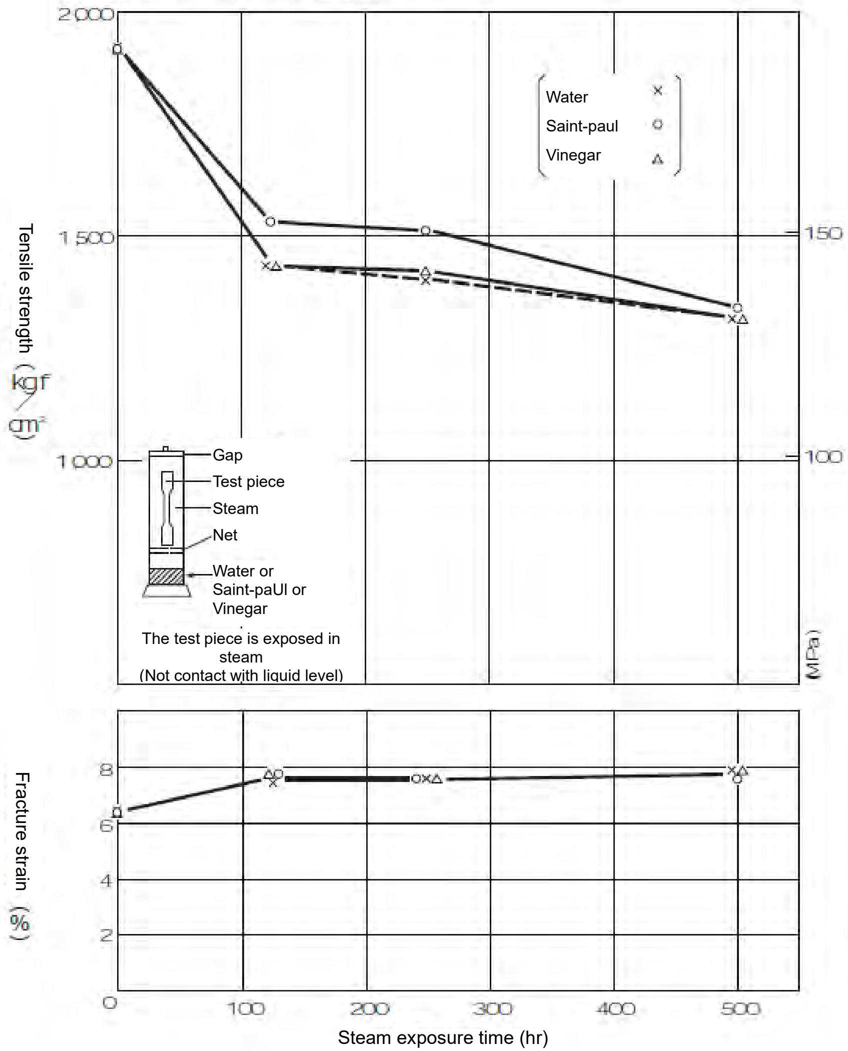
Figure-186 Drug resistance of 1300G (90℃)

The figure in () is the change rate according to the standard of water (100)



2 (Saint-paul and vinegar)

Figure-187 Drug resistance of 14G43



e) Ozone resistance

Table 31: Ozone resistance of 1402S

Cond
- Ozone (O_3): 0.05ppm
- Environment: 40℃×50～60%RH
- Test time: 30 days
- Specimen: start under balanced water absorption status (WET)

Item	Unit	Initial value	After test
Tensile yield strength	kgf/cm²	540	560
Fracture strain	%	300	300
Weight change	%	±0	−0.8
Dimensional change rate	%	±0	−0.3
Appearance change	–	–	Unchanged

f) Long-term characteristics of 1402S

(a) Drug resistance

Gasoline (standard, high octane, synthesis)
Oil (torque converter, transmission, motor and brake)
Lubricating oil (ALMIX, MARUTENP)
Ethyl alcohol (methanol, ethylene glycol)

Brine saturated solution: Sodium chloride, Magnesium chloride, Calcium chloride, Zinc chloride ($NaCl$, $MgCl_2$, $CaCl_2$, $ZnCl_2$)

Other: Window cleaning solution and supplementary acid for battery; 5% sulfuric acid and LLC

(b) Placement at high (c) temperature
(d) Wet fastness
(e) Brine spray
(f) Corrosive gas resistance...ozone
(g) Temperature shock
(O_3) Nitrous acid gas (SO_2)

Molding conditions of LEONA grade and test piece for evaluation

- LEONA1402S natural color (heat resistant grade)
- LEONA1402S black (color modulated by black masterbatch)
- LEONA1402S green (color modulated by green masterbatch)

Table 32: Molding conditions of test piece

Item		Conditions
Molding machine		Sumitomo NEOMATTO N47/28 :1OZ
Screw revolution		72rpm
Temperature	Charging barrel	Nozzle side Hopper side 280℃ – 280℃ – 270℃
	Mold	90℃
Injection molding		12kgf/cm²G (360kgf/cm²)
Back pressure		Natural • black: no load Green 60kgf/cm²
Injection speed		12 scale (intermediate speed)
Plasticization stroke		37mm (residual volume 2~3mm)
Time	Injection molding	10sec
	Cooling	20sec

Table 33: Test methods of long-term characteristics of 1402S

Class	Characteristics	Specified specification	Conditions and methods	Test piece status: At the start	Test piece status: When measuring	Validation items	Note
Ongoing change	Drug resistance		Drug: Refer to Table 18: " Treatment time: 1, 3, 5, 10, 30, 60 and 90 days	(Remark 1) WET	(Remark 2) NATURAL (WET)	Stretch, weight, dimensions and appearance	
	Placement at high temperature		Temperature: 100, 120, 140℃ Treatment time: 1, 3, 5, 10, 30, 60 and 90 days	DRY	DRY	〃	
	Weather fastness		Solar spectrum weather fastness test equipment Treatment time: 200, 400 and 1000hr	WET	NATURAL (WET)	〃	
	Wet fastness		Above 80℃×95%RH 1, 3, 5, 10, 30 and 60 days	〃	〃	〃	
	Brine spray	JIS Z2371	Treatment time: 1, 3, 5, 10 and 30 days 5% sodium chloride water ×35℃	〃	〃	〃	Use salt spray tester ST-JR manufactured by RKC
	O_3 resistance	JIS D0203	Treatment time: 1, 3, 5, 10 and 30 days 0.05PPM ×40℃×50～ 60% RH	〃	〃	〃	Use OMS -2 ozone monitor manufactured by RKC
	SO_2 resistance	DIN 50018	Treatment time: 1, 3, 5, 10 and 20 days 0.1PPM ×20～ 25℃× above 95% RH	〃	〃	〃	Use sulphurous acid gas testing unit GS-2 manufactured by RKC
	Thermal shock (thermocycling)		(140℃×1hr)→←(−50℃×1h r) (100℃×1hr)→←(−30℃×1h r) (80℃×2hr)→←(−30℃×2h r) Treatment time: 10 cycles Treatment time: 10, 50, 100, 200 cycle, from high temperature	DRY	NATURAL(DRY) ≒	〃	Use thermocycling test unit TSC-20 manufactured by ABzAIEPsC

(Remark 1) WET: Test piece water absorption 3.1%
(Remark 2) Natural: measure the weight, dimensions and physical properties under natural status without drying after treatment(WET) represents balanced water absorption status and (=DRY) represents absolute dry condition of the test piece.

Table 34: Oils and drugs for evaluation

Type	Name	Specification and trade name	Status in use	Remark
Gasoline	Regular gasoline	ENEOS siruba-gasoline	30℃	
	High-octane gasoline	ENEOS go-rudo gasoline	〃	
	Synthetic gasoline	Toluene (first grade) Iso-octane (") =6/4(vol)	〃	
Oil	Torque converter	Toyota Genuine CASTLE brake liquid	〃	
	Transmission (Gear)	Toyota Genuine CASTLE gear oil 90(GL-3)	〃	
	Motor (Engine)	Toyota Genuine MS-DM CASTLE 20V 40	〃	
	Brake oil	Toyota Genuine Brake fluid 2400F	〃	<Principal components> Castor oil Advanced ethanol or ethylene glycol
Lubricating oil	ALMIX	ALMIX T No.2	〃	
	MARUTENPU KYODO YUSHI	TA60 lubricating oil produced by KYODO YUSHI	〃	
Monohydric alcohol	Methanol	Primary chemical reagent	〃	
Brine saturated solution	Sodium chloride	〃	20℃	
	Magnesium chloride	〃	〃	
	Calcium chloride	〃	〃	
	Zinc chloride	〃	〃	
Other	Water	Tap water	〃	
	Wind Cleaning solution	Toyota Genuine Window cleaning solution	〃 (conc.)	<Principal components> Methanol, water, silicone oil and interfacial agent
	Battery Supplementary acid	Toyota Genuine Supplementary acid for battery	〃	<Principal components> Pure water
	Sulfuric acid	Primary chemical reagent	〃 (5% aqueous solution)	
	LLC	CASTLE antifreezing solution LLC	〃 (conc.)	<Principal components> Water and diethylene glycol
	Ethylene glycol	Primary chemical reagent	〃	

Table 35: Drug impregnation evaluation results (1402S-1)

╲ : Show further downtrend at the end of test
╱ : 〃 〃 〃 Increase 〃
└→ : Stable after decline
┌→ : Increas 〃 〃 〃
─╲ : Omen of decline
─→ : Unchanged

[Remark] 1. The samples are in balanced water absorption status (water absorption 3.1%) at the start of the drug resistance test.
2. The value is recorded at the end of the test and the scope of the values with fluctuations is recorded

	Chemical	Weight		Dimensions		Tensile yield strength		Breaking strain		Appearance	Influence of colorant	Test time	Remark
		Trend	%	Trend	%	Trend	kgf/cm²	Trend	%				
Gasoline	Standard	└→	(−) 04	└→	(−) 02	─→	540	─→	300	Unchanged	NA	90日	
	High-octane rating	└→	(−) 04	└→	(−) 03	─→	540	─→	300	〃	〃	〃	
	Synthesis	└→	(−) 03	└→	(−) 03	─→	540	─→	300	〃	〃	〃	
Oil	Torque converter	└→	(−) 04	└→	(−) 03	─→	540	─→	300	Slightly coloring to light red	Yellowing not obviously	〃	
	Transmission	└→	(−) 05	└→	(−) 03	─→	540	─→	300	Unchanged	NA	〃	
	Motor (Engine)	└→	(−) 05	└→	(−) 03	─→	540	─→	300	〃	〃	〃	
	Brake	└→	(−) 10	└→	(−) 05	┌→	660	─╲	260	〃	〃	〃	
Lubricating oil	ALMIX	└→	(−) 06	└→	(−) 05	─→	540	─→	300	〃	〃	〃	
	MARUTENPU	└→	(−) 03	└→	(−) 03	─→	540	─→	300	〃	〃	〃	
Monohydric alcohol	Methanol	┌→	(+) 52~60	┌→	(+) 25~30	└→	380	─→	300	Turn yellow	Yellowing not obviously	〃	

Table 36: Drug impregnation evaluation results (1402S-2)

Impregnation temperature: 20℃

	Chemical	Weight		Dimensions		Tensile yield		Breaking strain		Appearance	Influence of colorant	Test time	Remark
		Trend	%	Trend	%	Trend	kgf/cm²	Trend	%				
Alcohol	Ethylene glycol	╱	(+) 06	└→	(−) 01	┌→	610	─→	300	Unchanged	NA	90日	
Brine saturated solution	NaClaq.	╱	(+) 13	╱	(+) 04	╲	460	─→	300	〃	〃	〃	PH= 79
	$MgCl_2$aq.	╱	(+) 22	╱	(+) 06	╲	410	─→	300	〃	〃	〃	PH= 72
	$CaCl_2$aq.	└→	(−) 04	└→	(−) 02	└→	520	─→	300	〃	〃	〃	PH=55
	$ZnCl_2$aq.	╱	(+) 10	╱	(+) 04	╲	320	╲	10	Fracturing at the first day	〃	1日	PH=02
Other	Water	┌→	(+) 52	┌→	(+) 18	└→	370	─→	300	Unchanged	〃	90日	PH= 78
	Window Cleaning solution	┌→	(+) 82~84	┌→	(+) 36	└→	320	─→	300	Coloring to blue	Coloring not obviously (brown cannot be identified)	〃	
	バッテリー補充液	┌→	(+) 52	┌→	(+) 18	└→	370	─→	300	Unchanged	NA	〃	
	5% H_2SO_4aq.	┌→	(+) 56	┌→	(+) 18	└→	360	╲	220	Yellowing and pulverization	Yellowing not obviously	〃	PH=06
	Antifreeze LLC	╱	(+) 05	└→	(−) 02	┌→	600	─→	300	Unchanged	NA	〃	

(aq Aqueous solution)

Long-term characteristics of LEONA

Table 37: Environmental impact evaluation results

Enviro	Conditions	Weight		Dimensions		Tensile yield strength		Breaking strain		Appearance	Influence of colorant	Test time	Remark
		Trend	%	Trend	%	Trend	kgf/cm²	Trend	%				
(Note) Placement at high temperature	In 100℃ air		(−) 0.1		(−) 0.1		920		19	Yellowing	Yellowing not obviously	90 days	
	In 120℃ air		(−) 03		(−) 02		930		24	Coloring to dark brown	〃	〃	
	In 140℃ air		(−) 04		(−) 03		930		19	Coloring to black brown	Non-obvious black but obvious green coloring	〃	
Weather fastness	Sunny climate instrument		(−) 04~10		(−) 02		610		30	Unchanged (Attached with a little scale)	NA	1,000hr	
Wet fastness	Above 80℃×95% RH		(+) 4.5		(+) 1.8		400		300	Coloring to dark brown	Non-obvious black but obvious green coloring	60	
Brine spray	5%Na claq ×35℃		(+) 24~37		(+) 07~13		380 ~430		300	Unchanged	NA	30	
Corrosive gas	O_3 005ppm×40℃ ×50~60%RH		(−) 08~10		(−) 03		560		300	〃	〃	〃	
	SO_2 0.1ppm×20~25℃ ×95%RH		(+) 16		(+) 05		450		300	〃	〃	20 days	
(Note) Thermal shock	140℃ ×1hr ⇄ −50℃ ×1hr		(+) 04		(−) 0.1		800 ~870		34	Coloring to dark brown	Yellowing not obvious (especially black)	200 cycles	
	100℃ ×1hr ⇄ −30℃ ×1hr		(+) 05~08		(+) 0~02		800		35	Yellowing	〃	〃	
	80℃ ×2hr ⇄ −30℃ ×2hr		(+) 09		(+) 02		760		39	Unchanged	NA	10 cycles	

or: The measured value is shown in the solid line, but it should be shown in the dotted line according to the previous cognition.

(Note) Placement at high temperature and thermal shock start from the dry state and the samples in balanced water absorption status (water absorption 3.1%) are used for the other items.

7-6 Thermal aging resistance (in the air)

Figure-188 Thermal aging (contrast with nylon 6)

(1300S 125℃)

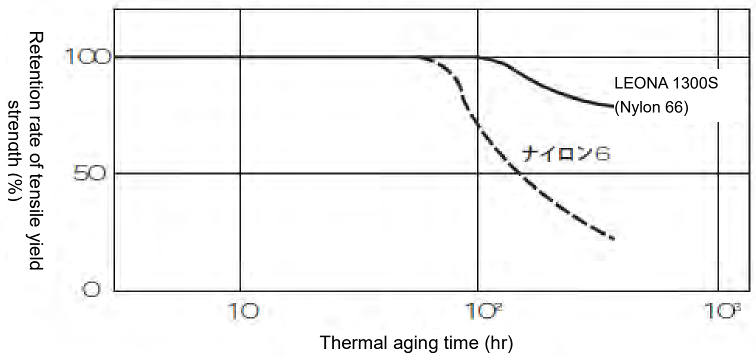
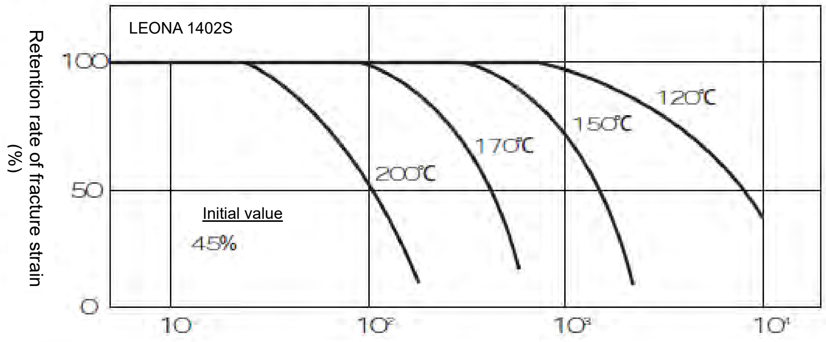
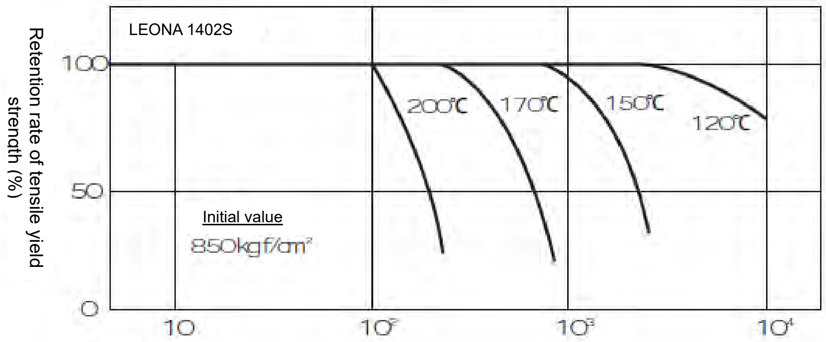


Figure-189 Thermal aging (1402S and 1402G)





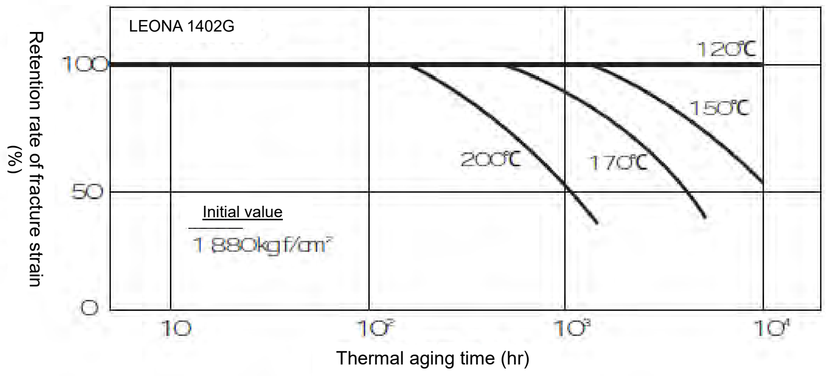


Figure-190 Life characteristics (keep tensile strain 50%)

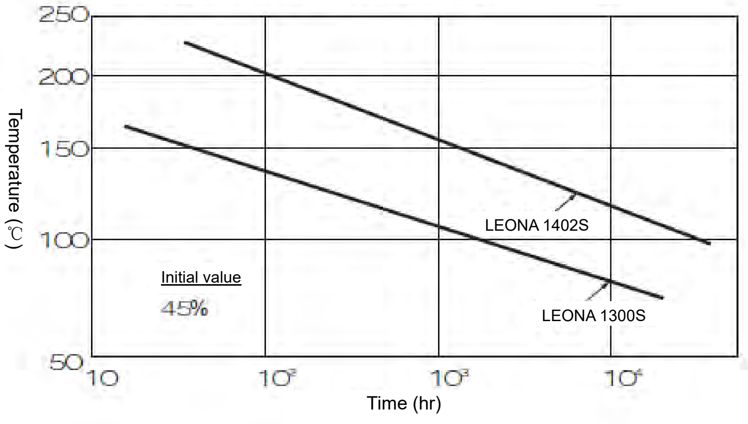


Figure-191 Life characteristics (keep tensile strain 50%)

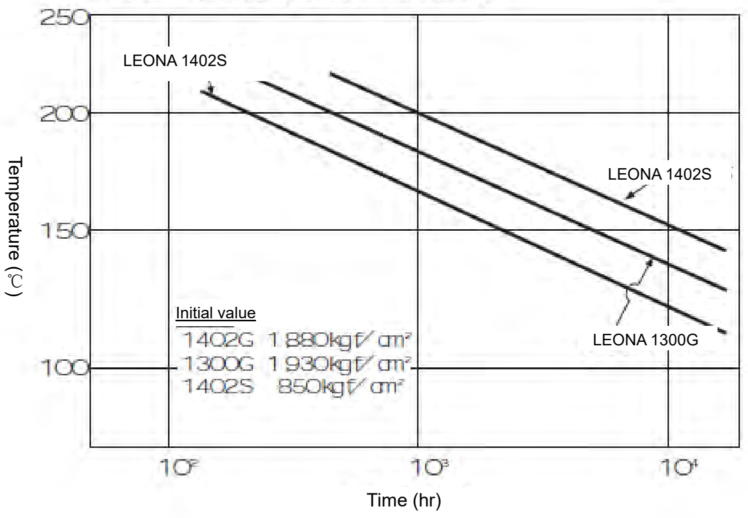
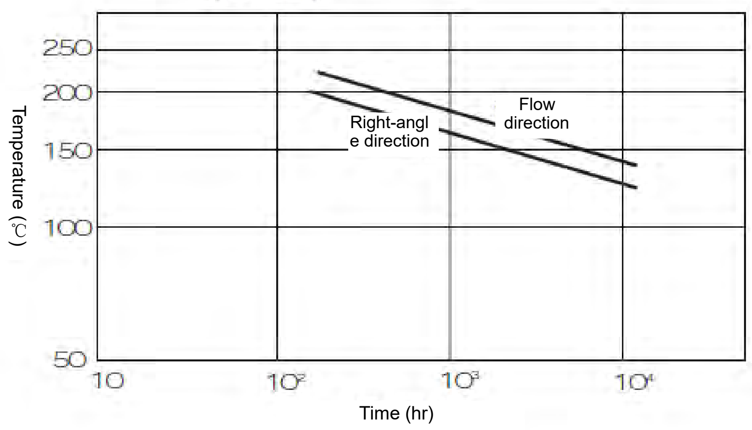


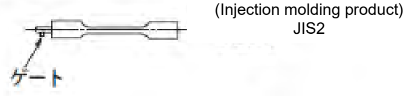
Figure-192 Life characteristics (keep tensile strain 50%)

(1300G)



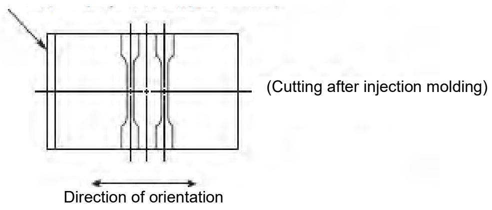
Test piece (thickness: 3mm)

1) Flow direction



2) Right-angle direction

Film gate (gate thickness: 1mm)



7-7 Weather fastness

(1) Conduct acceleration test with Solar spectrum weather fastness test equipment (irradiation by carbon arc lamp)

(a) Test methods

Implement according to JISA1415

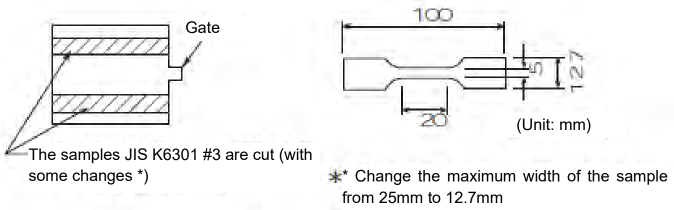
· Carbon arc lamp

· Black panel temperature 63±3℃

· Spray time (water): spray for 18min per 120min

(b) Test piece

Make a 130mm×110mm×3mm slab through injection molding and then cut into the following small test pieces for test.



(c) Judgment method of degradation

Take the samples subject to stipulated illumination time from the solar spectrum weather fastness test equipment and place in the environment at 20℃ and 50%RH for 20h for tensile test.

· Test conditions Tensile speed 50mm/min

Distance between the clamps: 45mm

Environment: 20℃ 50%RH

Figure-193 Weather fastness of LEONA (Solar spectrum weather fastness test equipment)

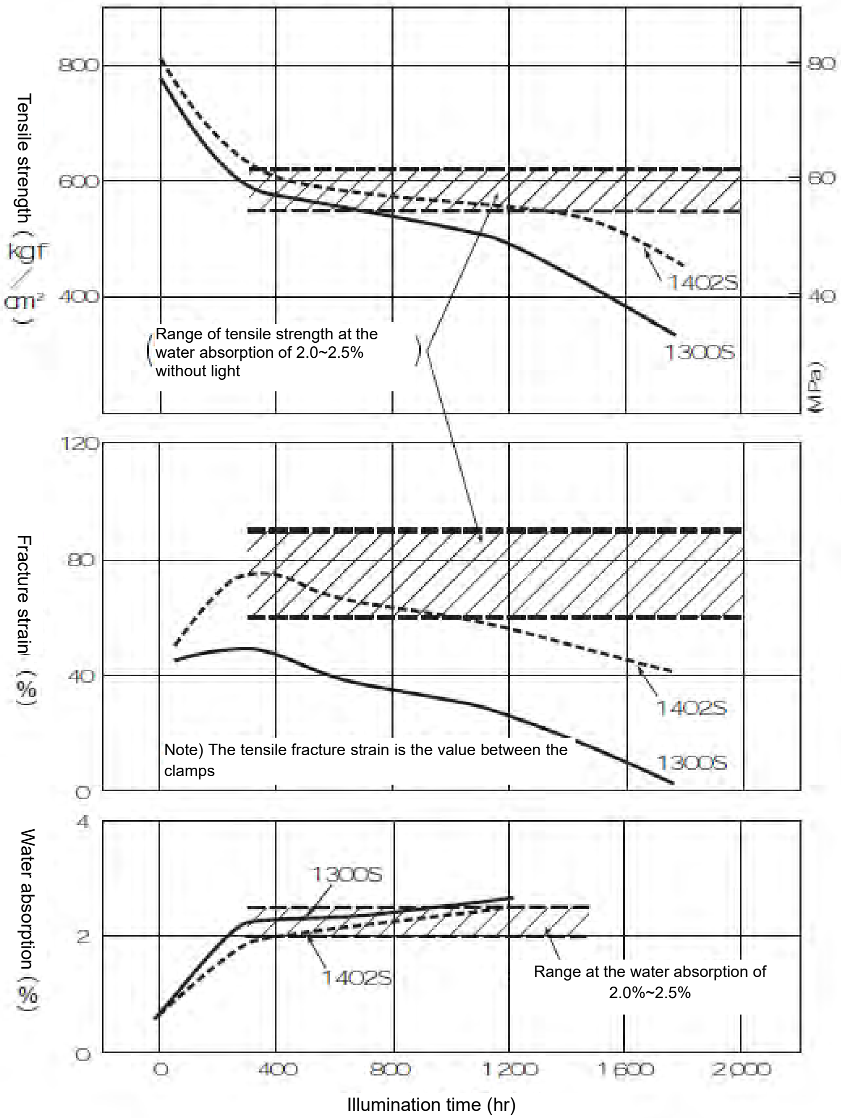
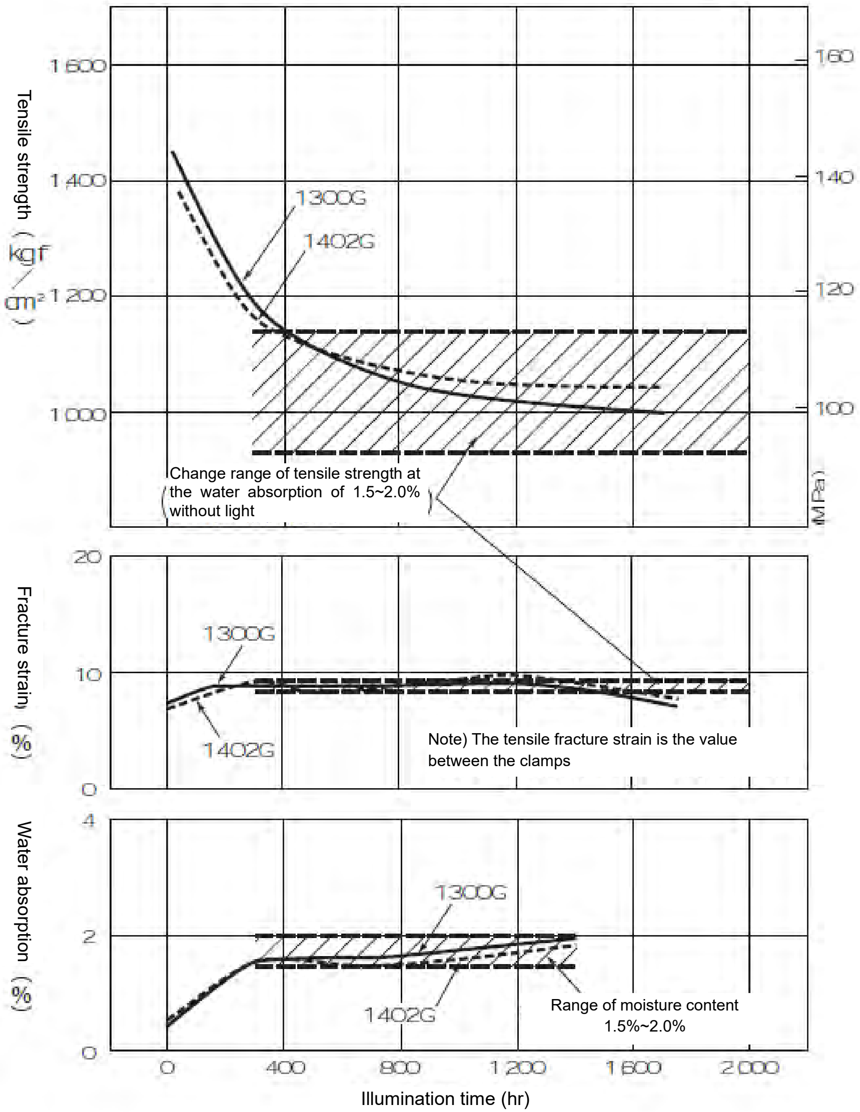


Figure-194 Weather fastness of LEONA (Solar spectrum weather fastness test equipment)



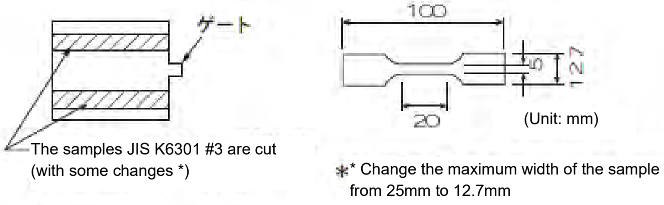
(2) Outdoor illumination test

(a) Test methods

Put the samples in the coast near Nobeoka, Miyazaki Prefecture and illuminate the samples outdoor for two years.Install the samples in a sample platform at 45° angle with the horizontal plane towards the south.

(b) Test piece

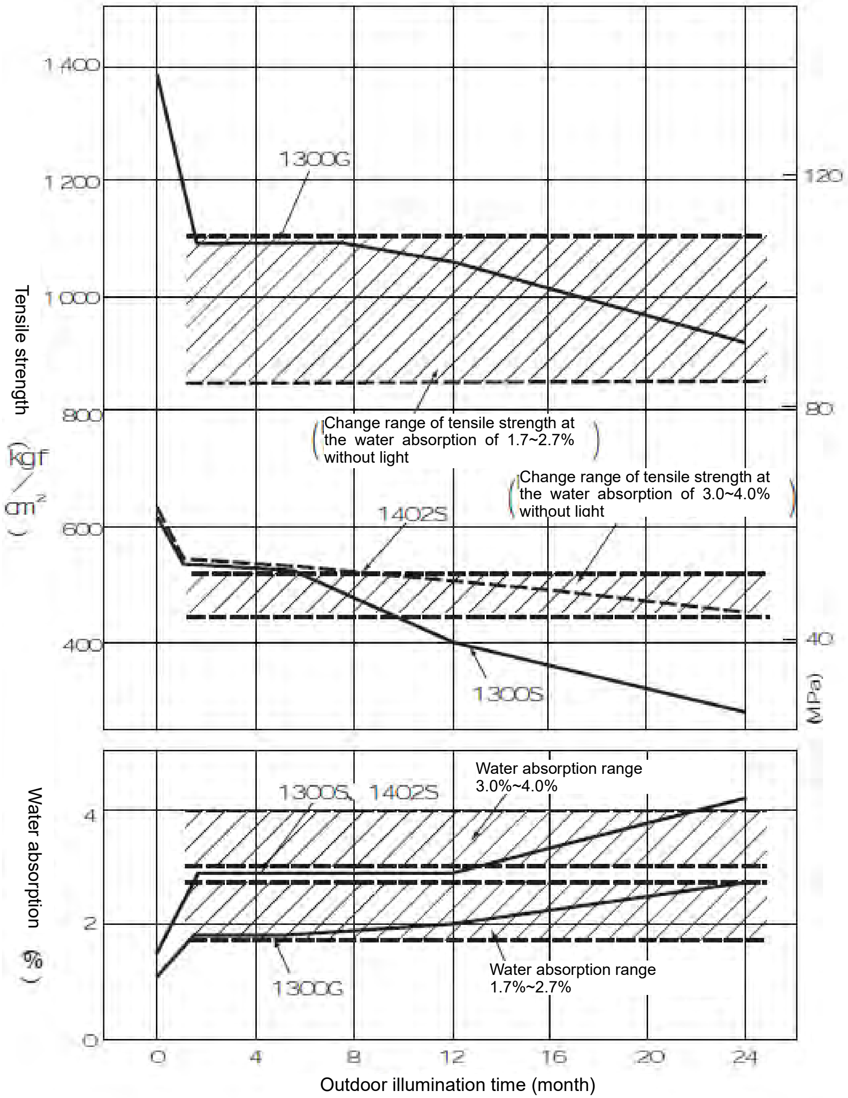
Make a 130mm×110mm×3mm slab through injection molding and then cut into the following small test pieces for test.



(c) Judgment method of illumination aging

Place the samples subject to stipulated outdoor illumination time under the environment at 20℃ and 50%RH for 24h before tensile test.

Figure-194 Weather fastness of LEONA (outdoor illumination)



(3) Xenon lamp illumination test

(a) Test methods

ASTM D2565

(Xenon lamp)

Black panel temperature

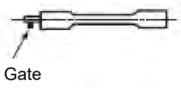
63±3℃

Spray time (water)

Average 18min per 120min

(b) Test piece (thickness: 3mm)

1) Flow direction



2) Right-angle direction

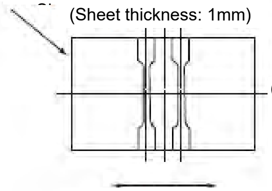
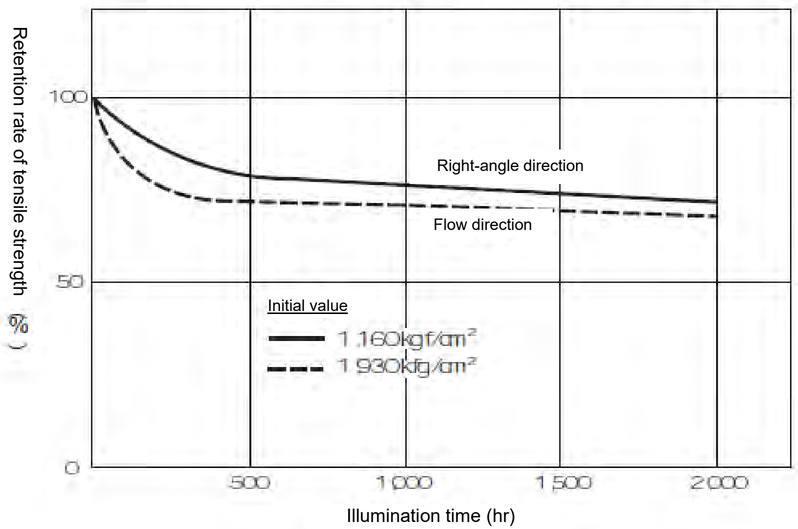


Figure-196 Weather fastness of LEONA (xenon lamp) (1300G black)



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7-8 Electrical characteristics under high temperature and high humidity conditions

(1) Dielectric strength ①

Humidifying method: JISC-5020 (use monopotassium phosphate saturated aqueous solution steam)
Sample thickness: 1mm
Measurement method: JIS K-6911
Rate of voltage rise: 1KV/sec
Humidifying environment: 40℃ 93% RH

Figure-197 Short time method

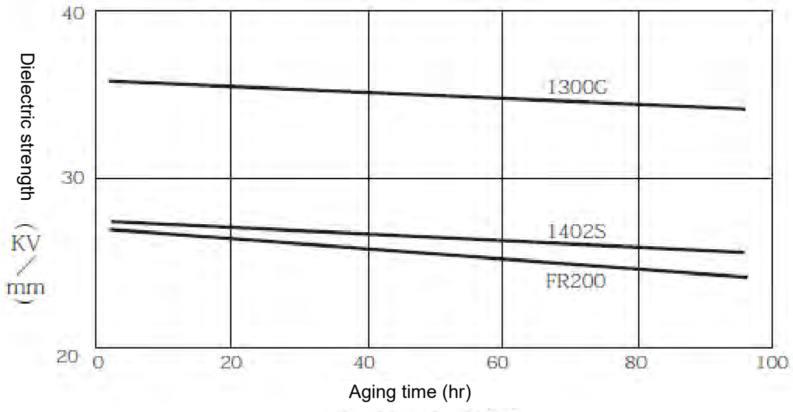
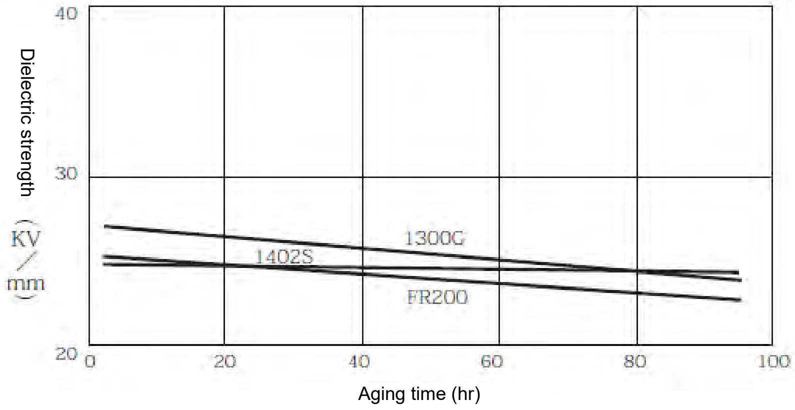


Figure-198 Phase method



(2) Dielectric strength ②

Humidifying method: JISC-5020 (use monopotassium phosphate saturated aqueous solution steam)
Sample thickness: 1mm
Test method: JIS K-6911
Rate of voltage rise: 1KV/sec
Humidifying environment: 25~30℃ 96~97%RH

Figure-199 Short time method

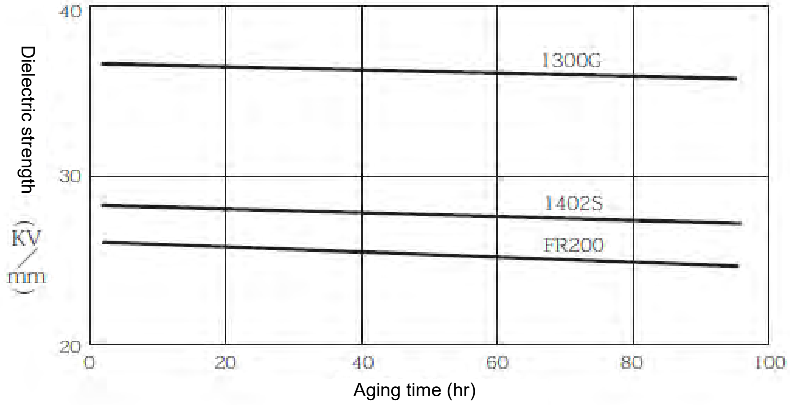
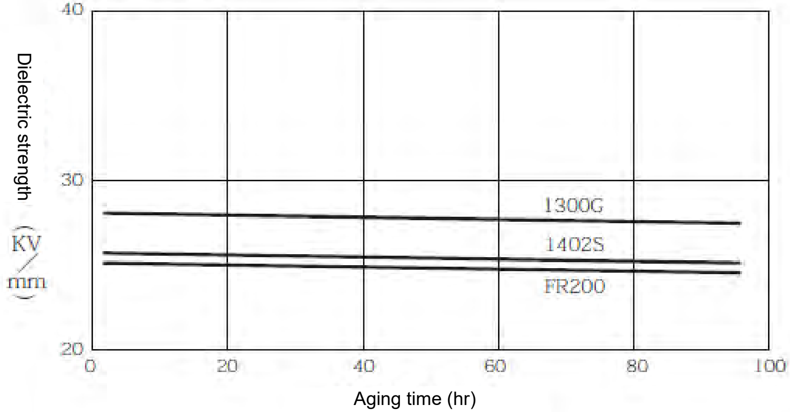


Figure-200 Phase method



(3) Surface resistivity

Figure-201 Change of surface resistivity

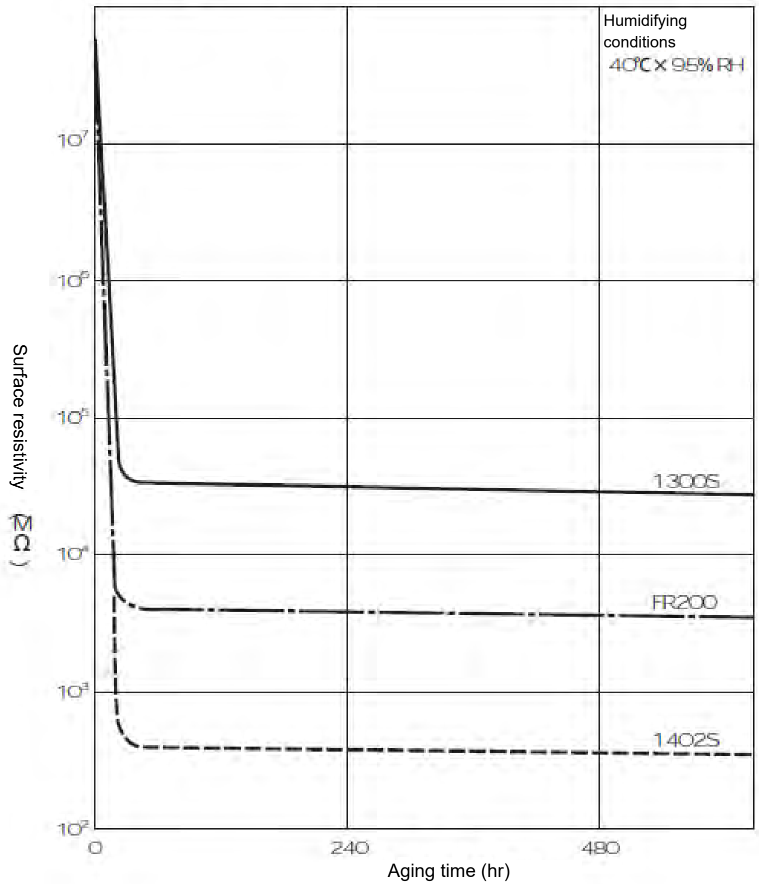
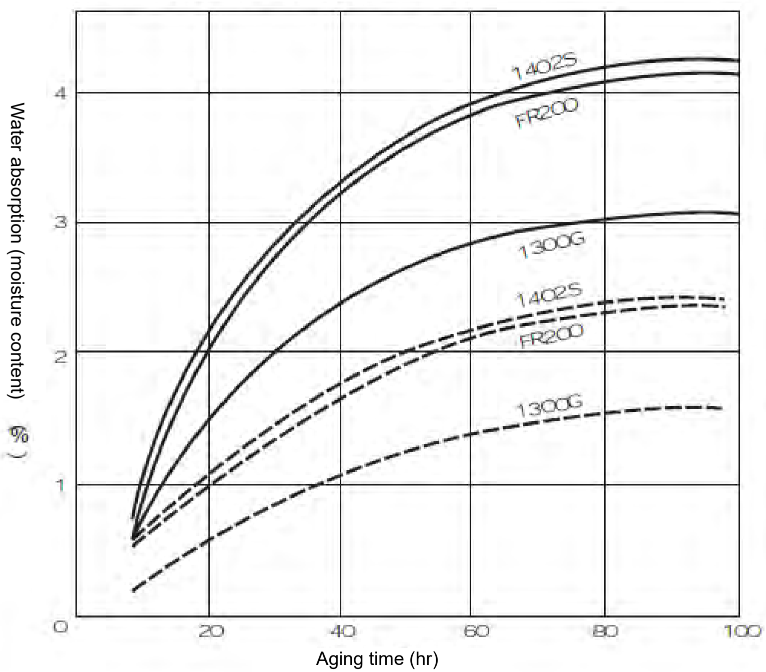


Figure-202 Aging time and water absorption (moisture content) (reference)



Test piece thickness: 1mm
Humidifying method: JISC-5020
Humidifying environment: { —— 40℃、93%RH ; - - - 25～30℃、96～97%RH }

Figure-203 Change of surface resistivity (1300S)

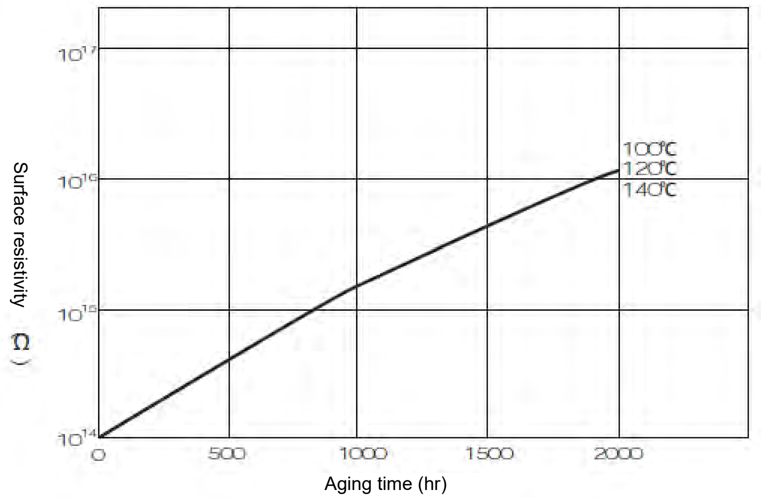
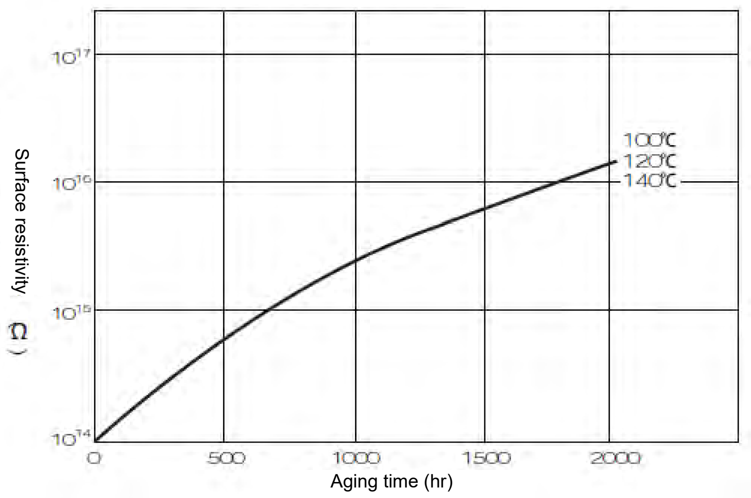


Figure-204 Change of surface resistivity (1300G)



(4) Dielectric constant

Figure-205 Change of dielectric constant (1300S)

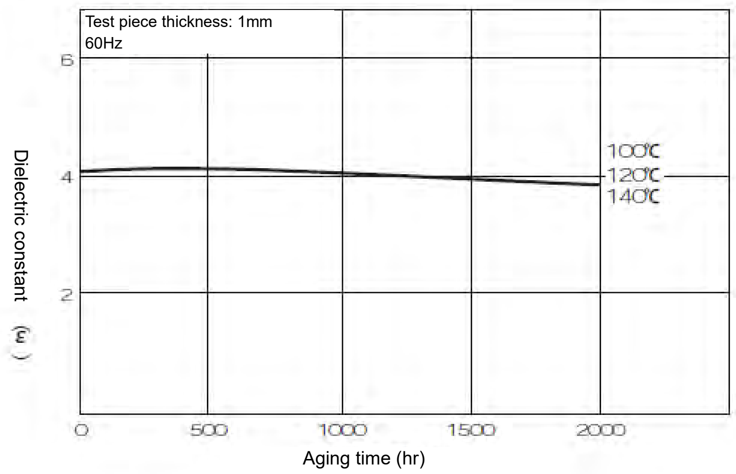
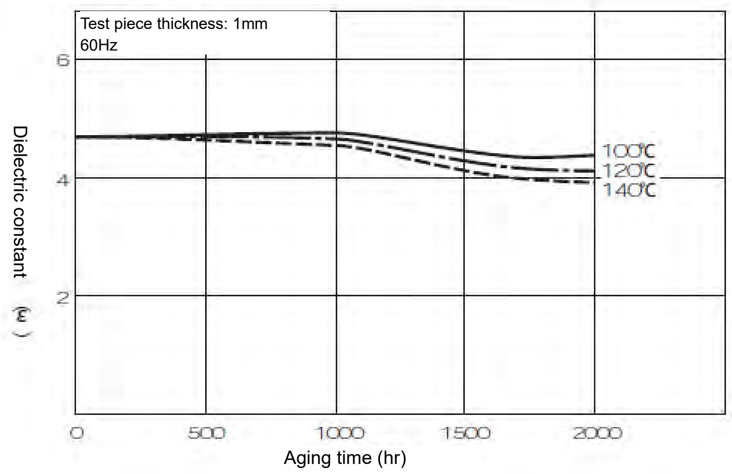


Figure-206 Change of dielectric constant (1300G)



(5) Dielectric dissipation factor

Figure-207 Change of dielectric dissipation factor (1300S)

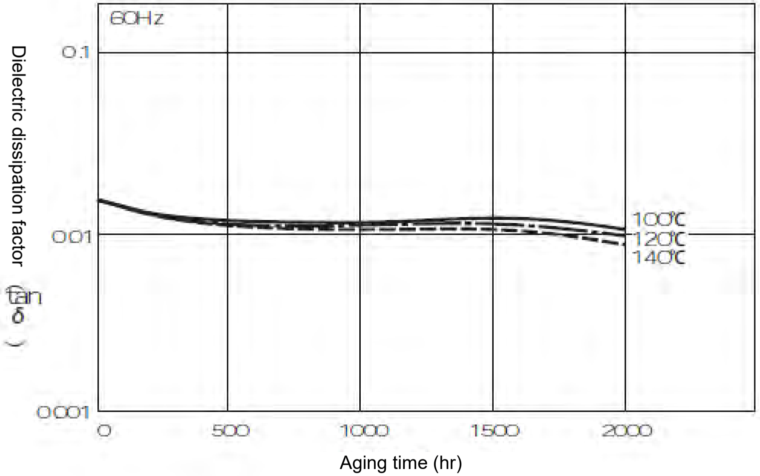
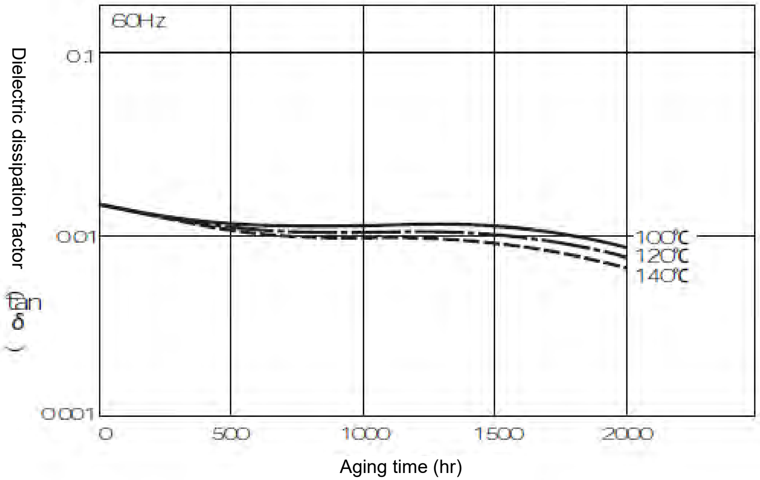


Figure-208 Change of dielectric dissipation factor (1300G)



(6) Conductive path resistance

Table 38: Change of conductive path resistance with water absorption (100℃, 120℃ and 140℃) (1300S、1300G)

Resin name	Aging time (hr)			
	0	500	1000	2000
LEONA 1300S	Above 600V	Above 600V	Above 600V	Above 600V
LEONA 1300G	Above 600V	Above 600V	Above 600V	Above 600V

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(7) Arc track resistance

Figure-209 Change of arc track resistance (1300S)

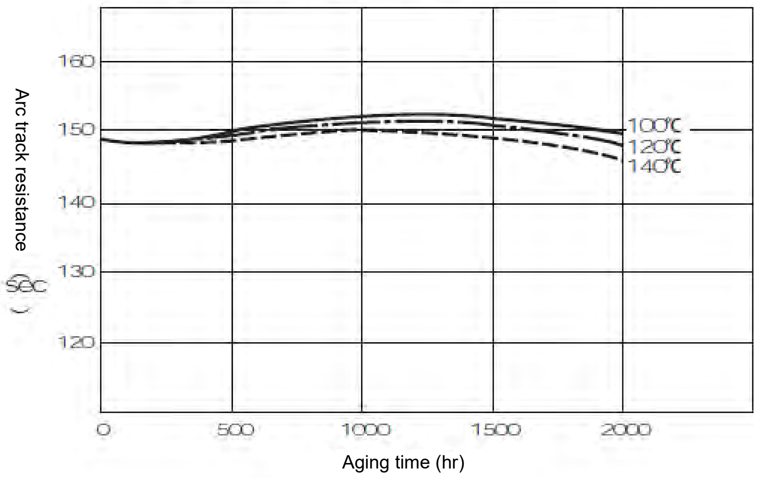
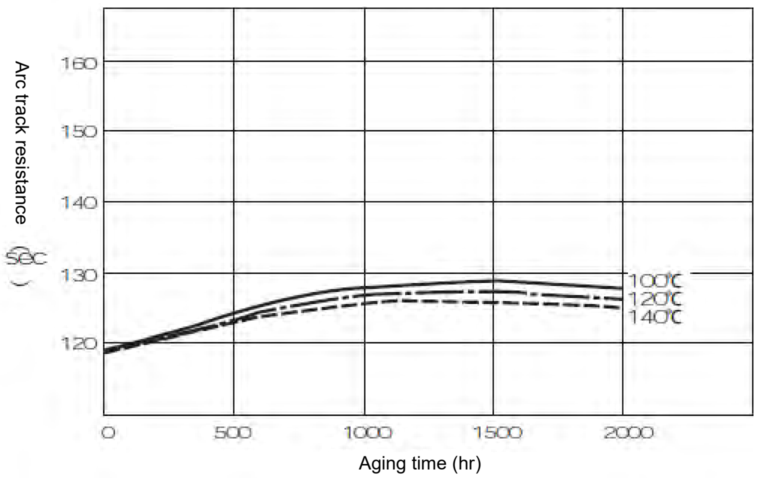


Figure-210 Change of arc track resistance (1300G)



8. Replacement of metal

With the characteristics of small relative density, easy processing, good electrical characteristics, easy color blending, low cost and high design freedom, the plastic is widely used in all walks of life. LEONA is also widely used and well received.However, LEONA as the alternative material of metal is greatly different from the metal in terms of physical properties and the operating environment shall be fully considered in design.

LEONA is mainly used for injection molding products, so this material mainly introduces the design of injection molding products.

Contrast with metal

1) Poorer dimensional accuracy than metal........... Greater coefficient of linear expansion than metal

2) Lower heat resistance than metal...................... Great melting point difference

3) Combustible .... Refer to Table 12 for burning temperature and ignition temperature of LEONA.

4) Lower strength than metal. .... Lower stiffness than metal.(Refer to the elasticity modulus in Table 11)

5) Water absorption .... The dimensions and physical properties will change with the water absorption.

Table 39: Contrast of LEONA with metal in terms of physical properties

General unit conversion method 1MPa＝10.1972kgf/cm^2, 1GPa＝10197.2kgf/cm^2

Physical properties	Coefficient of linear expansion	Melting point	Modulus of elasticity for tension	Tensile strength	Poisson's ratio
Unit	×10^{-5} (20~40℃)	℃	GPa	MPa	–
Hard steel	1.1	1 400	205 94	490 3	0 29
Aluminum	2 4	660	69 63	93 2	0 34
LEONA 1300S	8	265	3 04 (1% strain)	81 4	0 34
LEONA 1300G	3	265	9 32 (1% strain)	186 3	0 34

Table 40: Burning temperature and ignition temperature of LEONA

LEONA grade	Burning temperature (℃)	Ignition temperature (℃)
1300S	487~493	413~419
1300G	480~486	391~397
FR370	477~483	386~392

Measurement method: Panasonic TECHNO RESEARCH

9-1 Design steps of injection molding products

1. Product planning

   Appropriate materials shall be screened at this stage, so it is required to fully understand the basic physical properties and molding technology of the plastic in advance.

   Refer to relevant technical data and product catalog for the basic physical properties and molding technology and other detailed information of LEONA.
2. Product conception

   Product conception is product design stage.
3. Indicate the product use conditions and purpose

   Clarify the use conditions, especially the temperature, load and environment.

   Refer to the technical data for creep and long-term environmental data.
4. List necessary characteristics

   Do not omit unknown necessary characteristics at this stage.
5. Screen the resin and grade

   Select the appropriate resin and corresponding grade after product performance evaluation for soft mode or similar product molds.

   The database for various resins and grades may be available.
6. Product design and mold design

   Pay full attention to molding and mold release when designing the product and mold.

   CAE may be effectively used in product and mold design.
7. Injection molding technology and secondary processing technology

   Fully consider the appearance, dimensional accuracy, material and shape limitations, quantity, delivery period, cost and other factors before determining the technology.

9-2 Five principles for design of injection molding products

The design of injection molding products of general plastic is the same and there are the following five principles for reference.

(1) The wall shall not be too thick or too thin.

The wall thickness of general products is 1~3mm.If the product wall is too thick, the product is prone to shrinkage holes inside, sink marks and flow marks outside; if the product wall is too thin, the product is prone to incomplete filling, warping and other poor injection molding phenomena.

(2) The product wall thickness shall be uniform.

The product shrinkage is large if the product wall is too thick; otherwise, the product shrinkage is small.The difference in shrinkage will result in product warping and deformationand may result in increase in the residual stress depending on the product shape.The nonuniform wall thickness of reinforcing rib will also result in sink marks.

In the product design, the product wall thickness fluctuation is controlled within ±20%.

(3) The product shall not be designed into sharp corners.(Sharp corners easily lead to product fracture and cracking), R / T≧0.25 (T: product wall thickness) when rounding (R is rounded corner). The stress concentration factor is 2 when R/T=0.25, increases sharply when R/T＜0.25 and is almost not changed when R/T＜0.75.

Pay attention that the excessive rounding will result in too thick local wall thickness.

(4) Simplify the shape.

Try to design into the structure that can be uniformly cooled by mold rather than the undercut and complex mold structure.

(5) Design the draft.

The draft of fixed die of a pentahedral product shall be at least 1° generally.

(1.5° at the depth of 50mm~100mm and 1° at the depth of above 100mm).

The texture of some shapes is not easy to demold (will result in scratches), so sufficient draft is required (at least 6°).

The draft of reinforcing rib (at the bottom) is about 0.5° and of longitudinal reinforcing rib in the side wall is about 0.25°.To prevent shrinkage of thick wall, the root of the reinforcing rib is half of the wall thickness and the front end is at least 1mm from the restriction on mold making.

The grid distance shall be above 3mm (it is not easy to release mold if the distance is too small). If the overall grid is longer, the greater draft is required.

It is generally about 5°.

9-3 Design to optimize product strength

It shall be considered in product strength calculation that the rigidity of LEONA is two orders of magnitudes smaller than metal.

Moreover, the polyamide resin easily absorbs water and the strength and elasticity modulus will be reduced after water absorption. The strength value in balanced water absorption (in the air, 23℃ and 50%RH) is 60~70% of that in absolute dry condition.

(1) The wall shall not be too thin.

(2) The safety factor shall be based on tensile strength and the static load is about 5.
If the safety factor is based on the bending strength, the breaking strain shall also be considered.

(3) In case of large deformation caused by large stress and load, the reinforcing rib shall be considered for reinforcement.
The thickness (t) of the reinforcing rib should be about 1/2 of the thickness (T) of the standing bottom: (over-thickness will result in holes, so the reinforcing rib may play the role of reinforcement.)

(4) The product shall not be designed into sharp corners.
Stress concentration will occur in sharp corners.Try to avoid sharp corners to ensure impact resistance in low humidity environment.
Moreover, sharp turns will occur when the resin flows through sharp corners and will result in poor product appearance.

(5) The welding lines shall avoid large stress.
① Optimize gate position.
② Thicken the wall in the welding line part.

9-4 Design to optimize dimensional accuracy

(1) Discussion on dimensional accuracy

Precautions in discussion on dimensional accuracy

Pay attention to the following in design:

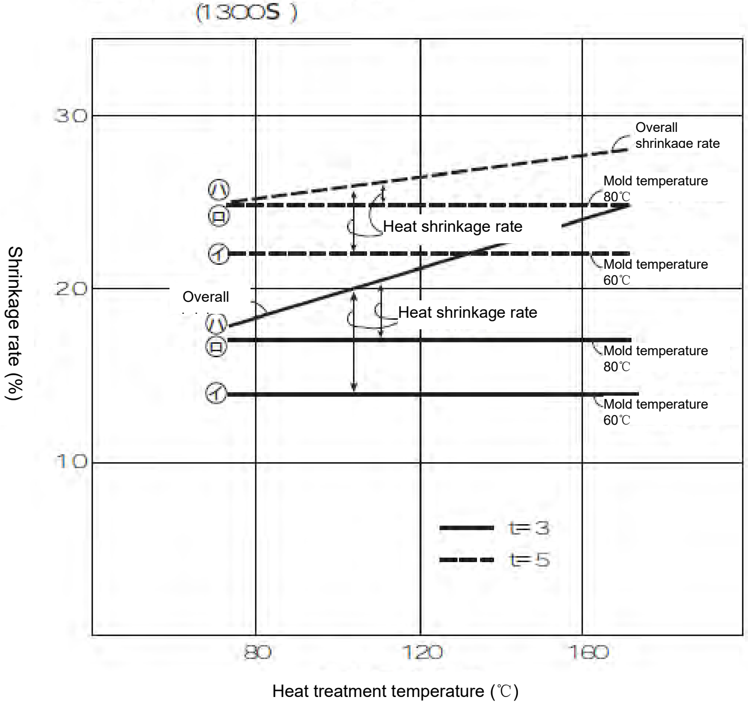
1) Differences between plastic molding products and metal products

The differences between general plastic molding products and the cut metal products are as follows:（①~⑦）

② Large coefficient of linear expansion
② Molding shrinkage and heat shrinkage
③ Ongoing changes
③ Affected by humidity (moisture).
④ Difficult to meet dimensional requirements due to mold structure.
⑤ It will also change due to the impact of the operating environment(creep and solvent)
⑥ The plastic products are soft and may subject to flexible elastic deformation in assembly.
The clip products are also flexibly embedded.

It is difficult for the plastic molding products to fully reach the high-precision dimensional tolerance of metal products, but the plastic products have above seven characteristics and can meet the service performance sometimes.

Figure-211 Heat shrinkage rate and overall shrinkage rate



Molding conditions: injection molding pressure 450kgf/cm^2, resin temperature 280℃

Sample: 120X80X product thickness t (mm) slab

2×2mm when gate size t=3 and 2×4mm when t=5

(Note) Heat treatment time 8hr

Interpretation chart

イ Molding shrinkage rate in molding at mold temperature of 60℃ (t=3mm, 5mm)

ロ Molding shrinkage rate in molding at mold temperature of 80℃ (t=3mm, 5mm)

ハ The overall shrinkage rate is the heat shrinkage rate 8hr after annealing within the heat treatment temperature range of 80℃~160℃ plus molding shrinkage rate.

Overall shrinkage rate ハ＝イ (or ロ) + heat shrinkage rate after annealing

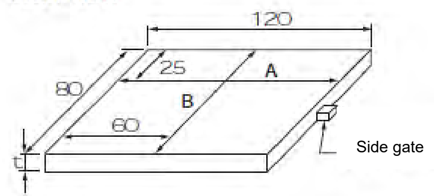
Sample molding conditions, shape and dimensional measurement method

Table 41: Molding conditions of test piece

Molding conditions \ Test piece / Wall thickness			1300S			1300G			MR001		
			1mm	2mm	3mm	2mm	3mm	5mm	2mm	3mm	5mm
Mold temperature		℃	76	76	76	76	76	76	76	76	76
Charging barrel Temperature	Hopper side	℃	270	272	270	272	270	275	272	270	270
			282	285	281	285	282	280	285	282	281
			285	293	283	293	285	290	293	285	283
	Nozzle side		285	290	290	290	290	290	290	290	285
Injection molding pressure	Injection pressure	kgf/cm²	840	340	340	780	500	560	750	560	780
	Dwell pressure		730	280	280	620	500	560	560	500	450
Back pressure		kgf/cm²	NA	NA	NA	NA	NA	NA	NA	NA	NA
Injection time		sec	7	10	15	10	10	15	7	10	10
Cooling time		sec	15	20	30	20	20	25	10	20	20
Screw revolution		rpm	80	80	80	80	80	80	80	80	80
Residual volume		mm	2~3	3	3	2~3	3	3	3	3	4
Gate size	Width	mm	2	4	4	4	4	6	4	4	6
	Thickness		1	2	2	2	2	2	2	2	2

(Note) Injection molding machine: I S-90B Internal thread screw injection molding machine of TOSHIBA MACHINE

Sample shape



(t: Product wall thickness)

Dimensional measurement method

Measurement by micrometer
Measure the dimensions in area A (flow direction)
and area B (flow right-angle direction)

Figure-213 Dimensional stability (1) (range of dimensional fluctuations after molding)

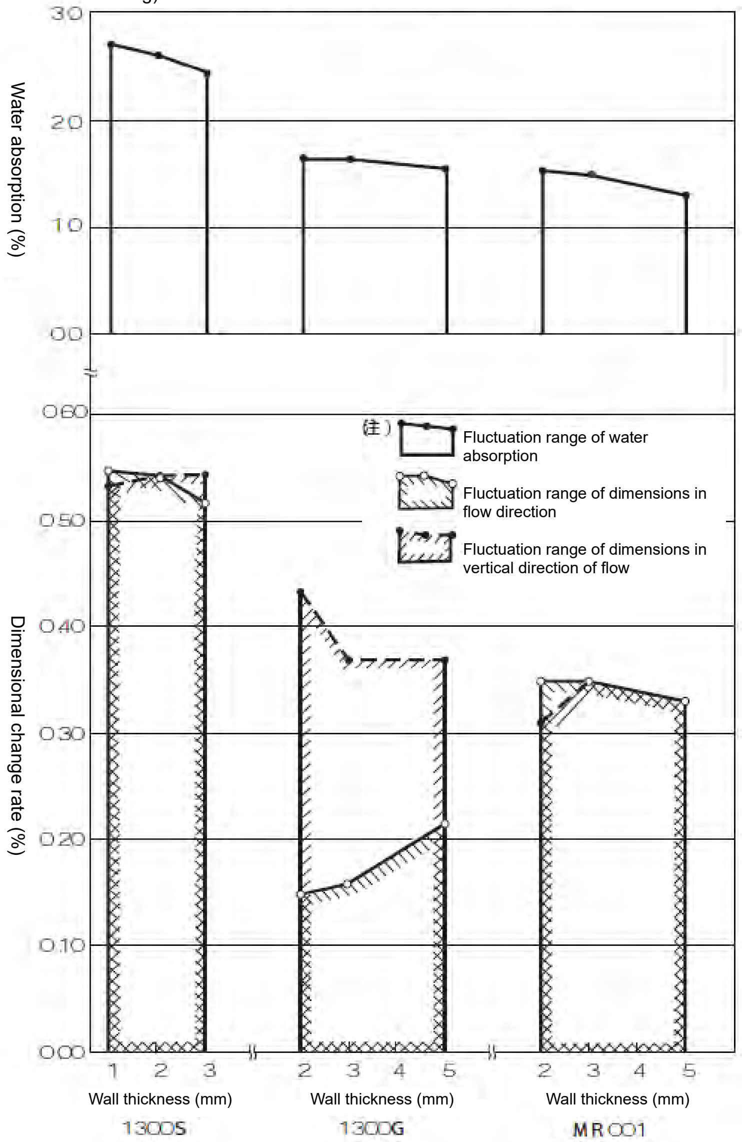


Figure-214 Dimensional stability (2) (range of dimensional fluctuations in case of seasonal changes)

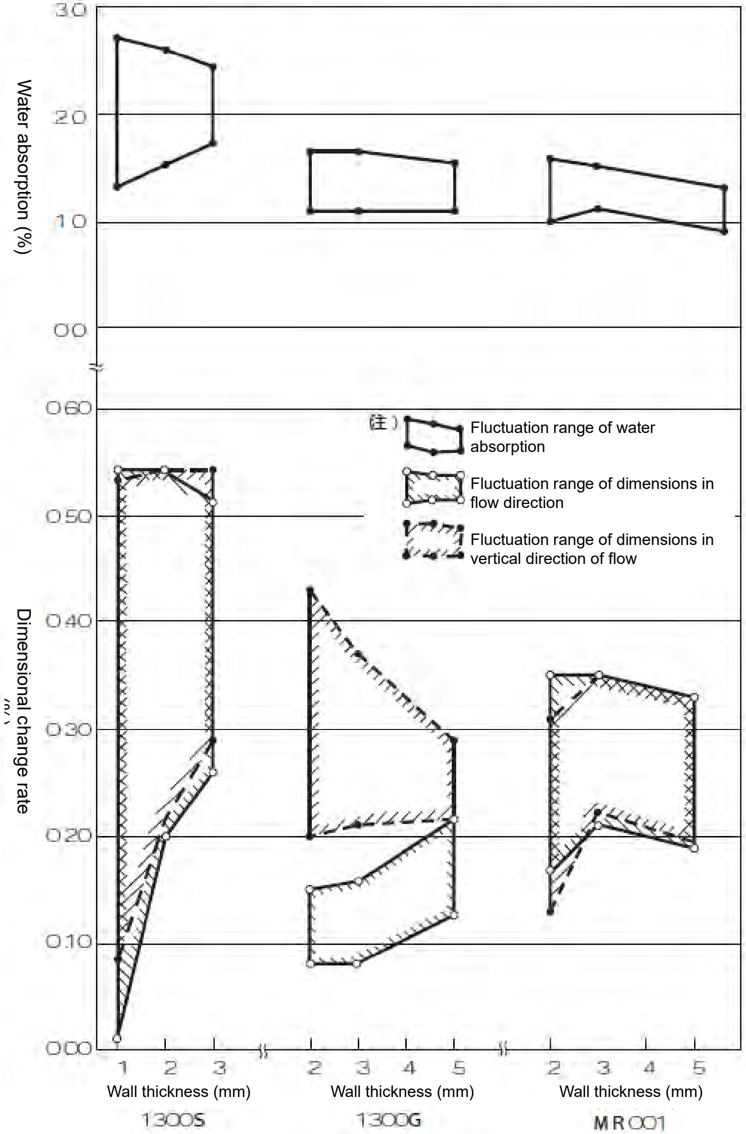


Figure-215 Dimensional stability of 1300 (product wall thickness 1mm)

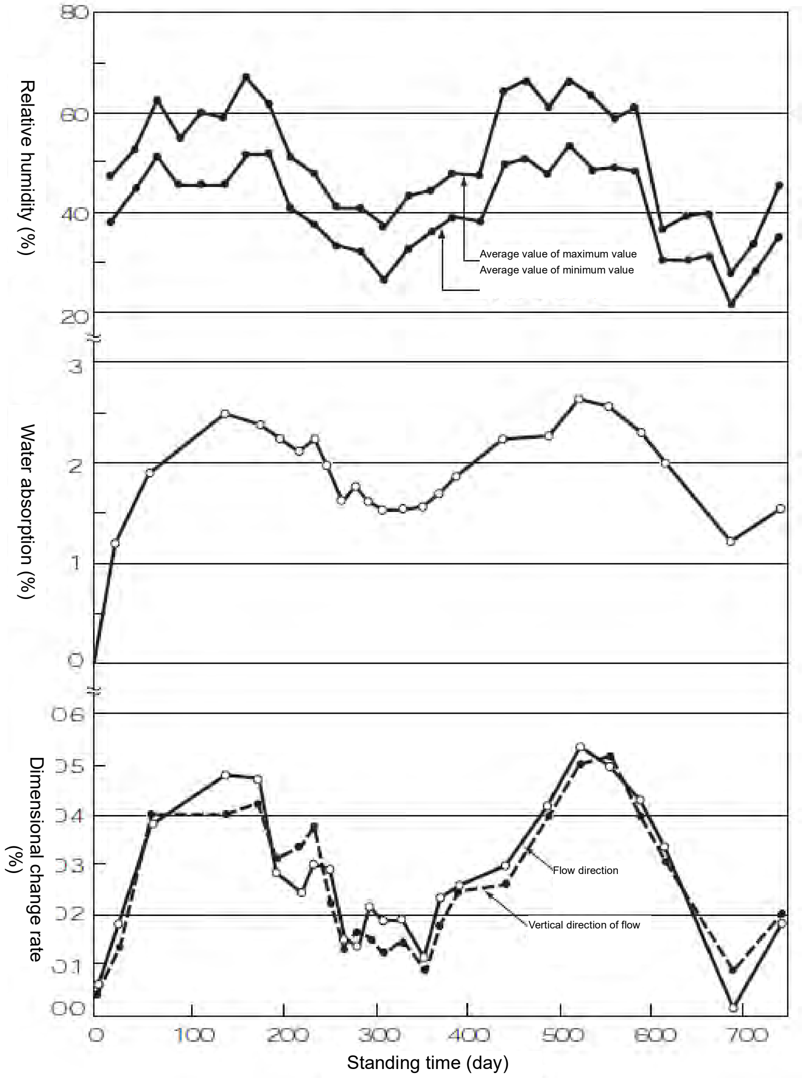


Figure-216 Dimensional stability of 1300 (product wall thickness 2mm)

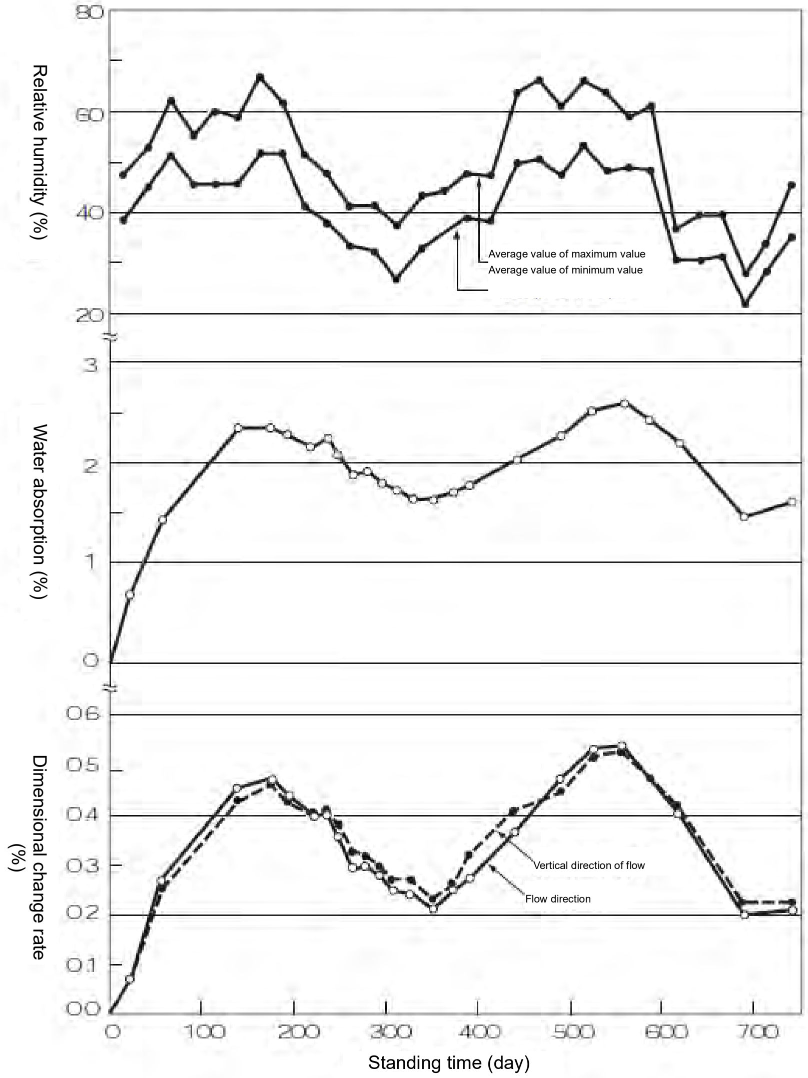


Figure-217 Dimensional stability of 1300 (product wall thickness 3mm)

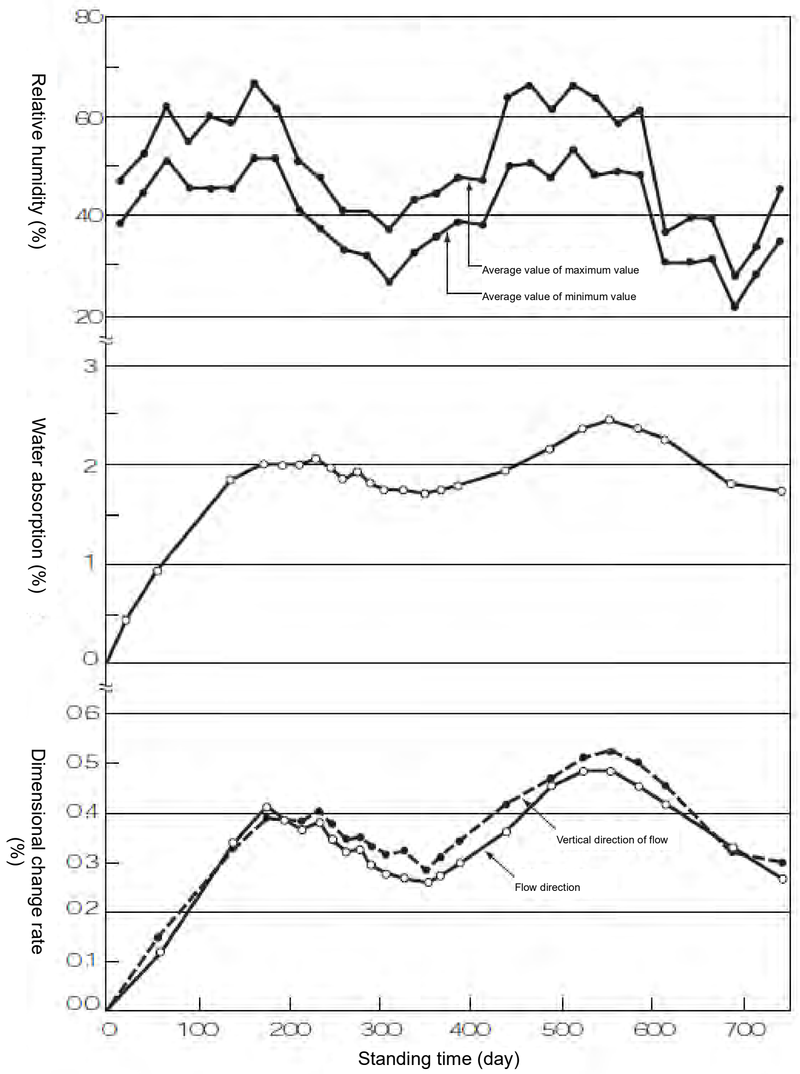


Figure-218 Dimensional stability of 1300 (product wall thickness 2mm)

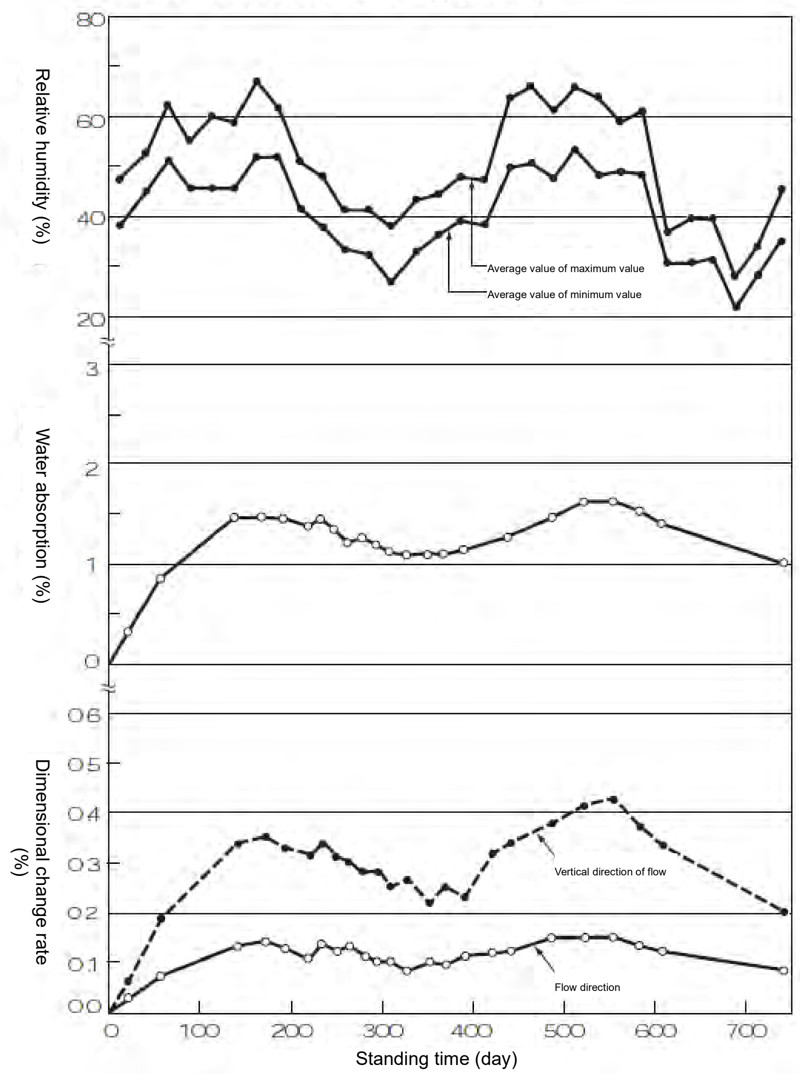


Figure-219 Dimensional stability of 1300 (product wall thickness 3mm)

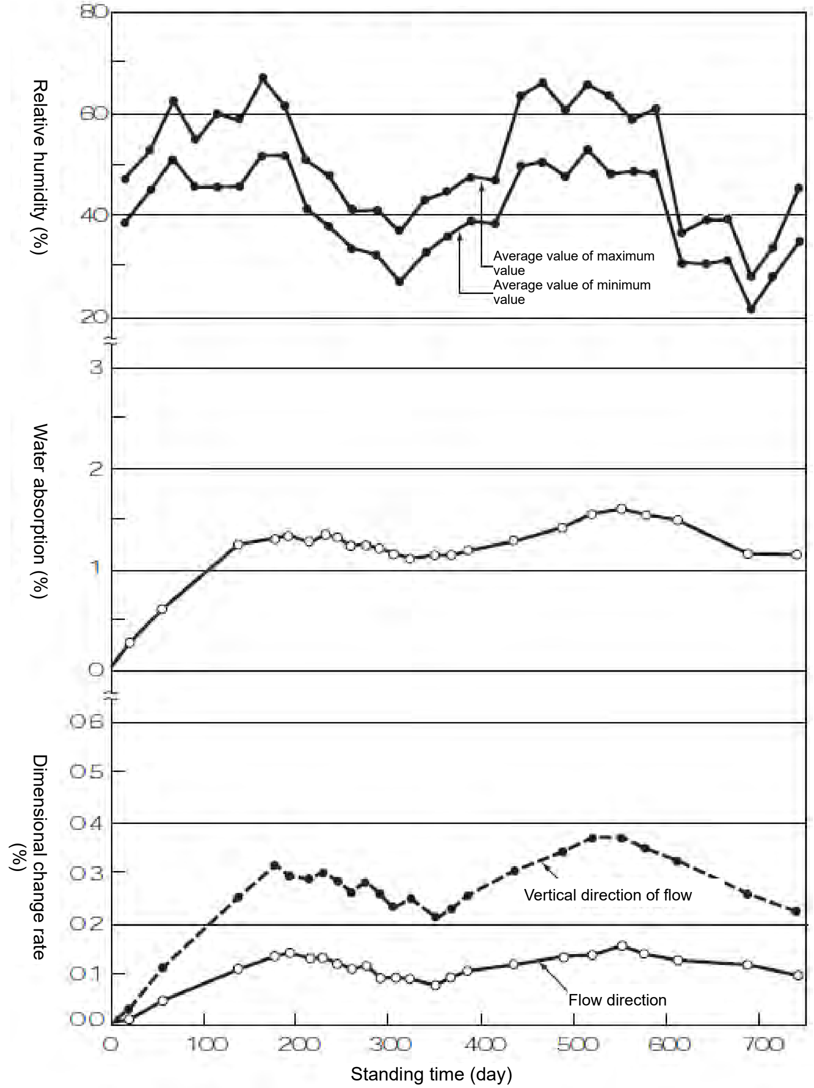


Figure-220 Dimensional stability of 1300 (product wall thickness 5mm)

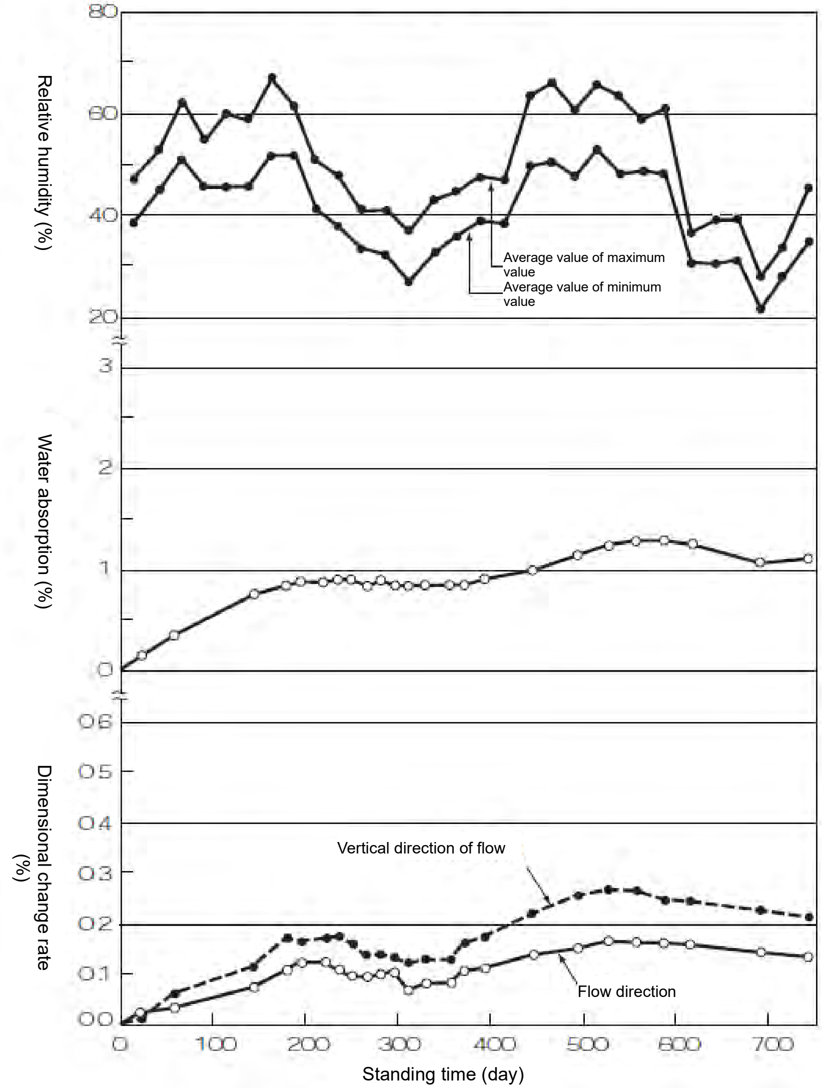


Figure-221 Dimensional stability of MR001 (product wall thickness 2mm)

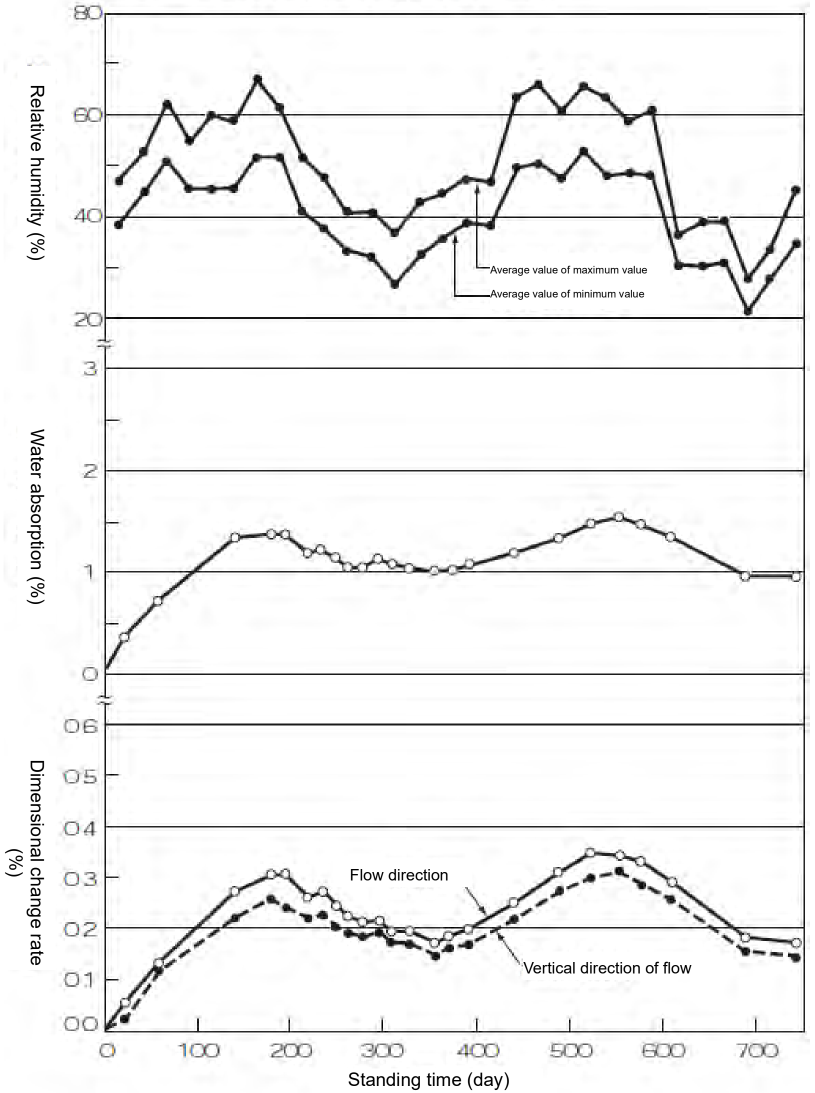


Figure-222 Dimensional stability of MR001 (product wall thickness 3mm)

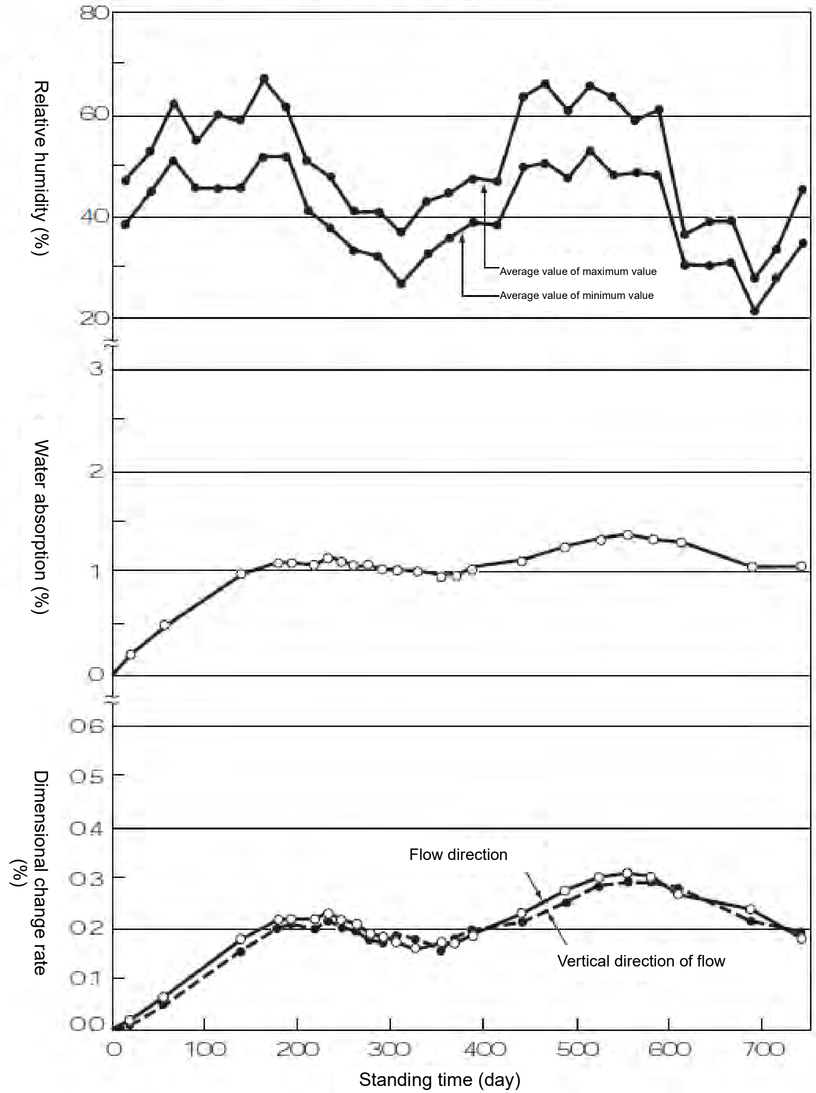


Figure-223 Dimensional stability of MR001 (product wall thickness 5mm)

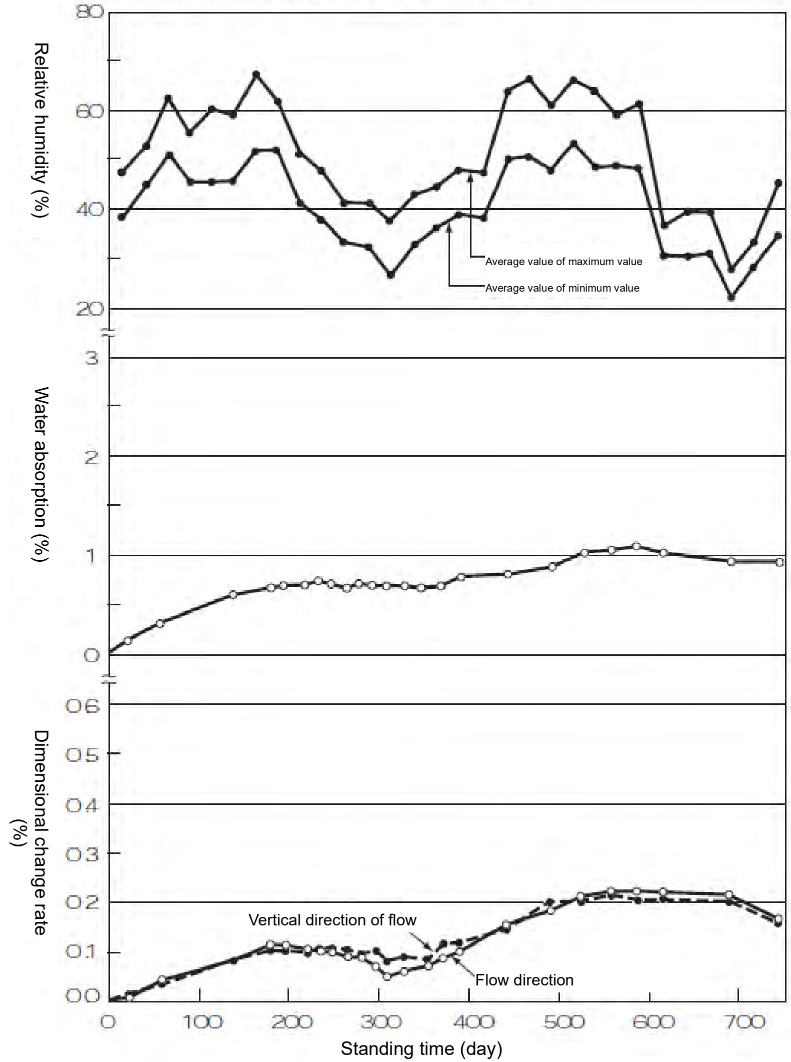


Table 42: Dimensional tolerance of unreinforced polyamide

Dimensions mm	Dimensional tolerance of the part without parting surface			Dimensional tolerance of the part with metal joint face or parting surface		
	Grade of tolerance			Grade of tolerance		
	Standard	Quasi accuracy	Accuracy	Standard	Quasi accuracy	Accuracy
a≦ 1	±0.13	±0.08	±0.06	±0.16	±0.11	±0.09
1< a≦ 3	±0.15	±0.09	±0.07	±0.18	±0.12	±0.10
3< a≦ 6	±0.17	±0.10	±0.08	±0.20	±0.13	±0.11
6< a≦ 10	±0.20	±0.11	±0.09	±0.22	±0.14	±0.12
10< a≦ 15	±0.22	±0.13	±0.10	±0.25	±0.16	±0.13
15< a≦ 22	±0.25	±0.15	±0.11	±0.28	±0.18	±0.14
22< a≦ 30	±0.28	±0.17	±0.13	±0.31	±0.20	±0.16
30< a≦ 40	±0.32	±0.20	±0.15	±0.35	±0.23	±0.18
40< a≦ 53	±0.37	±0.24	±0.17	±0.40	±0.27	±0.20
53< a≦ 70	±0.44	±0.28	±0.20	±0.47	±0.31	±0.23
70< a≦ 90	±0.50	±0.34	±0.24	±0.55	±0.37	±0.27
90< a≦ 115	±0.60	±0.41	±0.29	±0.65	±0.44	±0.32
115< a≦ 150	±0.75	±0.50	±0.35	±0.80	±0.55	±0.38
150< a≦ 200	±0.95	±0.65	±0.45	±1.00	±0.70	±0.48
200< a≦ 250	±1.20	±0.80	±0.55	±1.30	±0.85	±0.60
250< a≦ 315	±1.40	±0.95	±0.66	±1.50	±1.00	±0.70
315< a≦ 400	±1.80	±1.20	±0.82	±1.90	±1.30	±0.85
400< a≦ 500	±2.20	±1.50	±1.00	±2.30	±1.60	±1.10
500< a≦ 630	±2.80	±1.90	±1.20	±2.90	±2.00	±1.30
630< a≦ 800	±3.50	±2.40	±1.50	±3.60	±2.50	±1.60
800< a≦1000	±4.40	±2.90	±1.90	±4.50	±3.00	±2.00
1000< a≦1300	±5.50	±3.60	±2.40	±5.60	±3.70	±2.50
1300< a≦1600	±7.00	±4.40	±3.10	±7.10	±4.50	±3.20
1600< a≦2000	±9.80	±5.40	±3.90	±9.90	±5.50	±4.00

(From ISO)

Table 43: Dimensional tolerance of reinforced polyamide

Dimensions mm	Dimensional tolerance of the part without parting surface			Dimensional tolerance of the part with metal joint face or parting surface		
	Grade of tolerance			Grade of tolerance		
	Standard	Quasi accuracy	Accuracy	Standard	Quasi accuracy	Accuracy
a≦ 1	±0.13	±0.06	±0.04	±0.16	±0.09	±0.07
1<a≦ 3	±0.15	±0.07	±0.05	±0.18	±0.10	±0.08
3<a≦ 6	±0.17	±0.08	±0.06	±0.20	±0.11	±0.09
6<a≦ 10	±0.20	±0.09	±0.07	±0.23	±0.12	±0.10
10<a≦ 15	±0.22	±0.10	±0.08	±0.25	±0.13	±0.11
15<a≦ 22	±0.25	±0.11	±0.09	±0.28	±0.14	±0.12
22<a≦ 30	±0.27	±0.13	±0.10	±0.30	±0.16	±0.13
30<a≦ 40	±0.30	±0.15	±0.11	±0.33	±0.18	±0.14
40<a≦ 53	±0.35	±0.17	±0.13	±0.36	±0.20	±0.16
53<a≦ 70	±0.38	±0.20	±0.15	±0.41	±0.23	±0.18
70<a≦ 90	±0.43	±0.24	±0.17	±0.46	±0.27	±0.20
90<a≦ 115	±0.50	±0.29	±0.20	±0.55	±0.32	±0.23
115<a≦ 150	±0.60	±0.35	±0.24	±0.65	±0.38	±0.27
150<a≦ 200	±0.75	±0.44	±0.30	±0.80	±0.47	±0.33
200<a≦ 250	±0.90	±0.55	±0.36	±0.95	±0.60	±0.39
250<a≦ 315	±1.10	±0.70	±0.44	±1.20	±0.75	±0.47
315<a≦ 400	±1.30	±0.85	±0.55	±1.40	±0.90	±0.60
400<a≦ 500	±1.50	±1.00	±0.65	±1.60	±1.10	±0.70
500<a≦ 630	±1.90	±1.20	±0.80	±2.00	±1.30	±0.85
630<a≦ 800	±2.40	±1.50	±1.00	±2.50	±1.60	±1.10
800<a≦1000	±2.90	±1.90	±1.25	±3.00	±2.00	±1.30
1000<a≦1300	±3.60	±2.40	±1.70	±3.70	±2.50	±1.80
1300<a≦1600	±4.40	±3.10	±2.20	±4.50	±3.20	±2.30
1600<a≦2000	±5.40	±3.90	±2.70	±5.50	±4.00	±2.80

(From ISO)

2) Main influencing factors of dimensional accuracy

The main influencing factors of dimensional accuracy of molding products are as follows:

- Mold making error 50%
- Changes in molding conditions 30%
- Fluctuations between and in material batches 30%
- Other 10%

Therefore, it is required to pay special attention to the influence of the mold making and molding condition changes.

(2) Optimize the product shape design to ensure dimensional accuracy

Pay attention to the following in design:

1) Optimize the product wall thickness.

The wall of the finished products cannot be too thin or too thick.If the wall is too thin, the resin shear stress is increased, resulting in incomplete filling, significant polymer stereoregular polymerization, warping and deformation.If the wall is too thick, the shrinkage rate will be excessive, resulting in too thin, pores and inability to ensure dimensional accuracy.

If the product is too thick, the reinforcing rib structure is required to thin and uniformize.

2) Optimize the wall thickness uniformity

The wall thickness non-uniformity of molding products results in shrinkage rate non-uniformity, product warping and deformation.

3) Optimize the product shape balance degree

Pay attention to the binding resistance of the molding products in the shrinkage direction in the mold and the balance of the binding force.Consider that the shrinkage rate will not be balanced in advance if the binding force is unbalanced.

For example, it is required to optimize the gate position to achieve high accuracy and roundness.

Figure-224 Change of molding shrinkage rate with product thickness

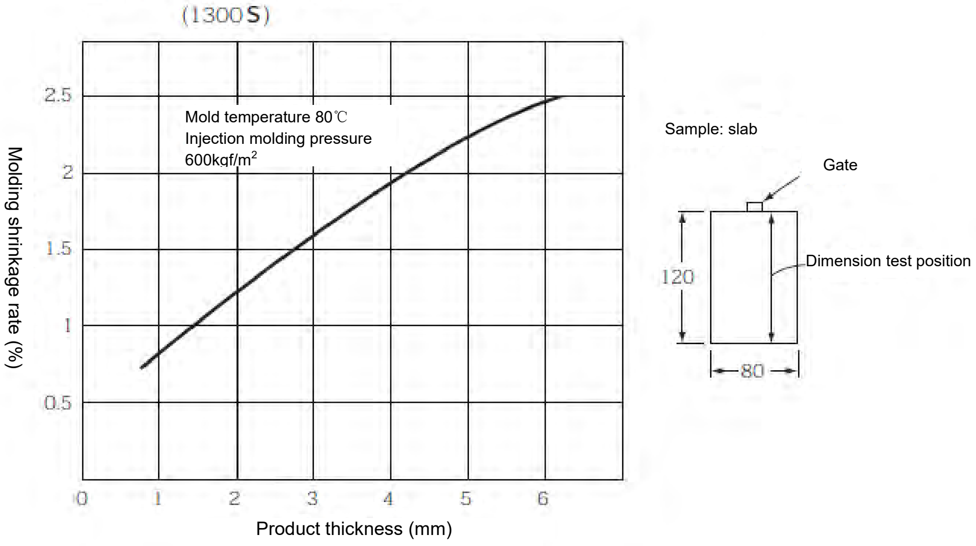
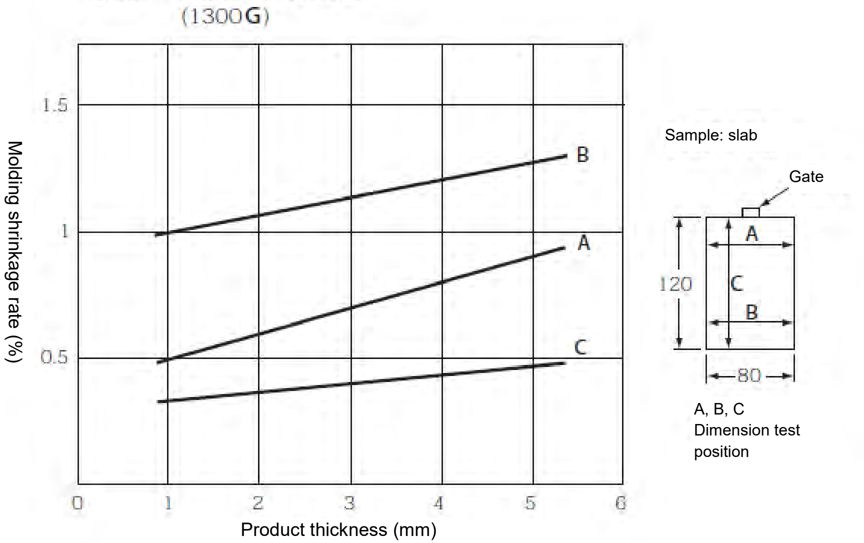


Figure-225 Change of molding shrinkage rate with product thickness



9-5 Optimize demolding design

Poor demolding often occurs in the injection molding process and is mostly caused by yje molds. It is considered to optimize under cut and draft when designing the molding products.

(1) Under cut

A reason for poor demolding is insufficient under cut.Forced demolding refers to demolding by means of the elongation, compression or bending deformation of molding products in elastic variation.

The under cut index is under cut rate.

The maximum under cut rate is calculated according to the following method.

The

maximum under cut rate (Ki) of inside under cut is calculated according to the yield strength of the demolding temperature of various resin molding products.

$$K_i = \frac{I}{B} \times 100 = \frac{\sigma_y}{W}\left(\frac{W+\nu_h}{E_h}\right) \times 100 \ (\%)$$

Where, Ki: maximum under cut rate

I :	Under cut rate (diameter) B-A	(mm)
B :	Maximum shaft diameter	(mm)
σ_y :	Product yield strength in demolding	(kgf/cm²)
W :	Shape $W = \left[1+\left(\frac{B}{A}\right)^2\right] / \left[1-\left(\frac{B}{A}\right)^2\right]$	
A :	A: Minimum diameter of hole	(mm)
ν_h :	Vh: Poisson's ratio of hole slotting material (resin) (0.34 for LEONA)	
E_h :	Eh: Longitudinal modulus of elasticity of hole slotting material (resin) (1% strain)	

Generally, the under cut rate of unreinforced LEONA is below 10% and of reinforced LEONA is 2~3%. The under cut rate is smaller taking into account the safety factor of the products.

Figure-226 Legend of design to prevent deformation

Figure-32·1 Edge making at the bottom of box

Figure-32·2 Edge making at the upper part of box

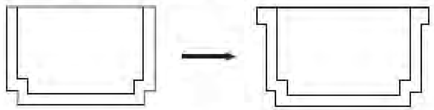
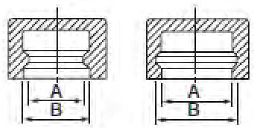


Figure-32·3 Symmetrical shape

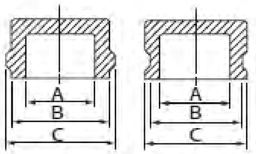
From "Validation list of plastic injection molding machine"

Figure-227 Definition of under cut rate



Inside under cut rate

$$K_i = \frac{|A - B|}{B} \times 100\ (\%)$$



Outside under cut rate

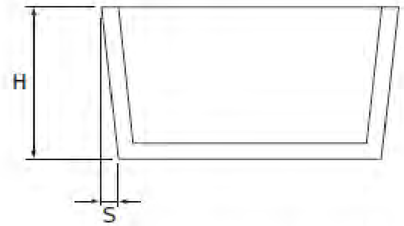
$$K_o = \frac{|C - B|}{C} \times 100\ (\%)$$

From "Molding product shape design"

(2) Draft

The draft value varies with the molding product shape, mold structure and molding product surface processing degree.It is necessary to be 1° generally.

Figure-228 Draft of box or cover



Object with H less than or equal to 50mm $\frac{S}{H} = \frac{1}{30} \sim \frac{1}{35}$

Object with H greater than or equal to 100mm $\frac{S}{H} = \frac{1}{60}$ Below

Object with shallow dermatoglyph $\frac{S}{H} = \frac{1}{5} \sim \frac{1}{10}$

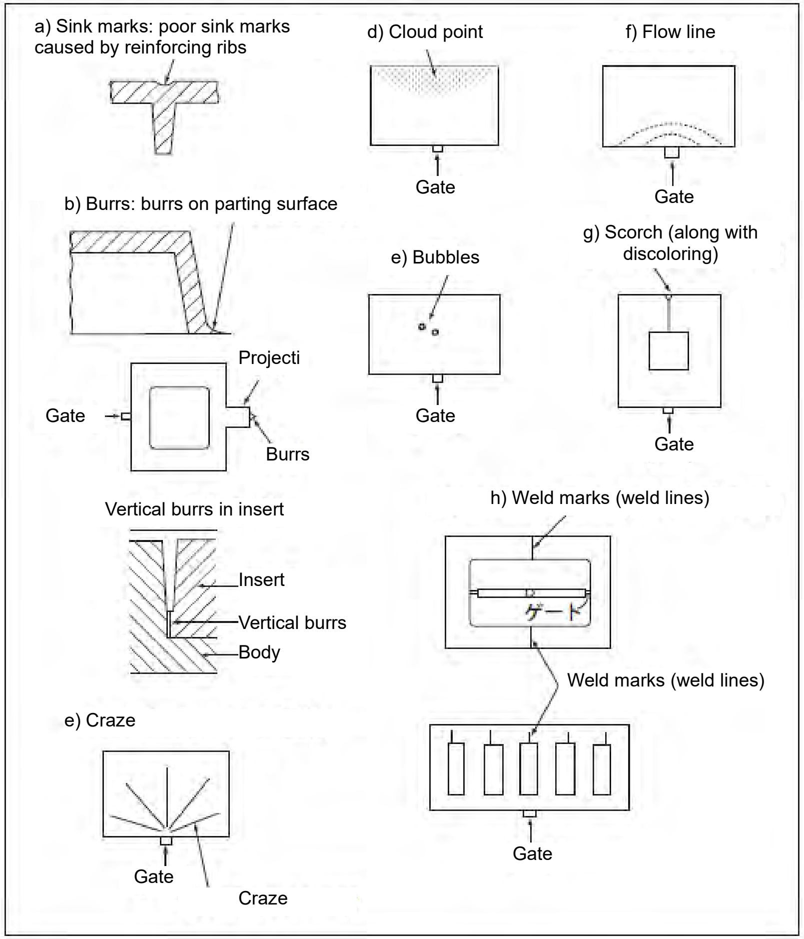
($\frac{S}{H}$: Draft)

9-6 Ensure appearance through design

Poor appearance includes sink marks, burrs, crazes, cloud points, bubbles, flow lines, weld marks (weld lines) and scorch.

The above phenomena shall be solved to a certain degree through design.

Figure-229 Poor appearance

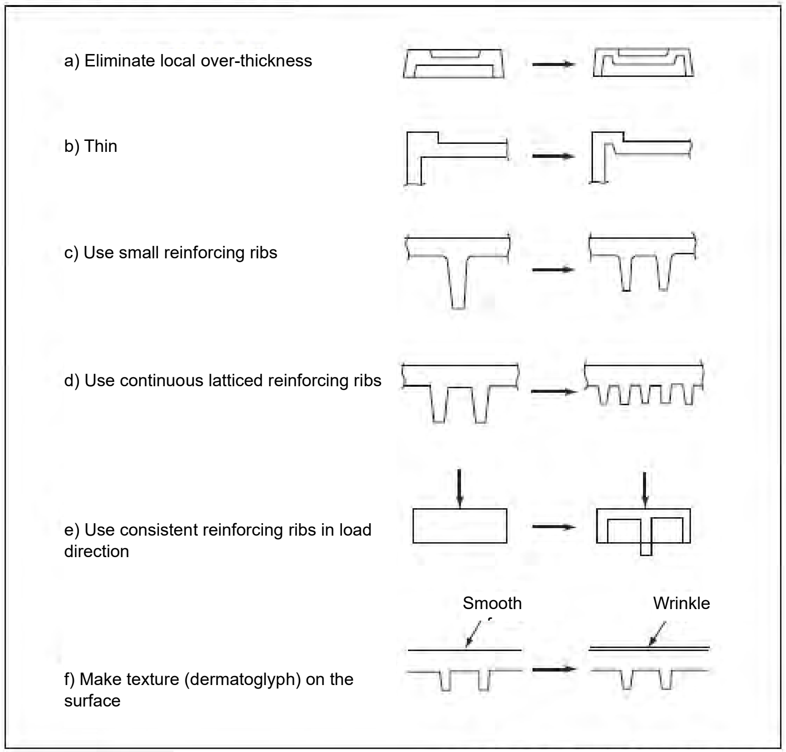


1) Design to prevent sink marks

Sink marks easily occur if the product is too thick, so the product shall be as thin as possible.

The ideal wall thickness of the product is 3~5mm.

Moreover, local thickness non-uniformity is not allowed.It is required to give up wall thickness design, make reinforcing rib structure and make a large independent reinforcing rib into several small reinforcing ribs.



From "Validation list of plastic injection molding machine"

2) Design to prevent burrs

The burrs generally appear in the parting lines and joint parts, so the part highlighting appearance shall be avoided as far as possible in the design.

3) Craze

Crazes easily appear when the resin passes through narrow passage at a high speed, so it is required not to design such part and required to pay attention to the gate position in the design.

4) Cloud point

Vents shall be designed in the mold design.

5) Bubble

The air in the die cavity will be involved in high-speed resin flow and forms bubbles on the surface of the molding product.Therefore, a gate shall be set at the thick part of the product and the runner shall be designed not to involve the air due to sudden flow change.

6) Flow line

The gate shall not be designed too small in the mold design.Moreover, it is also important to fully design a cold slug well(about 1.5~2 times the trunk diameter).

If the product is too thin, the weld marks are easily formed at flow front; if the product is too thick, the product is easy to overflow near the gate.

7) Weld mark (weld line)

Weld marks shall be avoided in the part highlighting the appearance in the gate position design.It is also effective to set overflow port (projection).

8) Scorch

Local discoloring caused by overheating of the molding materials in the molding process

1) Scorch easily appears in the part with poor ventilation in the mold. It is required to deepen and widen the ventilation surface to improve degassing.
2) Molding conditions may also cause scorch.The countermeasures such as reducing the barrel temperature, reducing the mold temperature and reducing the injection speed may be taken.

9) Spray line

The spray line is the mark formed by squeezed advance of incompletely cured resin by new resin entering the die cavity from the rear.Too small gate may result in spray lines, so the gate shall be properly enlarged.

Figure-231 Case of weld mark overflow part

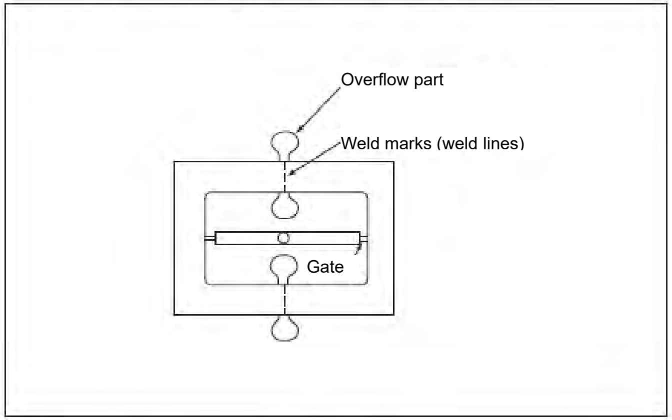
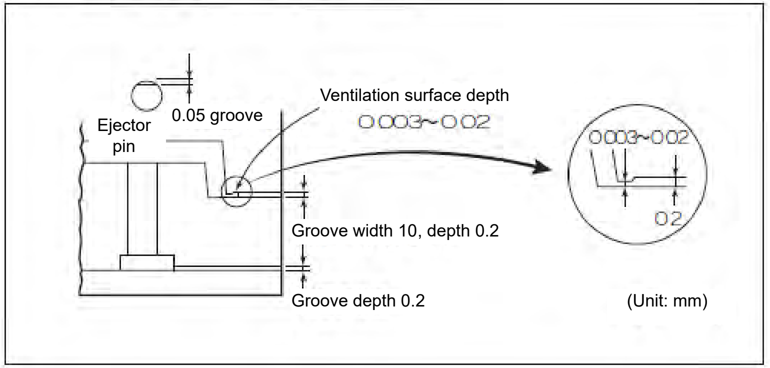


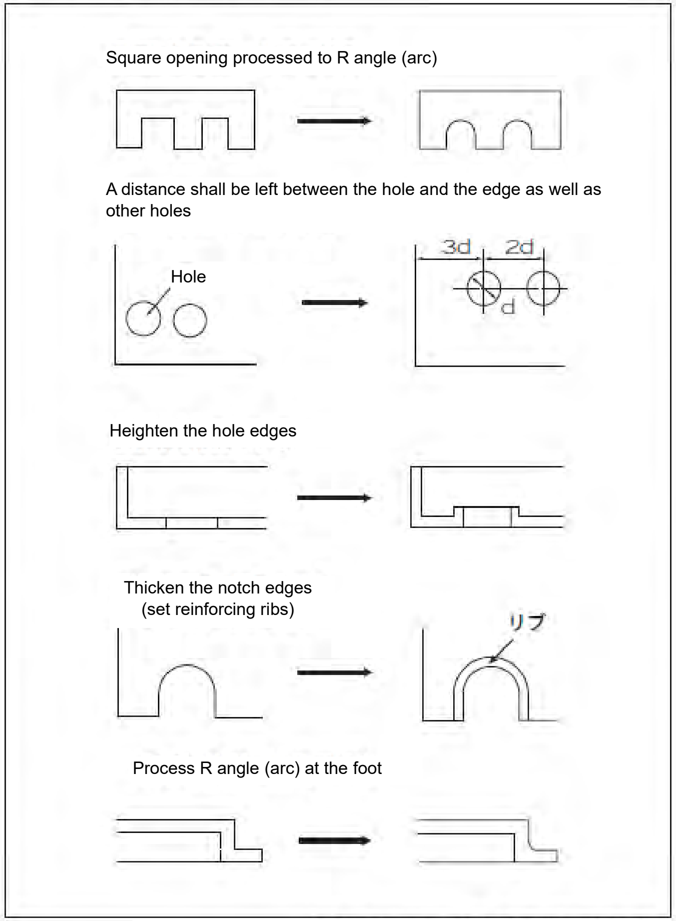
Figure-232 Exhaust (ventilation) design case



9-7 Design to reduce other problems

1) Design case to prevent cracking

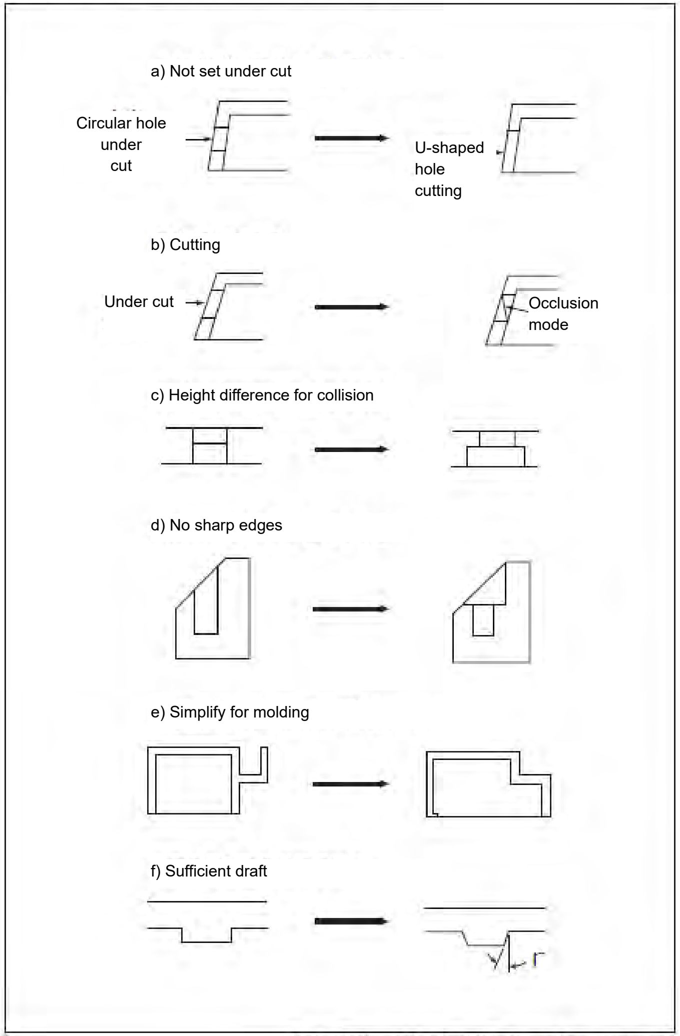
Figure-233 Design case to prevent cracking



From "Validation list of plastic injection molding machine"

2) Design case to reduce molding problems

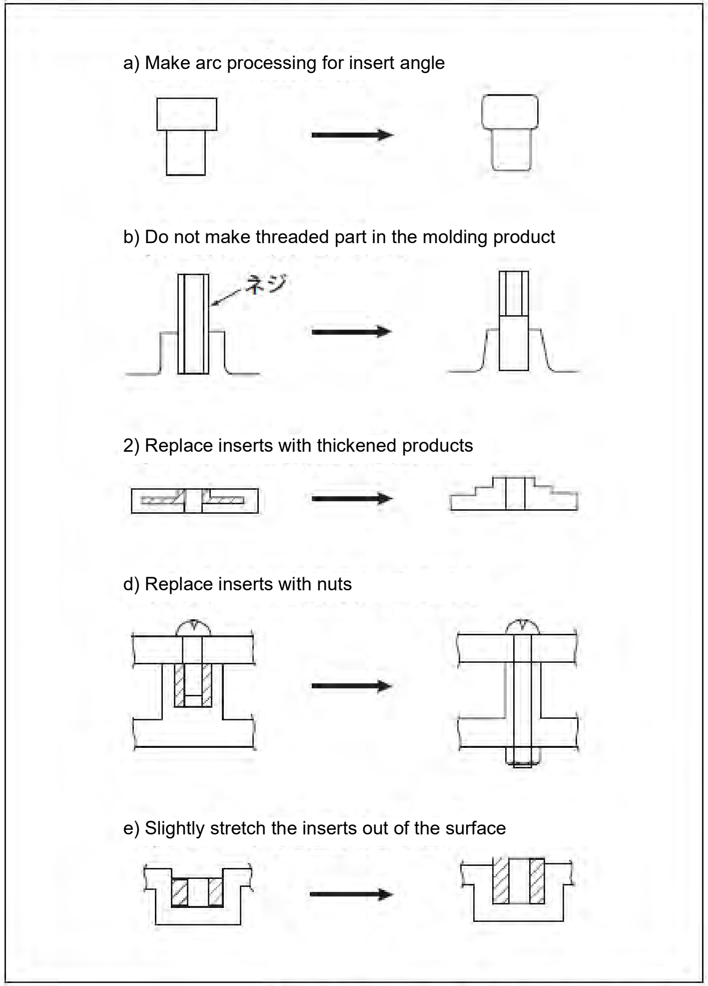
Figure-234 Design case to reduce molding problems



From "Validation list of plastic injection molding machine"

3) Design case to prevent metal insert problems

Figure-235 Design case to prevent metal insert problems

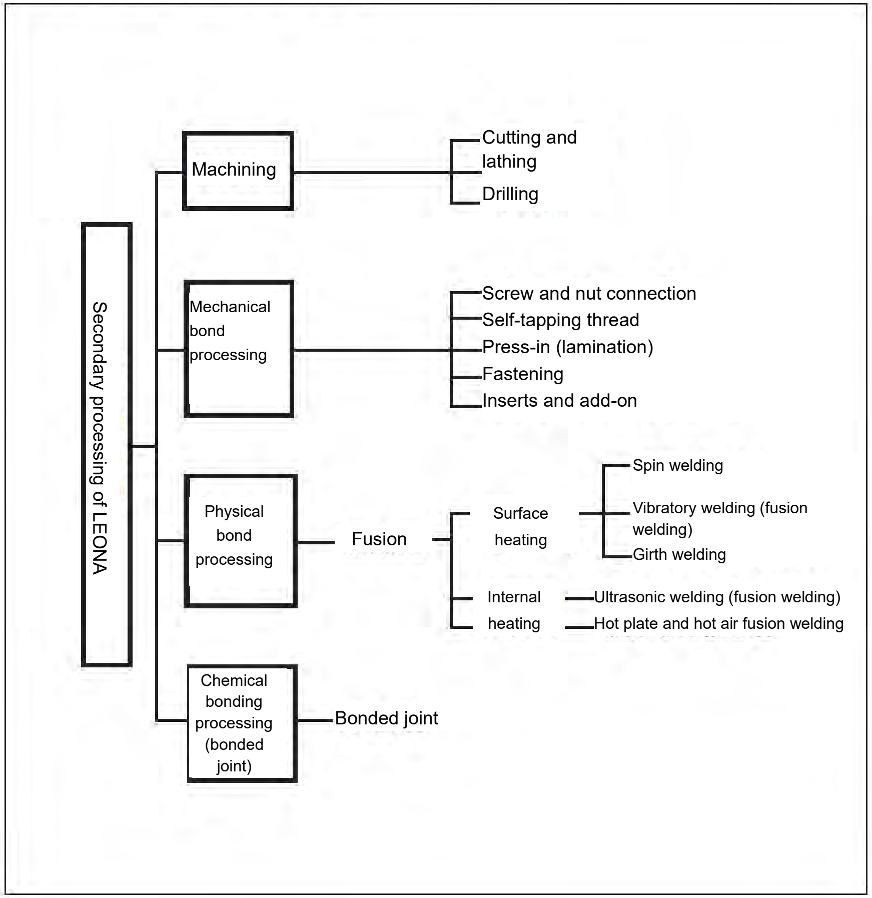


From "Validation list of plastic injection molding machine"

9-8 Relevant design for secondary processing

Injection molding and extrusion molding are called primary processing. If the product is not formed yet, further processing required is called secondary processing.The secondary processing of LEONA mainly includes machining, mechanical bond processing, physical bond processing and chemical bond processing.

Figure-236 General chart of secondary processing of LEONA



(1) Machining

1) Cutting

It is required to pay attention that the heat caused by high running speed during cutting by working angles may result in resin melting.It is recommended to use the air for cooling.(LEONA has strong water absorption, so it is not recommended to use water for cooling). The superhard alloy or high-speed tool steel is used for the cutting tool material and glass fiber reinforcement level. Moreover, large cutting inclination shall be adopted for glass fiber reinforcement level and small cutting inclination for non-reinforcement level.

2) Drilling

The drill for metal or the drill for plastics is used for peeling rather than cutting because the plastic is cut flexibly.Attention shall be paid in drill diameter selection that the cutting pore diameter is slightly smaller than the drill diameter.

The high speed tool steel (SKH2) for drill adopts glass fiber reinforced level and unreinforced level.

Moreover, large cutting inclination shall be adopted for glass fiber reinforcement level and small cutting inclination for non-reinforcement level.

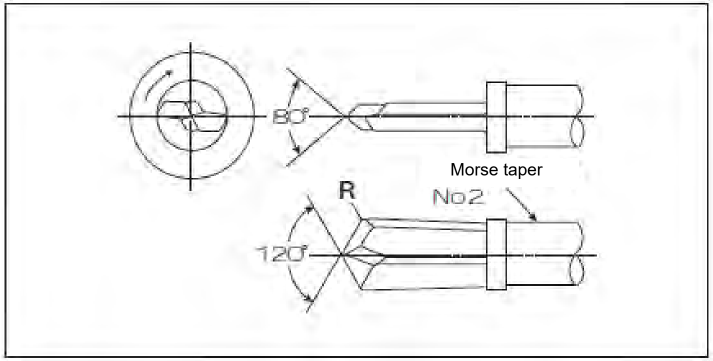
3) Buffing

Gate polishing, surface grinding or trace removal is required sometimes, but is not recommended for reinforced level of glass fiber since the surface glass fiber will peel off.

The polishing wheels are classified into rough polishing wheels, fine polishing wheels and cotton polishing wheels. For special surface polishing, fine polishing wheels are used.

The fine polishing wheel is buff made from about 50 pieces of flannel.Meanwhile, the fine polishing wheels are used with abradant, and PIKAL and KINGLIGHT (trade name) are used if the glossiness is specially required.

Figure-237 Drill case



General specification
Water absorption characteristics
Moisture dependency
Temperature dependency
Evaluation methods
Specifications and acts
Long-term characteristics
When replacing the metal
Product design
Mold for injection molding
Injection molding technology
Fault cases and countermeasures of molding products

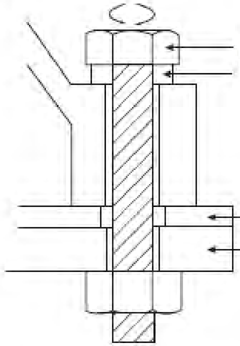
(2) Mechanical bond processing

1) Screw and nut connection

The method is very simple, but creep and stress relaxation may result in torque decline.The spring washer is recommended.

Determination method

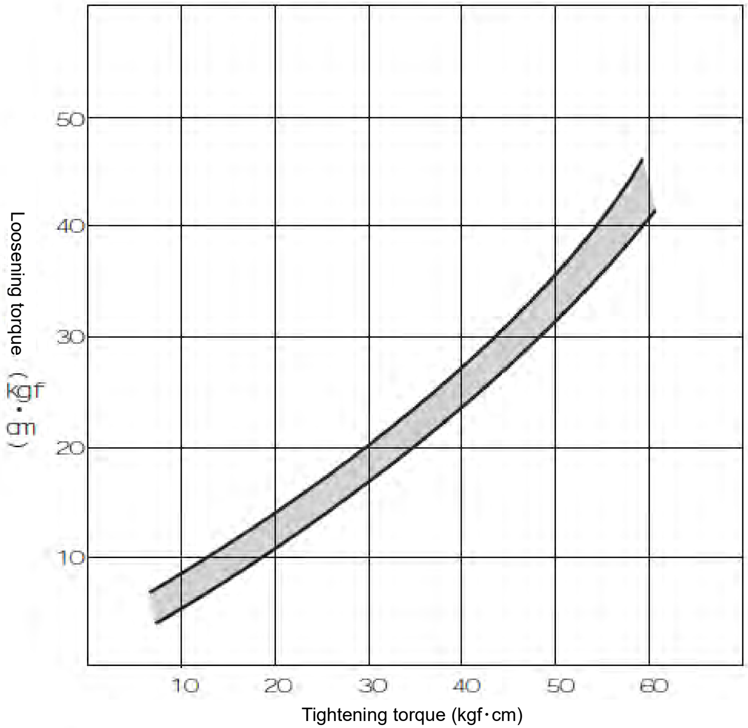
· Measured bolt and nut



· Torque measuring port

Measure the tightening torque (direction) and loosening torque (direction) with a torsiometer (with the selection range of 0~120kgf・cm).

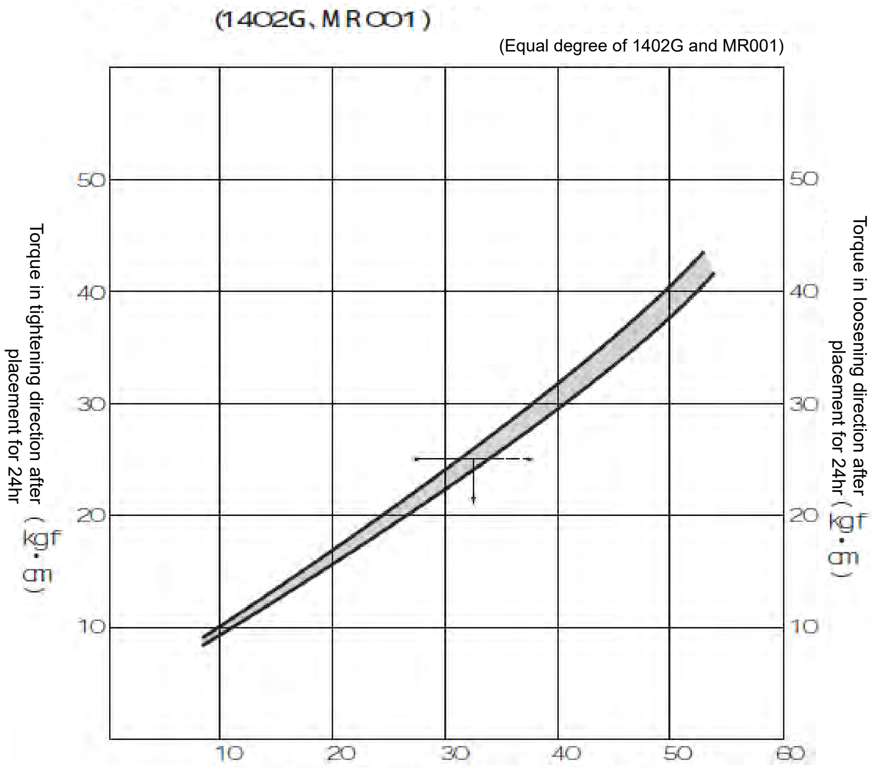
Figure-238 Tightening torque and loosening torque (torque of loosening following tightening) (1402G, normal temperature)



SI unit conversion

10kgf・cm=0.980665J

Figure-239 Tightening torque and loosening torque (after placement for 24h under room temperature)



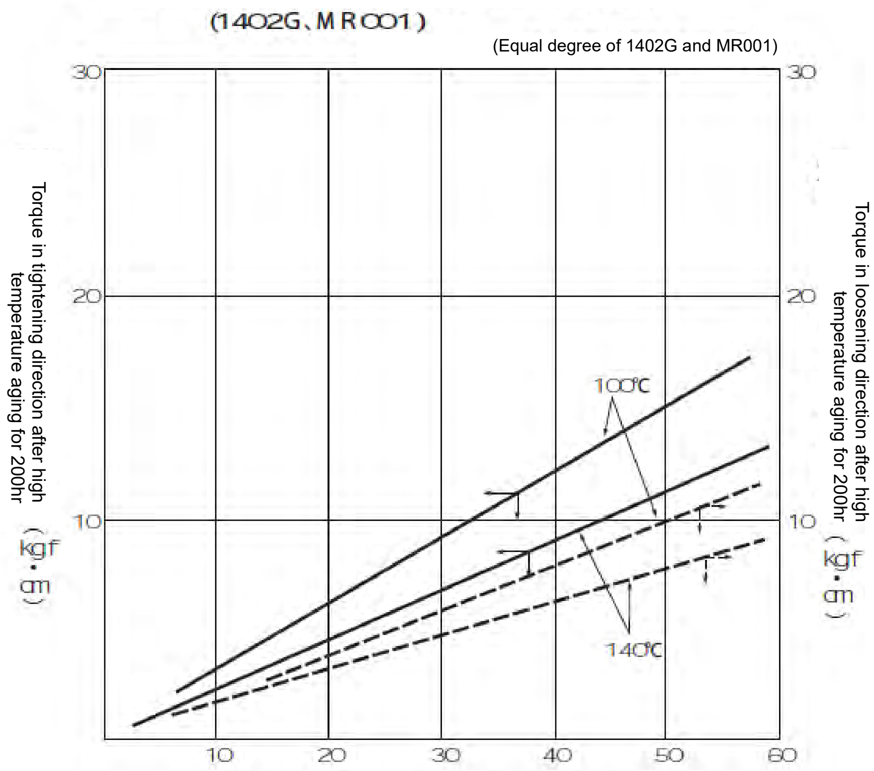
Tightening torque before placement (kgf・cm)

Loosening torque before replacement (kgf・cm)

Converted into SI unit

10kgf・cm=0.980665J

Figure-240 Tightening torque and loosening torque (before and after high temperature aging)



Tightening torque before aging (kgf・cm)

Loosening torque before aging (kgf・cm)

Converted into SI unit

10kgf・cm=0.980665J

2) Self-tapping thread

The self-tapping thread is a technique to cut up and connect the threads of untapped part with tapping screw. When making the self-tapping thread, the bottom hole diameter (inner diameter of tapping column) is about 90% of the outer screw diameter, and the outer diameter of the tapping column is 2~3 times the outer screw diameter. The length of fit has great impact on the tensile force and shall be about twice the screw diameter.The root of the tapping column is easily damaged, so R angle processed sufficiently is requiredand shall be more than 0.25 times the bottom thickness.

The torque will be reduced by about 30% after long-term pending.

Thread selection

The ideal thread type is the thread with small tapping torque.

If large-diameter thread is required for the strength, the thread with small length of fit is selected; if the small-diameter thread is used (when the tapping column height design is limited), the thread with large length of fit is selected.If the depth and diameter may be selected freely, it is recommended to select the thread with large length of fit.

Tensile force (F)

$$F = \tau \times A = \frac{\sigma_T}{\sqrt{3}} \times \pi \times D_P \times h$$

- F : Drawing force (kgf)
- τ : Shear strength (kgf/cm^2)
- A : Shear area (cm^2)
- σ_T : Tensile yield strength (kgf/cm^2)
- D_P : Effective diameter (cm)
- h : Length of fit (cm)

Failure torque (T)

$$T = F \times r \times \left(\frac{p + 2\pi \mu r}{2\pi r - \mu p}\right)$$

- T : Failure torque (kgf·cm)
- F : Drawing force (kgf)
- p : Spacing (cm)
- μ : Friction coefficient (-)
- r : Radius (cm)

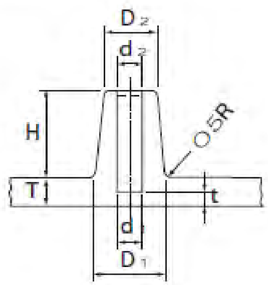
Converted into SI unit

$1kgf = 9.80665N$

$1kgf/cm^2 = 9.80665 \times 10^{-2} MPa$

$1kgf \cdot cm = 9.80665 \times 10^{-2} J$

Figure-241 Standard design case of tapping column for self-tapping thread



Unit: mm

T	25~30		35	Base plate thickness
D1	7	7	8	Outer diameter of tapping column
D2	6	6.5	7	
t	T/2 or 1.0~1.5			1/2 of base plate thickness
d1	2.3			Bottom hole diameter
d2	2.6			
H	<3.0			Tapping column height

Figure-242 Self-tapping screw performance determination method

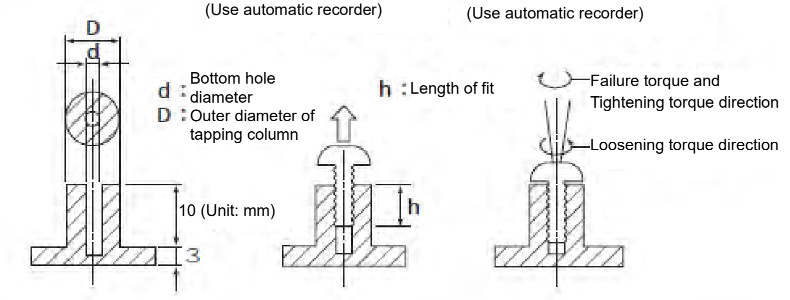
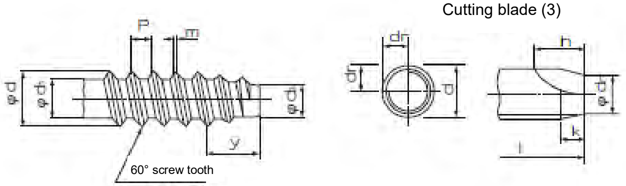


Figure-243 Recommended thread case (JIS thread)

Shape and size of two types of self-tapping thread (from JISB1003 and B1007)

2 types

Cutting blade (3)



d r= d − 1 6P
d r=0 5d ±0 5mm
k= 3P ±0 5mm
h= 5P ±0 5mm

Unit: mm

Nominal diameter			2	25	3	35	4	45	5	6	8
d		Maximum	2	25	3	35	4	45	5	6	8
		Minimum	19	24	29	34	385	435	485	585	78
d1		Maximum	15	19	23	27	3	34	38	46	61
		Minimum	14	18	22	26	29	33	36	44	59
d3		Maximum	14	18	22	26	29	33	36	44	59
		Minimum	12	16	2	24	27	3	33	4	54
P			063	091	106	127	141	159		181	212
Number of screw teeth		25.4mm About	40	28	24	20	18	16		14	12
m		Maximum	01						015		
y	Short thread end	Maximum	13	18	21	25	28	32		36	42
		Minimum	095	14	15	19	21	24		27	32
	Long thread end	Maximum	16	23	26	32	35	4		45	53
		Minimum	13	18	21	25	28	32		36	42

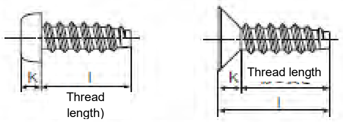
Remark

1. In class 2 thread, the conical part with the length y less than the value in the following table relative to the thread length (2) of the nominal diameter is short thread end and the part with the length exceeding the value in the following table is long thread end.

Unit: mm

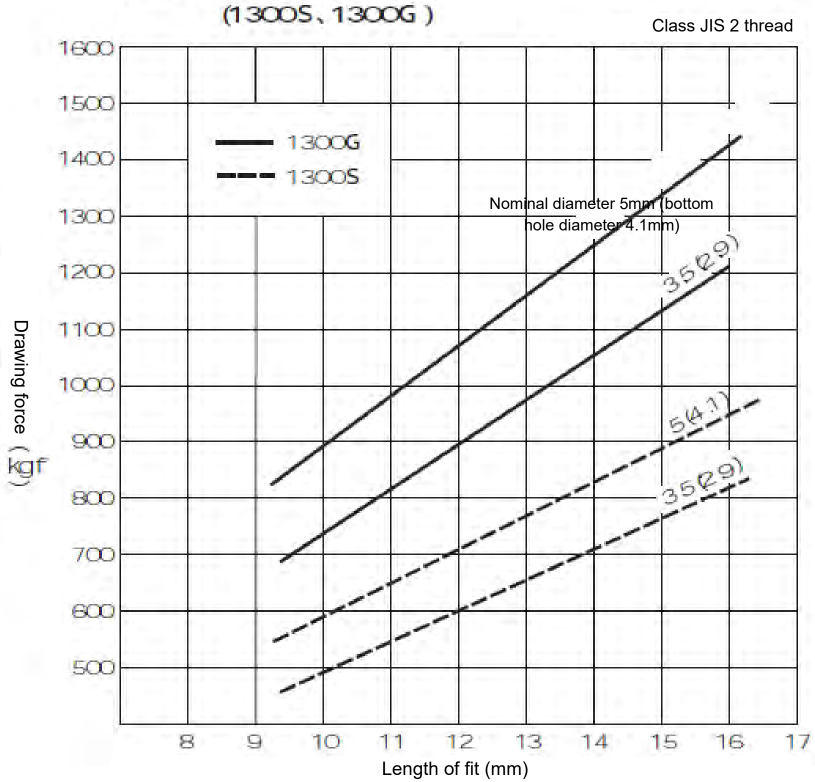
Nominal diameter	2	25	3	35	4	45	5	6	8
Thread length	32	45	53	64	7	8		9	10

(Note) (2) The thread length refers to the length from below the head to the end. For the flat head screws, large round flat head screws and stretched head screws, the thread length is equal to the nominal length 1; for small countersunk socket set screws and small circular countersunk socket set screws, the thread length is nominal length 1 subtracted by the head height k contained in the size.(Refer to the following figure)



2.Continuous thread with length of above 1/2 of the total length is required in the taper of class 2 thread.
3.The groove may be engraved in the front end of class 2 thread if required by the subscriber.

Figure-244 Drawing force and length of fit

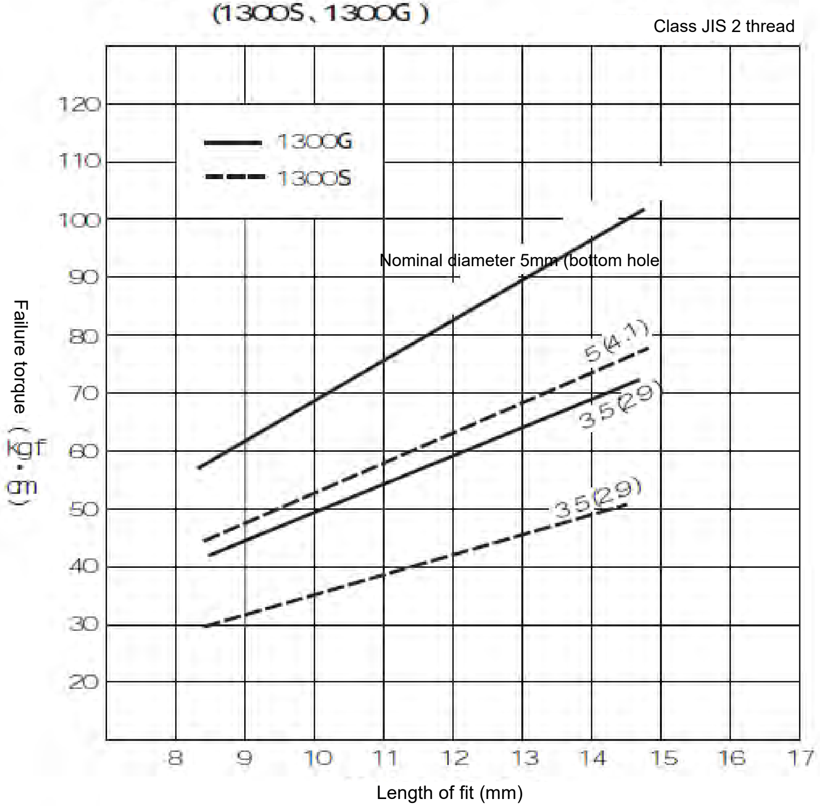


Converted into SI unit

100kgf=980 665N

Figure-245 Failure torque and length of fit

(1300S、1300G)

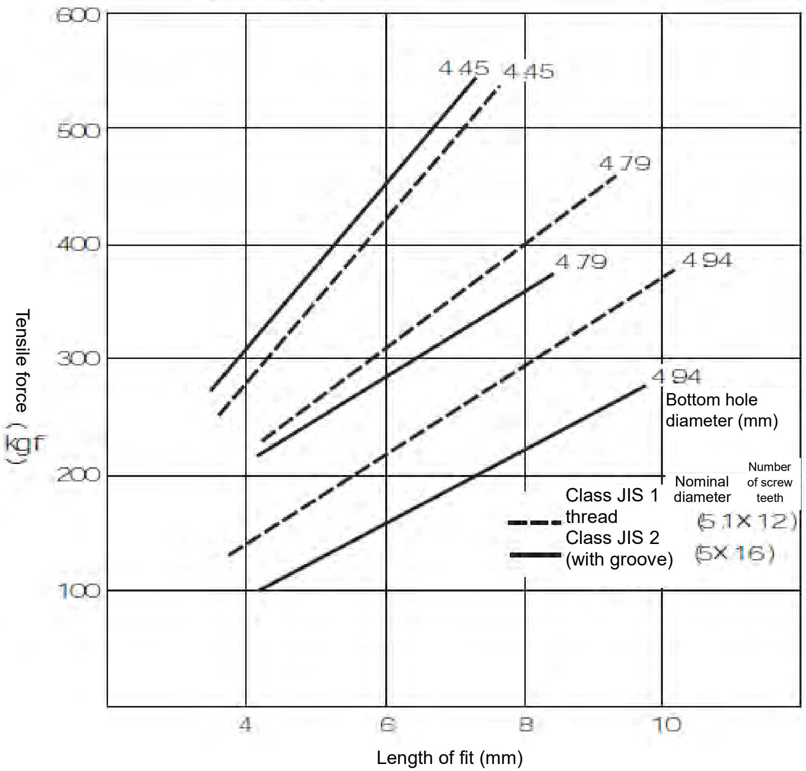


Converted into SI unit

1Okgf・cm=0.980665J

Figure-246 Drawing force and length of fit

(MR001)

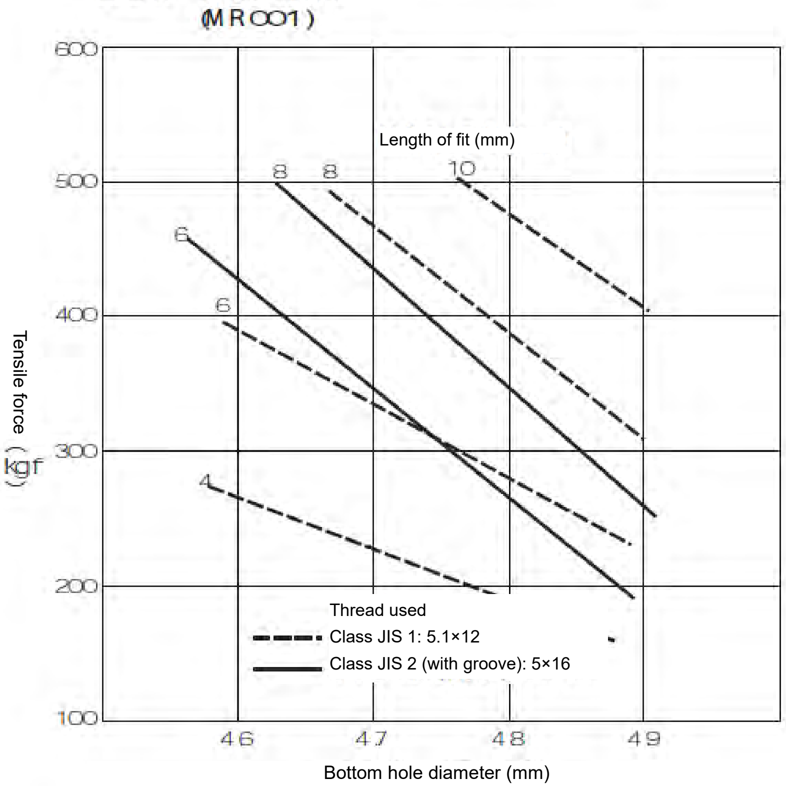


Converted into SI unit

100kgf=980.665N

General specification
Water absorption characteristics
Moisture dependency
Temperature dependency
Evaluation methods
Specifications and acts
Long-term characteristics
When replacing the metal
Product design
Mold for injection molding
Injection molding technology
Fault cases and countermeasures of molding products

Figure-247 Drawing force and bottom hole diameter

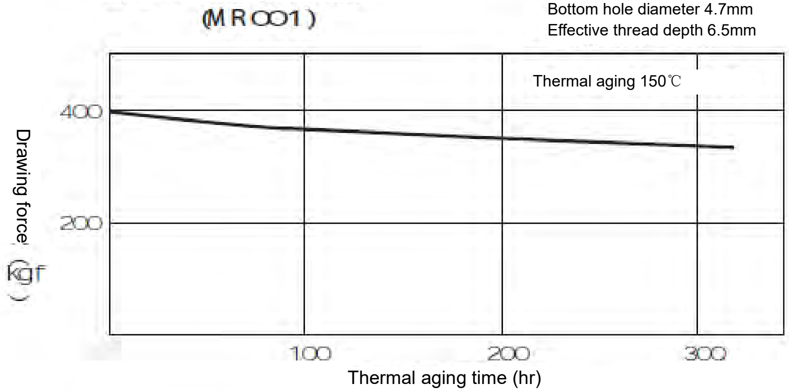


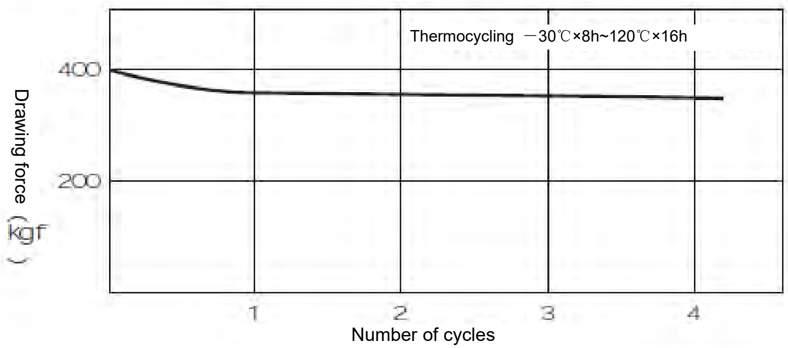
Converted into SI unit

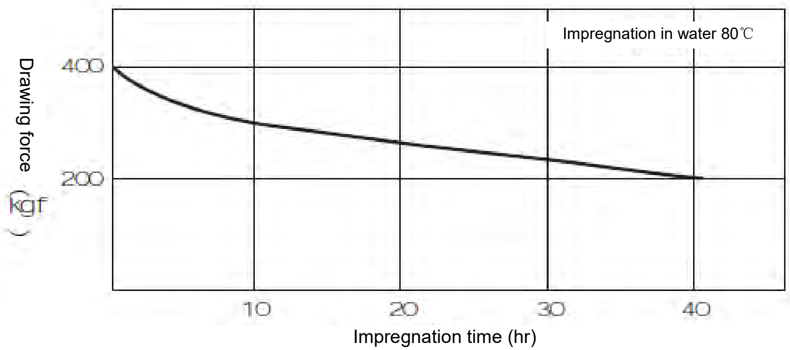
100kgf=980.665N

Figure-248 Ongoing change of drawing force

Class JIS 1 thread 5×25
Bottom hole diameter 4.7mm
Effective thread depth 6.5mm







Converted into SI unit 100kgf=980.665N

Figure-249 Failure torque and length of fit (1)

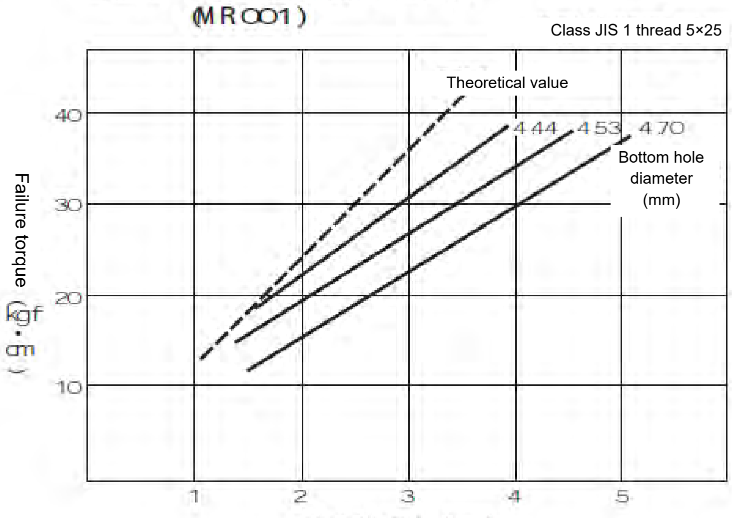
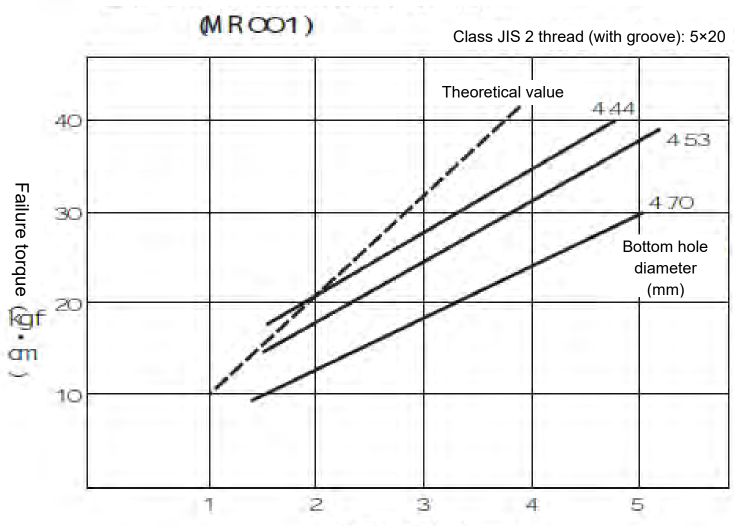


Figure-250 Failure torque and length of fit (2)



Converted into SI unit 1kgf・cm=0.980665J

Figure-251 Failure torque and length of fit (3)

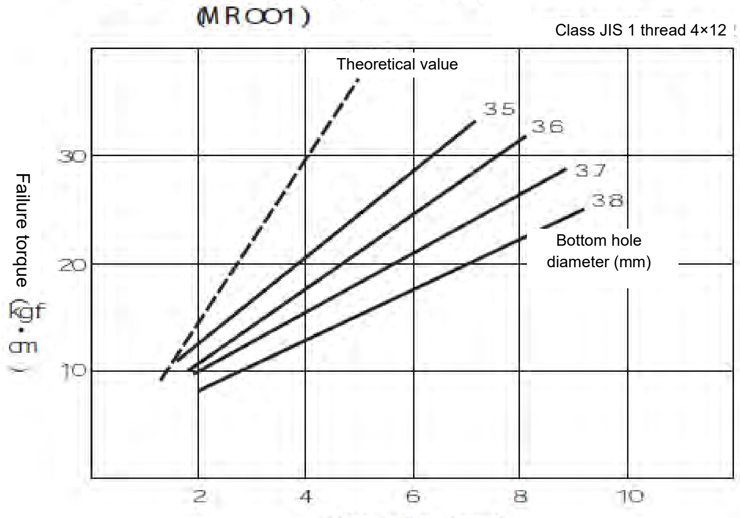
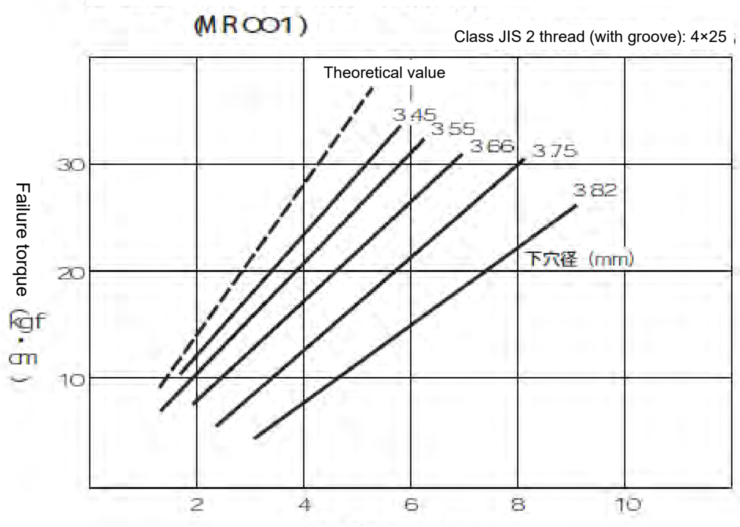


Figure-252 Failure torque and length of fit (4)



Converted into SI unit 1kgf・cm=0.980665J

Figure-253 Screw-in torque and failure torque (1)

(MR001)

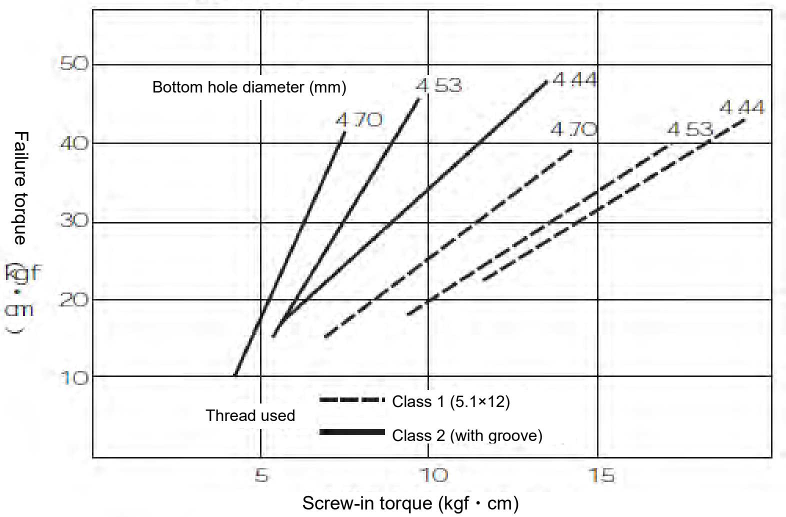
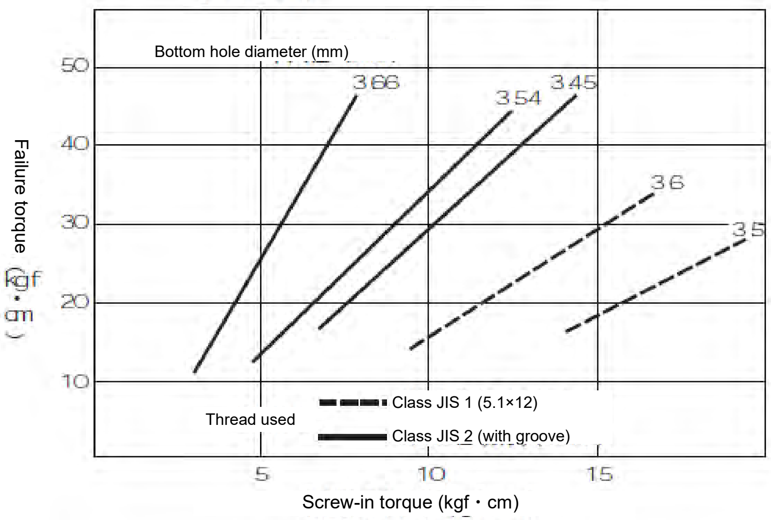


Figure-254 Screw-in torque and failure torque (2)

(MR001)



Converted into SI unit 1.0kgf・cm=0.980665J

3) Press-in (lamination)

Press-in is a joint method to insert the shaft into the shaft sleeve and is commonly used to insert metallic shaft into resin (LEONA) shaft sleeve.Press-in is an assembly method possibly generating very large stress, so special attention shall be paid.LEONA has excellent stress relaxation and creep characteristics, so it can be durable and the shaft will not be loose if the press-in reserve is well designed.The press-in reserve of LEONA is 3~5% for unreinforced level and 2~3% for reinforced level of glass fiber.

The formula of the tolerance range of the press-in reserve is as follows:

$$B=\frac{\sigma d\, Ds}{W}\left[\frac{W+\nu h}{Eh}+\frac{1-\nu s}{Es}\right]$$

$$W=\frac{1+\left(\frac{Ds}{Dh}\right)^2}{1-\left(\frac{Ds}{Dh}\right)^2}$$

B= Allowable press-in reserve (mm) (shaft diameter - inner diameter of shaft sleeve)
σd = Design stress (kgf/cm^2)
Dh= Outer diameter of HUB (shaft sleeve) (mm)
Do= Inner diameter of shaft sleeve (mm)
DS= shaft diameter (mm)
Eh= longitudinal modulus of HUB (shaft sleeve) (kgf/cm^2)
ES= longitudinal modulus of shaft (kgf/cm^2)
vh= coefficient of LEONA for HUB (shaft sleeve) =0.34
vS= Coefficient of steel as shaft material =0.29
W= Shape factor

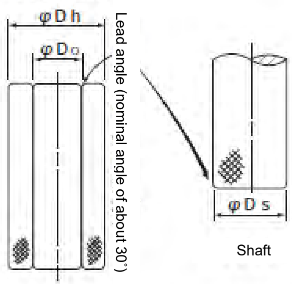
In addition, the press-in force or drawing force may be calculated approximately by the following formula.

$$F=\pi\mu P\, Ds\, L$$

$$P=\frac{\sigma d}{W}$$

F= Press-in force or drawing force (kgf)
μ=Friction coefficient (0.19 for LEONA)
P = Bonding pressure (kgf/cm^2)
DS= shaft diameter (mm)
L = Shaft insertion length (mm)
σd = Design stress (kgf/cm^2)
W= Shape factor

HUB (shaft sleeve)



Shaft

*Note: It shall be noted that the weld lines in HUB (shaft sleeve) may result in cracking and other problems.

Converted into SI unit

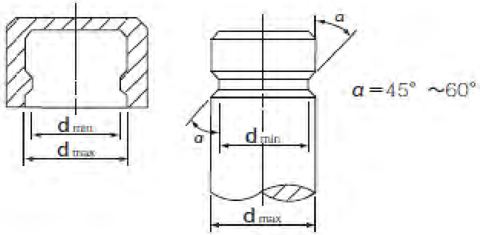
1kgf/cm^2=9.80665×10^{-2} MPa

4) Fastening

LEONA is elastic, so the fastening method may be used in assembly.As shown in the following case, fastening is to insert the object in the right figure into the recess subject to injection molding in the left figure by pressure.

It shall be noted in the design that the groove is required in fastening.

(Refer to under cut.)



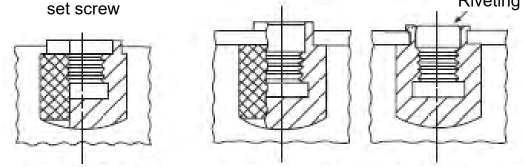
5) Inserts and external inserts

① Insert

Metal inserts are often used in threaded parts to increase strength.However, the metal and other foreign matters will enter the plastics in insert molding, so it is required to fully pay attention to the design and molding conditions of the insert part; otherwise, the part may suffer from fracture and strength decline.To prevent problems, the following matters shall be noted:

1. The oil stuck to the metal for inserts may result in environmental stress crack, so the metal shall be unoiled before use.
2. The flowing high temperature resin contacts the low temperature metal, generating great residual stress and the difference in the coefficient of linear expansion of the plastics and the metal will result in thermal stress crack, so the mold shall be kept at a high temperature as far as possible and the metal for inserts shall be preheated before use.
3. The metal for inserts shall have no sharp corners to prevent stress concentration.
4. The inserts are subject to knurling frequently to keep the insert metal in the plastics.

Figure-255 Insert case



* Knurl: Knurls are processed on the metal surface sometimes when the insert is making, so that the metal and the plastics are meshed more closely.
* Knurling: To prevent slipping on the screw heads, parts pickup and other grasp parts, the cancellous patterns are processed on the workpiece surface by lathing with a knurling tool.

② External insert

It is a method to install various functional units through injection molding in metal and other hard base metals, place the metal and other base metals in the mold, make injection molding of plastic parts in the wood metal and make bonding.Compared with inserts, the amount of resin occupies a small part in the external inserts relative to the amount of metal.

(3) Physical bond processing

This method is to melt, cling and harden the parts to be bonded in the molding part through various methods before bonding.Spin welding, girth welding, ultrasonic welding, linear vibratory welding (vibratory welding), laser welding and other methods are often suitable for LEONA.

1) Spin welding

This method is to pressurize the plastics to be bonded to each other, spin one side in this case for friction heating, stop spinning after melt fusion of the bonding position and cool the cured workpiece for slight bonding.

① Design of bonding position

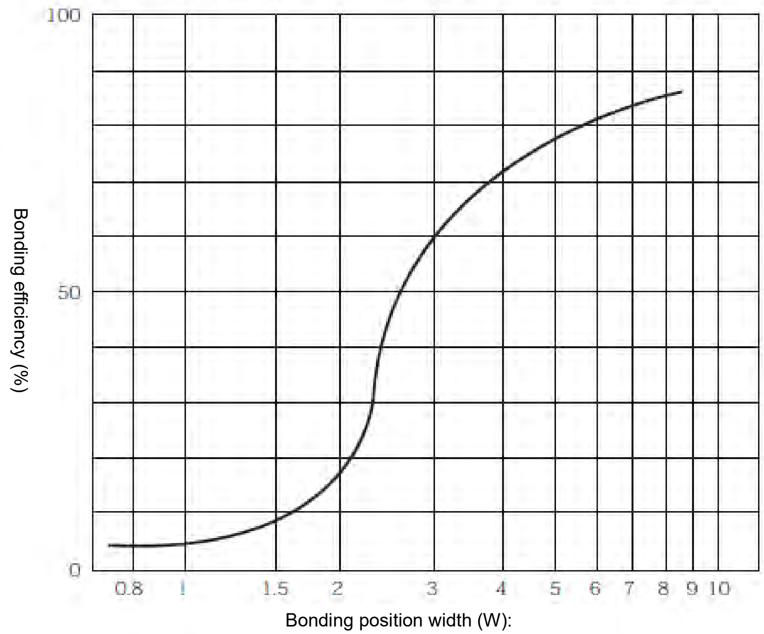
Spin welding is a friction motion of spinning towards the same direction, so the flat shape of the bonding position is mostly circular and the width and section shape of the bonding position are important in the design.

a.Bonding position width: it shall be as large as possible in principle to improve the bond strength.Excessive amplitude will result in abnormal high temperature in the center of melting layer in the bonding process. When the bonding position has relatively small radius and excessive width, the inner and outer diameter ratio of the bonding position will be increased and the ratio of the friction velocity inside and outside the bonding surface will be increased and sometimes deviate from the range of applicable conditions.The inner and outer diameter ratio of 1~1.5 and the bonding position width o 4~6mm are suitable.

b.Section shape: increase the bonding area to improve the bond strength.Refer to the following application case.

c.Melting allowance (molten allowance): amount of melting indentation during bonding.(Refer to P262) At least 0.5mm is required if LEONA 1300G is used.

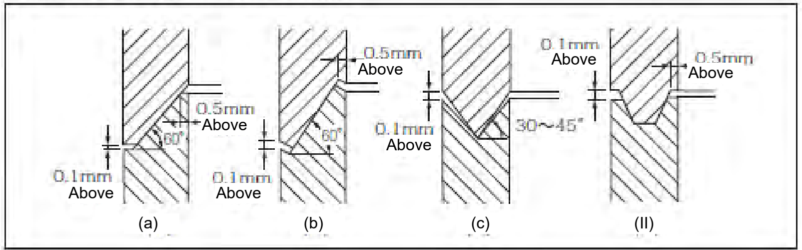
Figure-256 Bonding efficiency of 1300S (width relative to bonding position)



Bonding

Friction velocity (V): 260cm/sec
Friction time (T): 0.7sec
Forge welding pressure (Po): 31kgf/cm^2(3.0 MPa)
Time required for stop (Ts): 0.028sec

Figure-257 Case of section shape of applicable

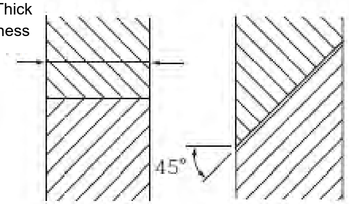


② Bonding properties

Table 44: Bonding case of LEONA

Item / Material	Base metal strength (kgf/cm²)	Bond strength (kgf/cm²)	Bonding conditions: Bonding position shape	Forge welding pressure (kgf/cm²)	Friction velocity (cm/sec)	Friction time (sec)	Stop time (sec)	Remark
1300S	830	830	B	12	200	0.35	0.028	
1300S	830	800	A	12	250	0.4	0.035	
1300S (Black) M3300	830	830	B	15	250	0.4	0.035	Coloring material Master batch 20:1
1300G	1880	830	B	15	250	0.4	0.035	
MR001	1020	520	B	20	350	0.3	0.05	
1300G-1300S	—	830	B	15	250	0.4	0.035	
1300-Nylon 6	—	730	B	15	250	0.3	0.035	

Note) Bonding position dimensions
- Outer diameter: 30mm
- Inner diameter: 20mm
- (Thickness: 5mm)
- Bonding position shape *: as shown in right figure



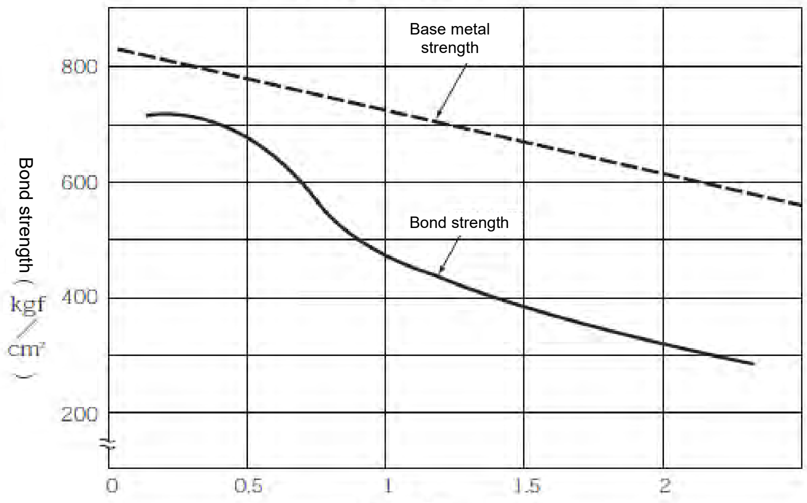
(A) (B)

Converted into SI unit

$1kgf/cm^2 = 9.80665 \times 10^{-2} MPa$

It shall be particularly noted that the water absorption of the molding product, if any, will result in decline in physical properties.

Figure-258 Bond strength and moisture content of 1300G



Bonding conditions

- Friction velocity (V): 260cm/sec
- Forge welding pressure (Po): 20kgf/cm^2
- Friction time (T): 0.4sec
- Bonding position width (W): 5mm
- Time required for stop (Ts): 0.03mm

Note) Moisture content (material in bonding position) is measured before bonding.

Converted into SI unit

$100kgf/cm^2 = 9.80665MPa$

2) Girth welding

Girth welding means that in a pair of bonding position materials, a material moves along the small circular orbit rather than autoratation relative to the other material and the materials are melted through the friction heat generated from the autorotation and forge welding pressure.

Therefore, all shapes of bonding surfaces with plane can be melted and applied to large equipment.

① . Design of bonding position

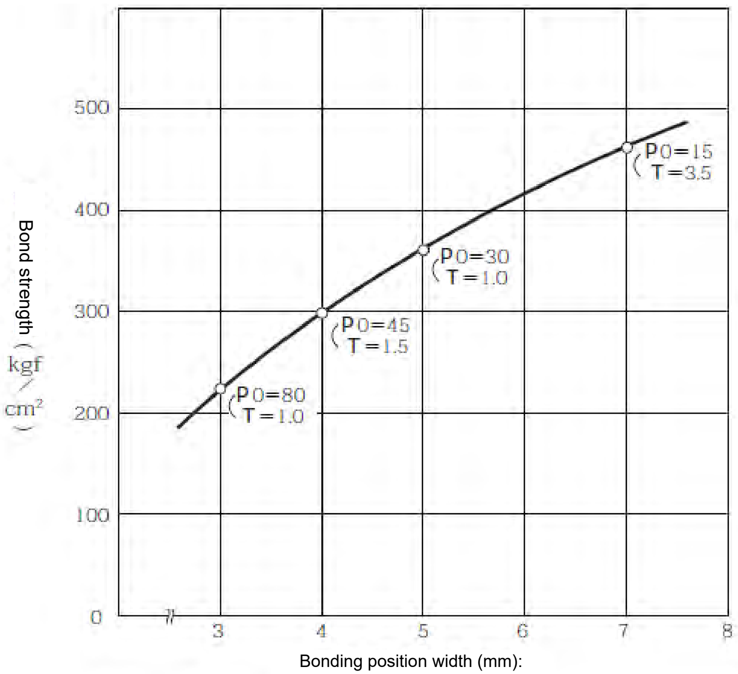
Similar to the design in spin welding generally.

a. Width of bonding position

Like spin welding, the bonding position width is very important.

To obtain practical bond strength, the bonding position width shall reach a certain degree (about 4mm).

Figure-259 Bond strength and bond width of 1300G



P0: Forge welding pressure (kgf/cm^2)
T: Friction time (sec)

Converted into SI unit

100kgf/cm^2=9.80665MPa

b. Melting allowance (molten allowance)

Like spin welding, the melting allowance of girth welding shall be more than 0.5mm/

Figure-260 Definition of melting allowance

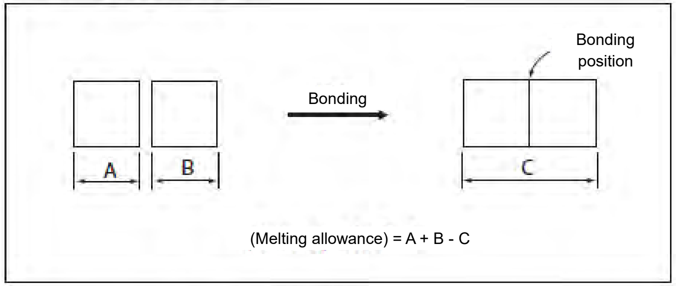
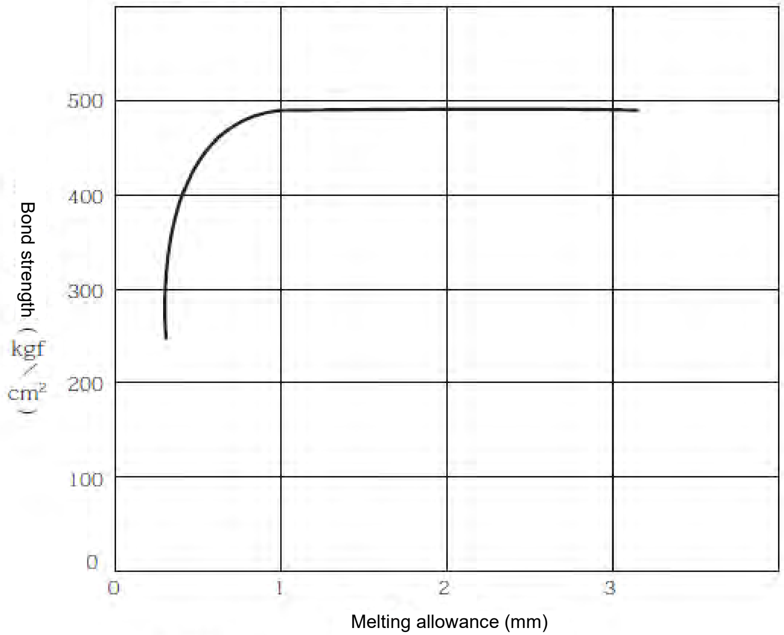


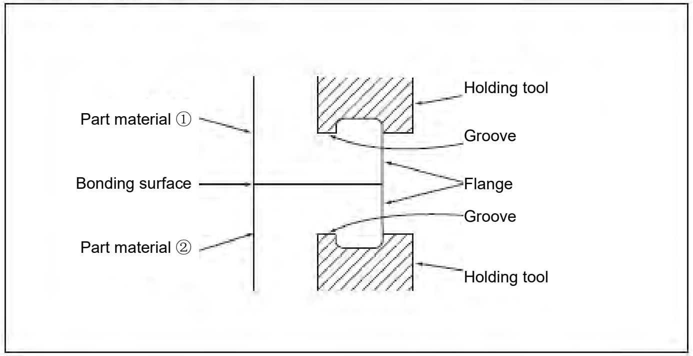
Figure-261 Bond strength and melting allowance of 1300G



Converted into SI unit 100kgf/cm^2=9.80665MPa

c. Flange design in bonding position

To uniformly apply the forge welding pressure to the bonding surface and make the orbital motion fully induce to the bonding surface, it is ideal to design a flange in the bonding position, clamp the flange and apply the forge welding pressure.Refer to the following application case.



3) Ultrasonic welding

Ultrasonic welding is to convert the high-frequency energy into periodic mechanical vibration energy and melt the contacted plastic surface through the pressure generated from friction and reciprocating motion for bonding.The processing cycle is short and about 0.5~2s. The solvent and the bonding surface may not be subject to pretreatment and the bonding surface is beautiful. Moreover, certain air tightness and water tightness are required.

① Precautions in design

a. The forge welding pressure 100~300kgf/cm^2 shall be applied to the molding product, so the strength of the molding product can withstand this pressure.

b. The rectangular welding head is 40cm and the maximum diameter of the circular welding head is 25cm, so they do not apply to welding of large molding products.

c. The closer the welding point to the welding head the better

d. To prevent dislocation of the bonding position due to vibration, the section shall be designed into coordination type.

e. There are various design types of welding ribs, mainly including energy director welding rib, shear welding rib, mortise welding rib and beat welding rib.

f. To facilitate welding head processing, the contact surface of the welding head shall be plane or simple surface.

Figure-263 Case of bonding position of thin molding product

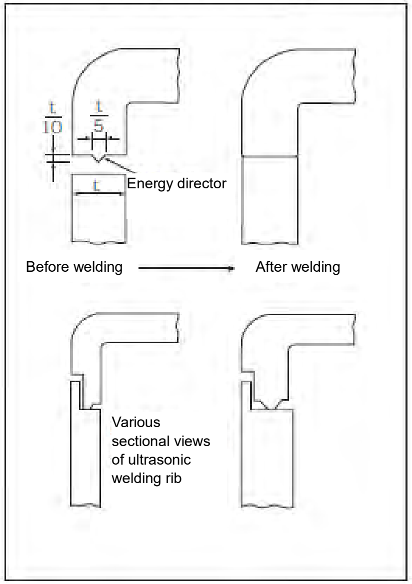
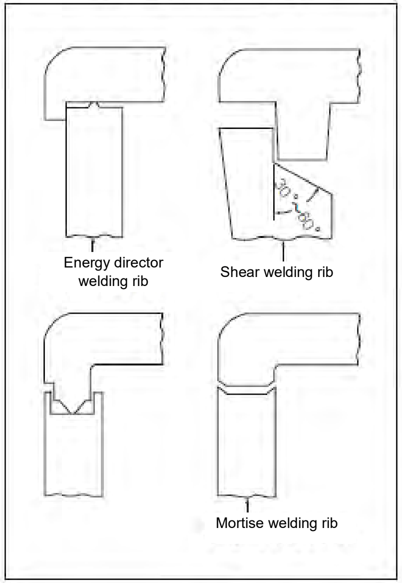


Figure-264 Case of bonding position of thick molding product



(4) Chemical bonding processing (bonded joint)

The cement bonding, solvent bonding and other bonding methods are very simple and commonly used in amorphous resin, but LEONA is crystalline resin, so the bond strength is not high.It shall be fully noted that it is very important to select the cement due to few actual application cases.

The cement bonding cases and application cases of formic acid in LEONA in solvent bonding are as follows:

① Advantages and disadvantages of cement bonding

Advantages: • High temperature is not required for bonding.

- Different types of materials may be bonded.
- The complex structure may be bonded.
- The materials of different thickness may be bonded. It is most suitable for bonding of thin materials.
- Smooth bonding position, good gas and fluid tightness.
- Low production cost

Disadvantages: • The tear strength of the bonding position per unit area varies with the cement type and the type of the bonded material.

- For wide application, necessary date must be collected each time.
- The cement is of poor thermal stability.

② Cements suitable for LEONA

a.Cements used for bonding between LEONA and other materials

LEONA and ceramics: nitrile cement

LEONA and textile: neoprene cement and nitrile cement

LEONA and leather: neoprene cement and nitrile cement

LEONA and paper: nitrile cement and latex

LEONA and rubber: neoprene cement, reclaimed rubber and butadiene/styrene vinylpyridine latex and resorcinol/Formaldehyde mixture (90~80/10~20)

LEONA and wood: neoprene cement and nitrile cement

LEONA and metal (Cu, Al and Ti): epoxy resin, resorcinol resin and neoprene cement

b.Cements for LEONA and LEONA

Resorcinol resin

Epoxy resin

Nitrile cement/phenolic cement

Neoprene cement (solvent type)

9-9 Schedules

Schedule 1: Nature of metallic materials and LEONA

	Relative	Elasticity modulus (GPa)		Breaking stress (MPa)			Poisson's ratio
		Longitudinal (E)	Transverse (G)	Tensile	Compression	Shear	
Mild steel (C0.12～0.20%)	7.7	207.9	82.4	422	422	343	0.28～0.3
Hard steel C0.40～0.50%)	7.5	205.0	82.4	440<	440<	390<	
Cast steel	7.9	210.8	81.4	520	520	—	
Cast iron	7.3	93.2	52.0	178	735	196	0.2～0.29
Nickel steel (Ni 2～3%)	—	205.0	82.4	588	588	—	
Copper	8.9	122.6	46.1	196	294		0.34
Phosphor bronze	8.6	131.4	42.2	392		373	
Gunmetal	8.9	93.2	39.2	235	235	—	
Brass 7:3	8.5	110.8	41.2	255			
Brass 6:4	8.4	91.2	39.2				
Aluminum	2.7	70.6	26.5	93			0.34
Hard aluminum	—	68.6	26.5	441			0.34
LEONA 1300S	1.1	3.04	0.88	79	114	69	0.34
LEONA 1300G	1.4	9.32	3.04	186	167	88	0.34

Note) 1. Longitudinal modulus of elasticity E (modulus of elasticity, Young's modulus)

$$E=\frac{\sigma}{\varepsilon}\ \mathrm{[GPa]}$$

σ: Stress
ε: Strain

2. Transverse modulus of elasticity G (modulus of rigidity, rigidity, shear modulus)

$$G=\frac{\tau}{\gamma}\ \mathrm{[GPa]}$$

τ: Shear stress
γ: Shear strain

3. Poisson's ratio

$$\nu=\frac{\varepsilon'}{\varepsilon}$$

ε: Longitudinal strain
ε': Transverse strain

Converted into former unit

1 Mpa=10.1972 kgf/cm², 1 GPa=10197.2 kgf/cm²

Schedule 2: Allowable stress of steel and LEONA (MPa)

Load		Mild steel	Medium hard steel	Cast steel	Cast iron	1300S	1300G
Tensile	I	88～147	118～177	59～118	29	15～20	29～39
	II	59～98	78～118	39～78	20		
	III	29～49	39～59	20～39	10		
Compression	I	88～147	118～177	88～147	88	20	34
	II	59～98	78～118	59～98	59		
Bending	I	88～147	118～177	74～118	—	20～25	49～59
	II	59～98	78～118	49～78	—		
	III	29～49	39～59	25～39	—		
Shear	I	71～118	94～141	47～94	29	15	15～20
	II	47～78	63～94	31～63	20		
	III	24～39	31～47	16～31	10		
Distortion	I	59～118	88～141	47～94	—		
	II	39～78	59～94	31～63	—		
	III	20～39	29～47	16～31	—		

(Note) In the load column, I is static load, II is repeated load and III is alternating load.

From "Material mechanics basis"

Old unit conversion method 1 MPa =10.1972 kgf/cm²

Schedule 3: Safety factor

Material	Static load	Dynamical load		
		Repeated load	Alternating load	Impact
Cast iron	4	6	10	15
Mild steel	3	5	8	12
Cast steel	3	5	8	15
Copper (soft metal)	5	6	9	15
Wood	7	10	15	20
Brick and stone	20	30	—	—
1300S	5	(10)	(15)	(20)
1300G	5	(10)	(15)	(20)

() is for reference

10-1 Notes for making molds

1) Fully understand the use purpose of molding products and design according to basic steps.

2) Complex mold structure will reduce productivity. Moreover, the time and costs required for repair of mold in case of failure will also be increased.Therefore, simple structure shall be considered first in mold design.

3) The faults in the molding process are mostly molding machine faults and mold faults.The mold faults are mostly concentrated in the sliding block due to complex structure.

10-2 Mold material

The shape and material of the main parts of the mold are described in JIS.

Any kind of steel may be used for molding of LEONA except flame retardant LEONA; the corrosion-resistant and wear-resistant materials are used for molding of flame retardant LEONA; the wear-resistant materials are recommended for GF reinforced LEONA.

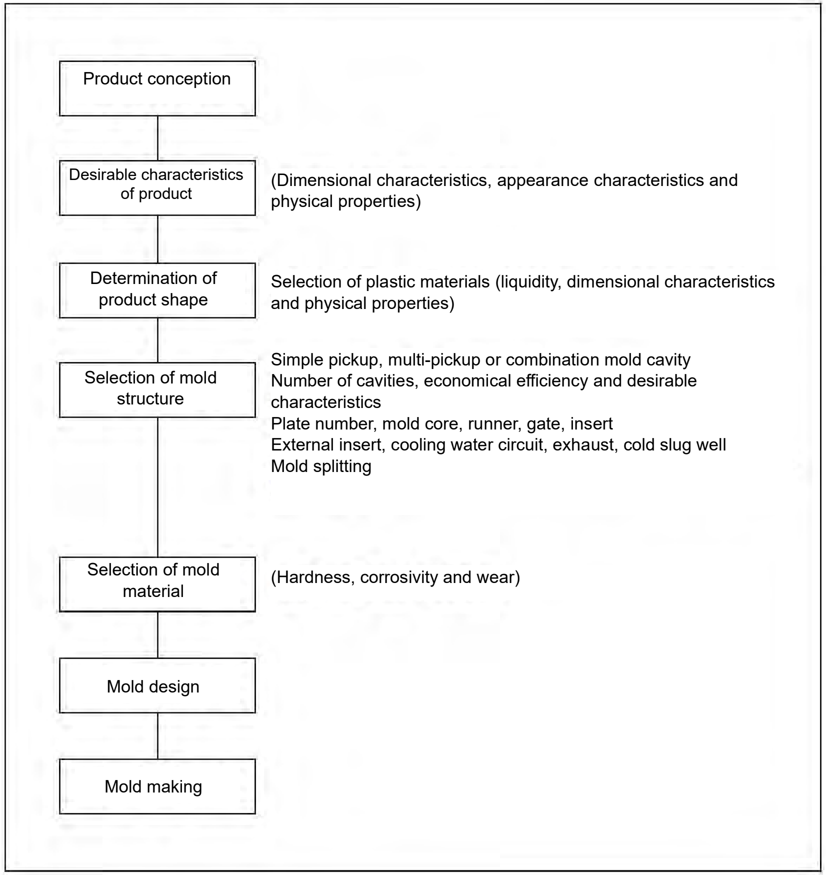
Corrosion-resistant materials: SKD61, SKD11, SUS420 J2 and SUS440C

Wear-resistant materials: SCM440, SKD61 and SKD11

10-3 Mold design

(1) Mold design and making flow

Figure-265 Mold design and making flow



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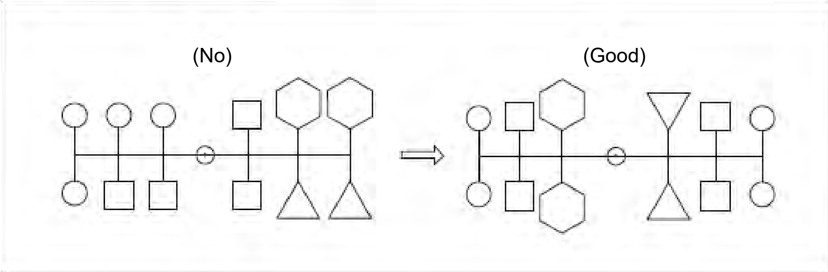
Mold for injection molding
Injection molding technology
Fault cases and countermeasures of molding products

(2) Fetch and arrangement of molding products

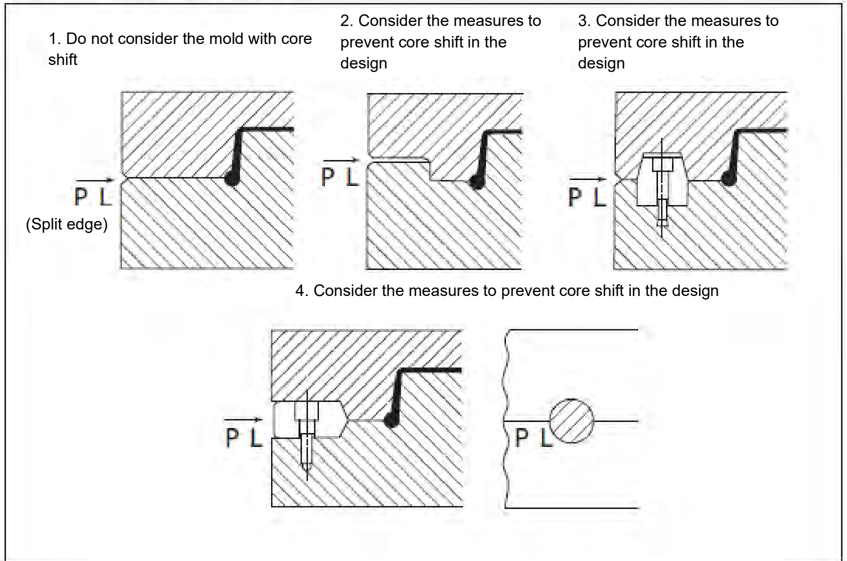
To obtain high-precision molding products, a mold is used to make a kind of molding products and the fetch quantity shall be as small as possible. If more molds are fetched, the cavity configuration shall not be biased to a side.Uneven distribution will result in unbalanced clamping force and trimming.The distance from the main runner to the gate shall be as equal as possible.

Figure-266 Fetch and arrangement of molding products



(3) Countermeasures for prevention of mold core shift

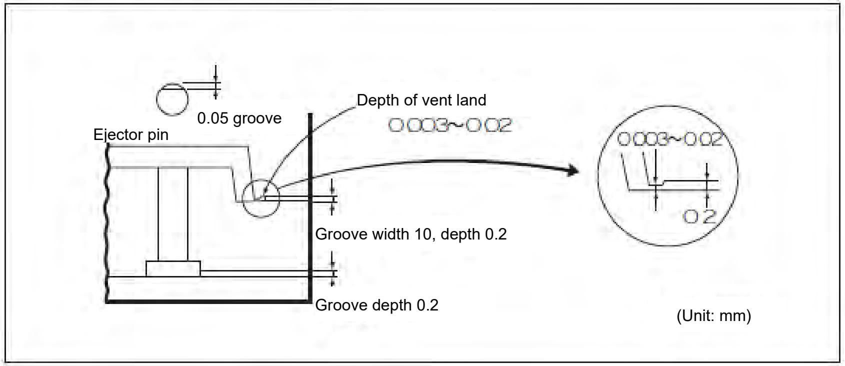
Figure-267 Countermeasures for prevention of mold core shift



(4) Vent hole and exhaust

Generally, the depth of the vent holes (vent groove) is 0.003~0.02mm and the length of the gas vent (vent groove) is about 1.0mm.

Figure-268 Vent hole and degassing

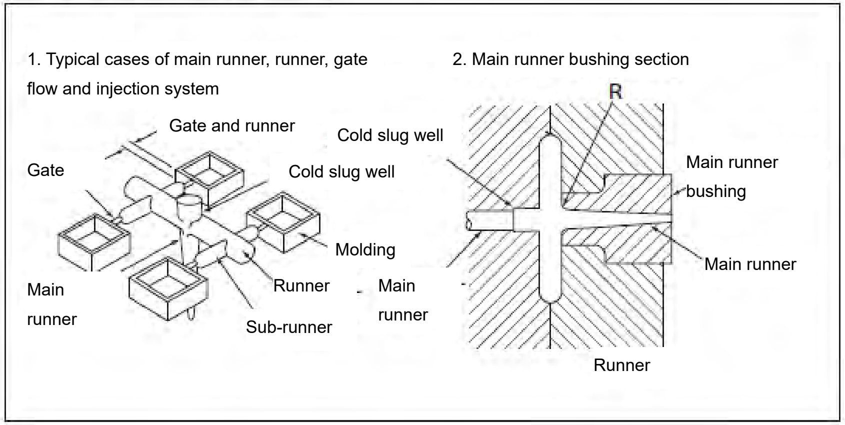


(5) Cold slug well

Reserve the cooled resin at the nozzle.

The depth of the cold slug well is generally 1.5~2 times the diameter.

Figure-269 Cold slug well



(6) Main runner bushing

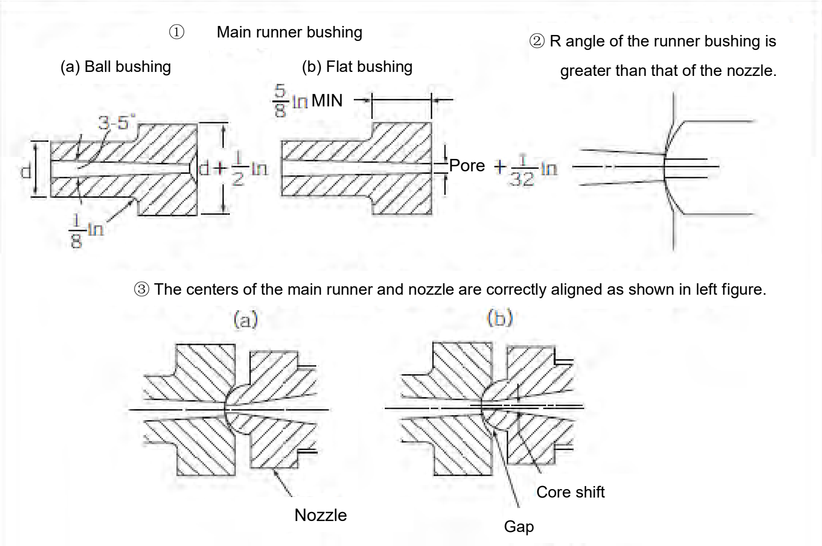
① The ball bushing is used generally.

② R angle of the main runner bushing should be 1mm greater than R angle of the nozzle end.

③ The minor diameter (mouth diameter) is also about 0.5~1mm greater than the nozzle diameter.

④ The length is as short as possible.

Figure-270 Main runner bushing



(7) Cooling water circuit

The mold is generally cooled by warm water and sometimes by high temperature medium (oil).

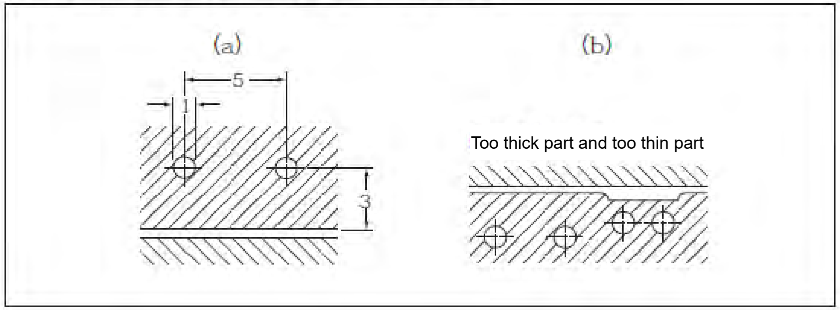
Sometimes, the water may be cooled and the low-temperature water is used.

The position is particularly important when the cooling water circuit is processed in the mold.

The maximum ratio of the cooling water circuit diameter, cooling water circuit spacing and the distance from the cavity surface is 1:5:3.

As shown in (b), a cooling tank may be designed near the cavity to effectively cool the thick part in the product.

Figure-271 Relationship between water circuit diameter, interval and cavity distance



(8) Cooling of narrow mold core

The narrow mold core may be cooled by designing a blind hole in the core center, inserting a duct thinner than the pore diameter in the center and supplying water to the hard duct to cool the overall core (spray pipe method). The method of combined use of the air and water can also be used.

The core is very fine. When the spray pipe cannot be inserted in, the core may be processed by beryllium copper (Be-Cu) with high thermal conductivity and its end is cooled by water.

Figure-272 Cooling water circuit of narrow mold core (1)

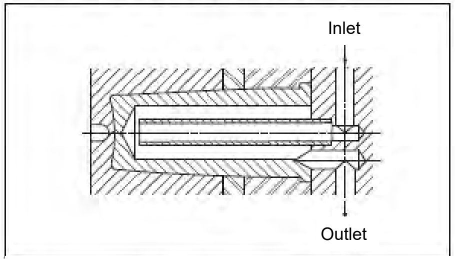


Figure-273 Cooling water channel of narrow mold core (2)

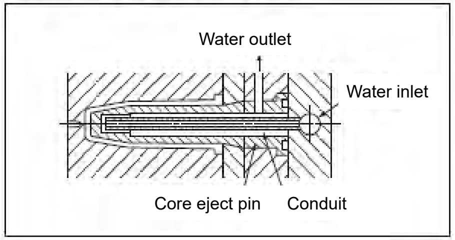


Figure-274 Cooling duct using water and air in the narrow mold core

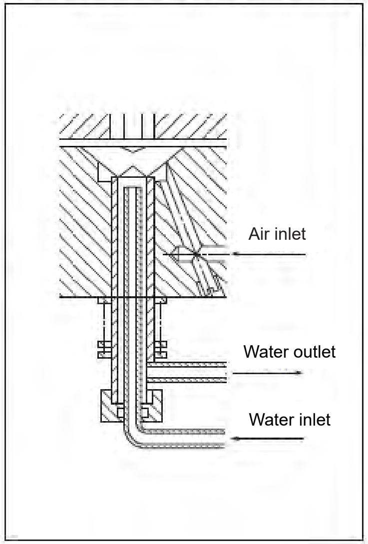


Figure-275 Cooling method of narrow mold core (1)

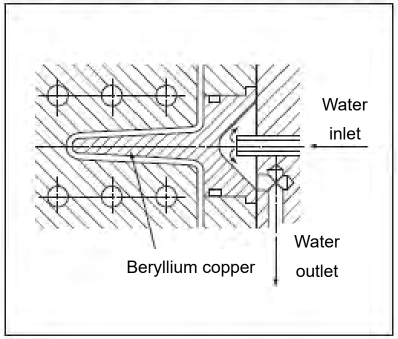
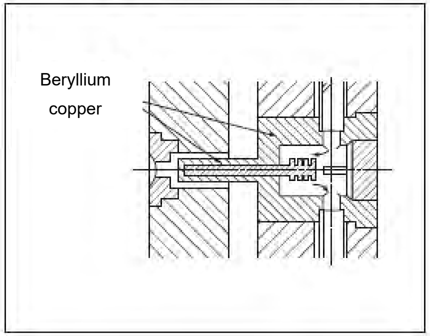


Figure-276 Cooling method of narrow mold core (2)



(9) Runner

The runner is connected by main runner and cavity to melt the resin. The flow resistance shall be minimized and the runner shall be not easy to cool.Therefore, the runner shall be as thick as possible and the section shape is close to proper circle. The molding cycle shall not be affected due to the thickness. The runner shall be not greater than 9.5mm generally.As shown in Figure-277, there are many rubber types and section shapes.

Figure-277 Runner section shape

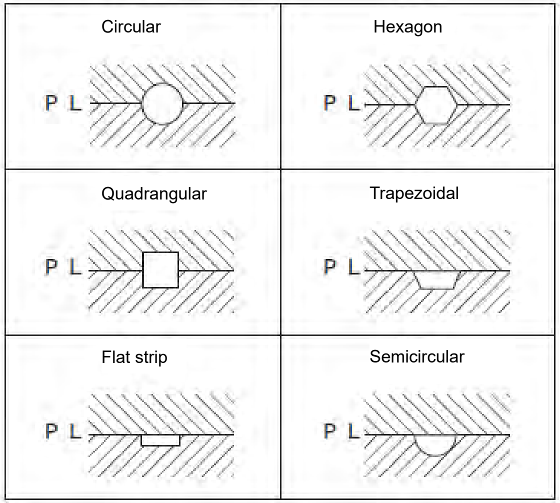
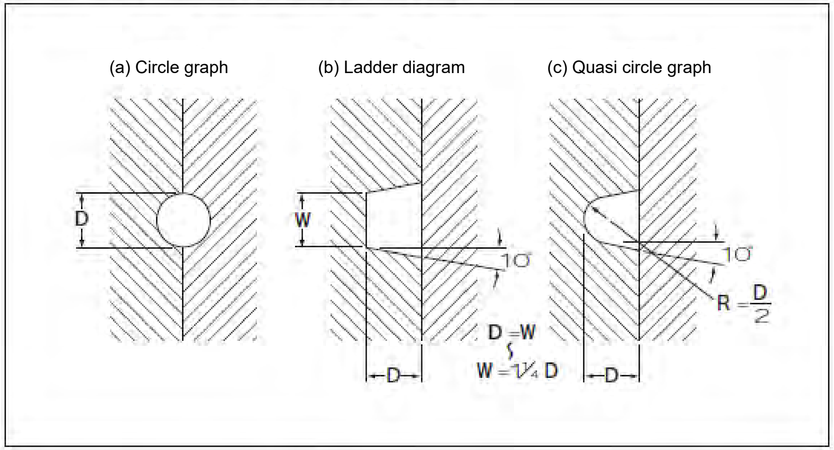
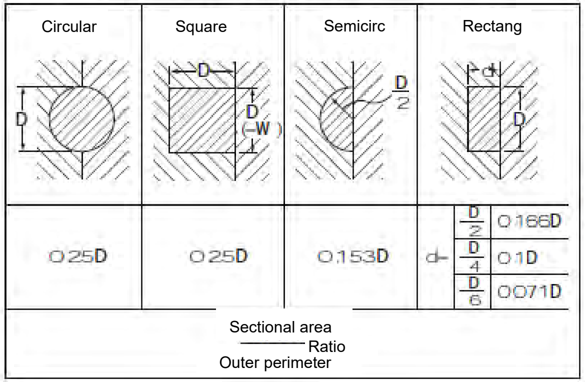


Figure-278 Case of runner section shape and main runner size



The sectional area of the rubber shall be maximum in terms of pressure transmission and the outer perimeter must be minimum in terms of heat transfer surface.The ratio of the sectional area to the outer perimeter is the runner efficiency.The efficiency of the circular and rectangular runners is the same. Since the square is difficult to eject, the trapezoid by about 10° tilt is used actually.

Figure-279 Efficiency of different shapes of runner section



Relationship between runner diameter and length
(Example 1: simple type)

$$D = \frac{\sqrt{W} \times \sqrt[4]{L}}{8}$$

D: Circular runner diameter (in)

W: Molding product weight (oz)

L: Runner length (in)

The usable range of D is 3.2φ~9.5φ

The usable range of W is 7oz

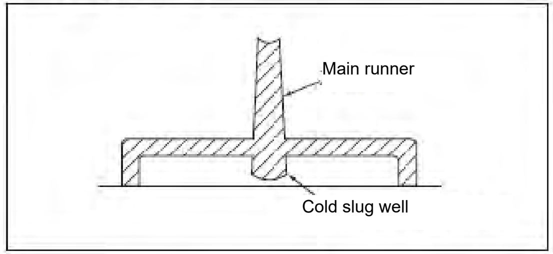
(10) Gate

① Direct gate

This method is to inject resin to the molding project directly through the main runner.

For this gate, a cold slug well is set at the opposite side of the main runner to prevent the cooled and cured resin from flowing into the cavity.

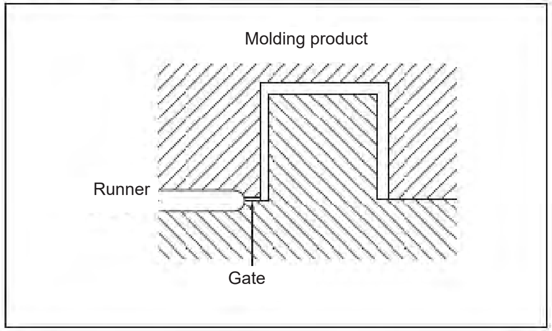
Figure-280 Direct gate



② Common gate (side gate)

Common gate refers to the side gate to inject the resin from the side of the molding product.The common gates are selected according to the resin type or molding product shape.

Figure-281 Common gate



③ Restrictive gate

The structure restricting the gate thickness to rapidly cure the gate is called restrictive gate.Due to large pressure loss, the restrictive gate slot shall be about 0.8~1mm.

④ Lug gate

The injection pressure shall be improved for molding of the resin with poor liquidity, but it will result in stress concentration at the gate, so the lug may be set to relieve the stress.

The lug types include projection behind the local extension of one end of the molding product and an additional lug in the part of the same thickness in the molding product.

Figure-282 Lug gate

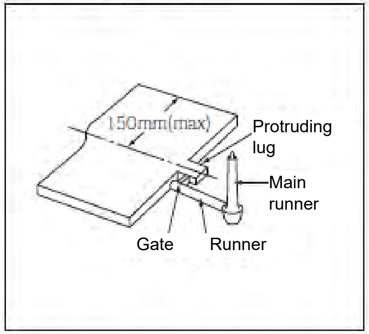
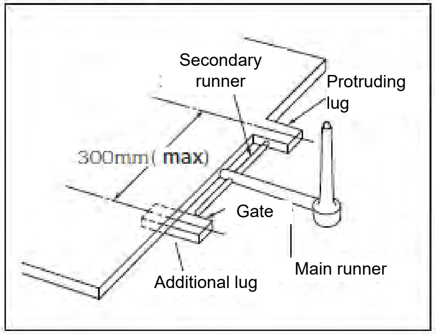


Figure-283 Plural lug gate

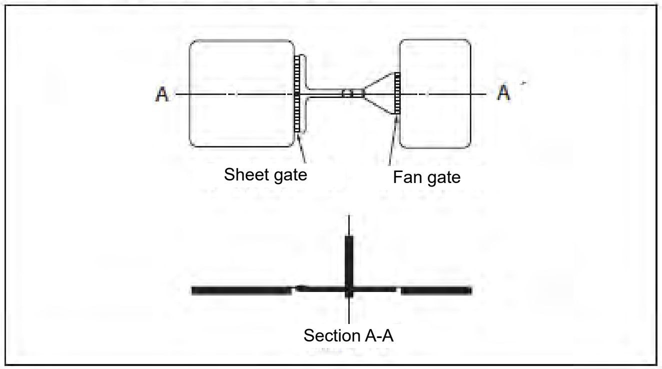


⑤ Flat seam gate and fan gate

For flat molding product with large area, the common gate, if used, is narrow and may result in bubbles and flow lines, so the shallow gate with large area shall be used.

The gate thickness is 0.2~1.0mm and the gate slot length is about 1mm.

Figure-284 Flat seam gate and fan gate



⑥ Ring gate

This gate is used for cylindrical, thin and long molding product.The thickness of the gate is about 0.15~1.5mm.

Figure-285 Ring gate (a)

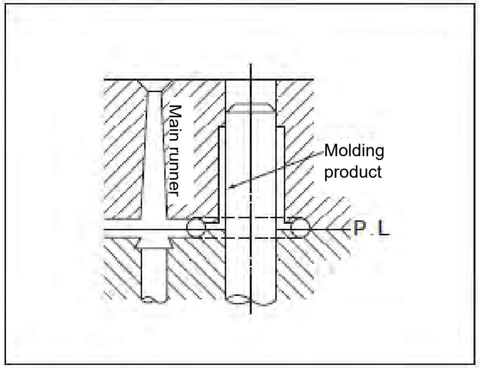
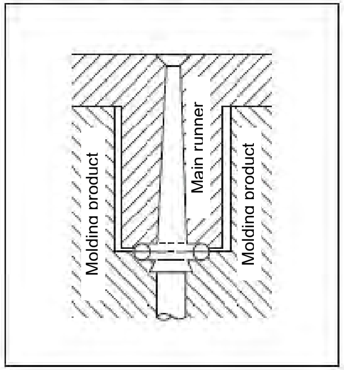


Figure-286 Ring gate (b)



⑦ Diaphragm gate

The diaphragm gate is used when there is a hole greater than the main runner diameter near the center of the discoidal molding product.The thickness of the gate is about 0.2~1.2mm generally.

Figure-287 Diaphragm gate (a)

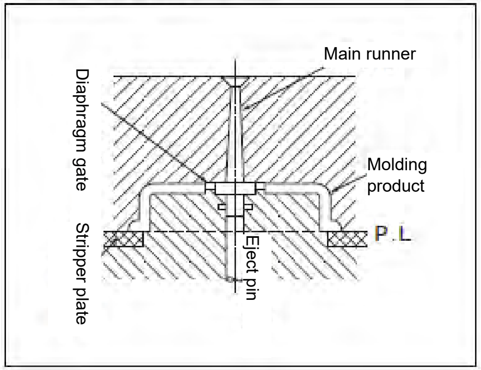
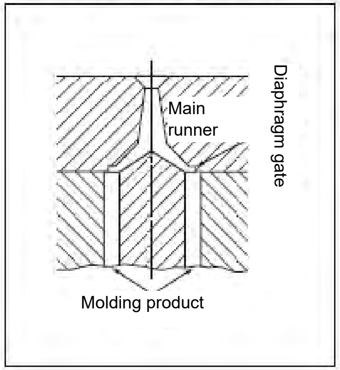


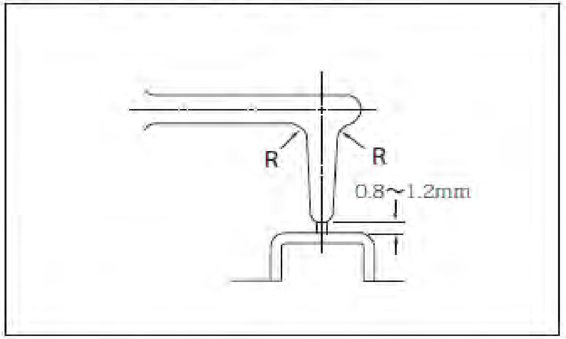
Figure-288 Diaphragm gate (b)



⑧ Pin-point gate

High injection molding pressure is required for the gate with small sectional area. To minimize the pressure loss, the gate slot shall be controlled at about 0.8~1.2mm.To reduce the flow resistance in the runner cross section, R angle is processed.The gate diameter varies with the molding product size and resin liquidity and is generally about 0.3~1.2mmφ.

Figure-289 Pin-point gate groove face



⑨ Submarine gate (tunnel gate)

Relative to common gates located in the parting surface, only the groove face of the submarine gate is located in the parting surface, and the gate submerges in the fixed mold or movable mold and enters the cavity.Therefore, the gate will be broken in mold opening.The gate may be also set in the surface, side, end face and internal surface.

Figure-290 Use case of submarine gate

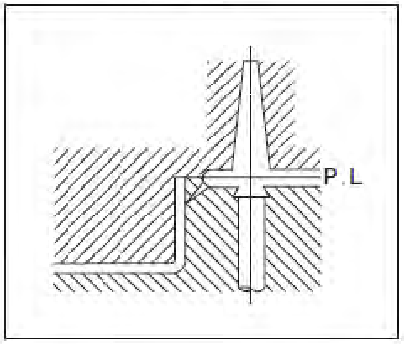
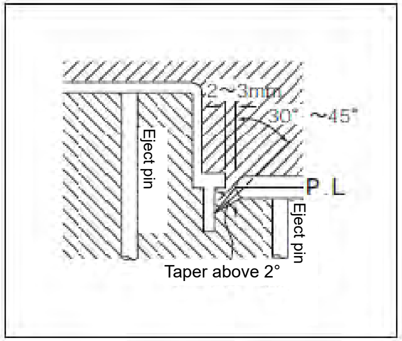


Figure-291 Submarine gate dimension figure



11-1 Injection molding machine selection

(1) Molding machine type

The coaxial reciprocating screw type injection molding machine is ideal.

Reasons:

1) It can be uniformly plasticizing.

2) The material retention position is small, so there is no risk of decomposition.

3) Easy and simple material replacement and color replacement

.

The horizontal type molding machine is favorable in terms of automatic molding and the vertical type molding machine is favorable in terms of insert molding and external insert molding.

(2) Molding machine size

The size of the molding machine that can achieve operation in 30~70% capability interval in terms of clamping force and plasticizing capacity is ideal.

(3) Nozzle

An open-type nozzle and common needle nozzle

11-2 Screw selection

(1) Screw type

The screw for engineering plastics or nylon is recommended.

(The full thread type is ideal and the double thread is also used.)

(2) Screw length

It is ideal that the screwed nail is 18~22 times the diameter.

(3) Screw compression ratio

The compression ratio is 2.5~3.5 (quick compression).

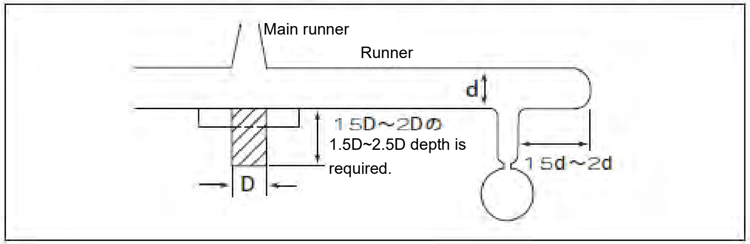
(4) Check valve

A check valve is installed at the head of the screw.

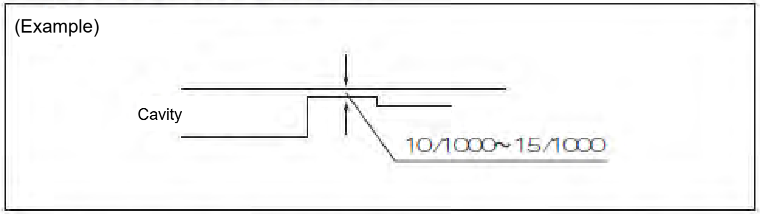
11-3 Mold selection

(1) Mold design

1) As shown below, the cold slug well in the front of the main runner shall be set long.



2) The gas vent must be set at the end of flow.



3) The gate shall be adjusted to be balanced to prevent short shot and trimming when a number of molds are taken.

The runner and gate shall be designed short and thick to reduce pressure loss.

4) The nylon resin is of low melt viscosity, the hard steel as follows shall be selected for the mold to resolve the trimming problems.

・Use corrosion-resistant and wear-resistant material (such as SUS) for flame retardant grade.

Mold material

Note that the corrosion or wear types may exist depending on the grade.

Unreinforced level: the die steel stipulated in JIS can be used.

Reinforced level of glass fiber: Wear-resistant materials [SCM440, SKD61 and SKD11]

Unreinforced flame retardant grade: corrosion-resistant materials [SKD61, SKD11, SUS420 J2 and SUS440C]

Reinforced flame retardant level of glass fiber: Wear-resistant materials [SCM440, SKD61 and SKD11]

Corrosion-resistant materials [SKD61, SKD11, SUS420 J2 and SUS440C]

5) Other

• The gate shall be set in the thick part of the product in principle.

• The surface of the main runner and the runner shall be ground to ensure smoothness, so that the resin can flow smoothly.

(2) Dimensional tolerance of mold

The shrinkage rate of the molding products varies with the grade.

(3) Gate

Generally, the common gates include site gate, pin-point gate and tunnel gate.

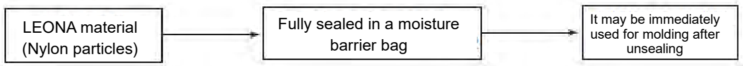
11-4 Instructions for LEONA material

(1) Drying of LEONA particles

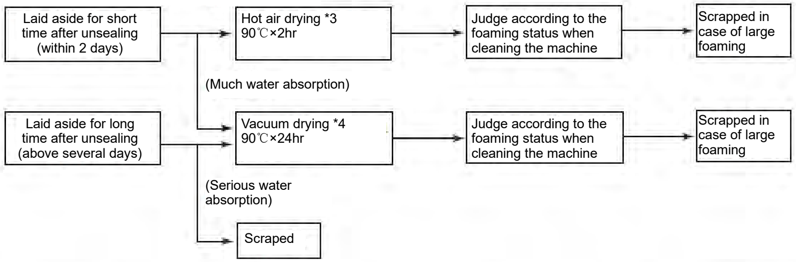
LEONA has sealed package and shall be immediately used without drying treatment after unpacking.However, LEONA will also absorb water like other nylon resins. The nylon particles may absorb water some time after unpacking (varying with the environmental conditions and based on about 3hr at 20℃and 65%RH) and may result in crazing if they are directly used for molding.To prevent above problem, the particles shall be saved in the sealed metal container with rubber blanket or pre-dried before molding.

The materials are distinguished as follows:

1) Recently unsealed material



Unsealed material (refer to Figure-292 and 293)



(Note) *1. Varying with the environmental conditions and based on about 3hr at 20℃and 65%RH

*2. The water absorption degree is different depending on the level.

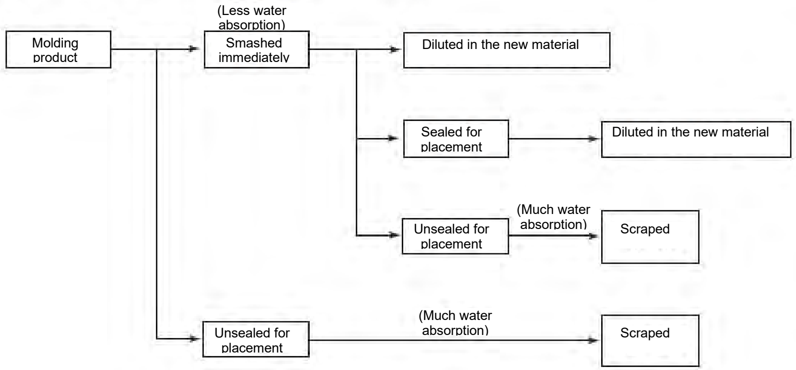
*3. The material may be discolored (yellow brown) after drying for above 3hr.(Refer to Figure 294)

*4. Compared with hot air drying, the vacuum drying is not easy to result in particle discoloring.

3) Feed back

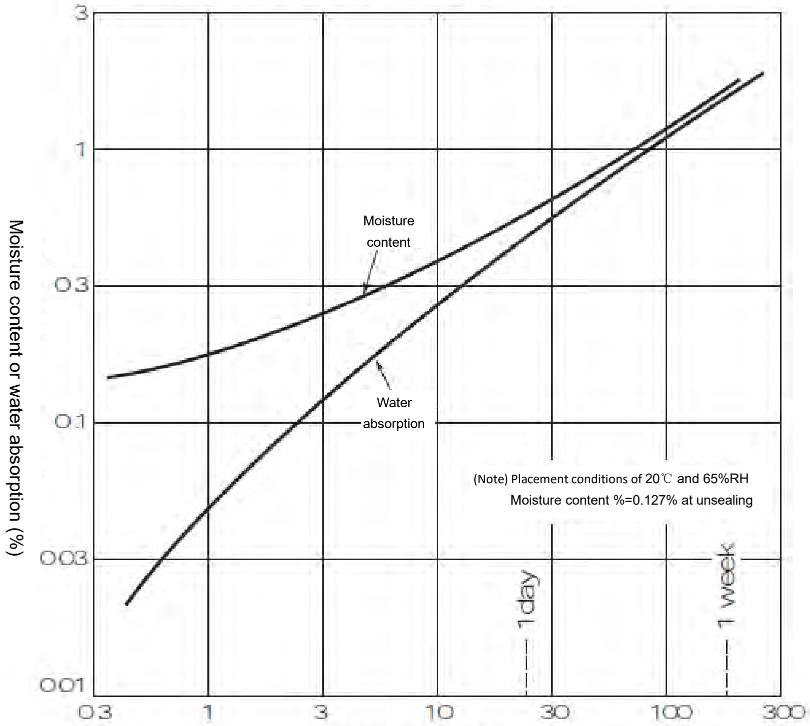
The material in the main runner and runner shall be smashed directly in feed back and used on the same day or next day.But the mixing ratio of the reclaimed materials must be below 25% in UL746 D.

The materials must be sealed and saved if not used immediately.



Large fed-back smashed particles will result in instable plasticizing and molding problems, so large particles shall be smashed to the equal degree with initial particles.

Figure-292 Water absorption of LEONA 1300S nylon particles



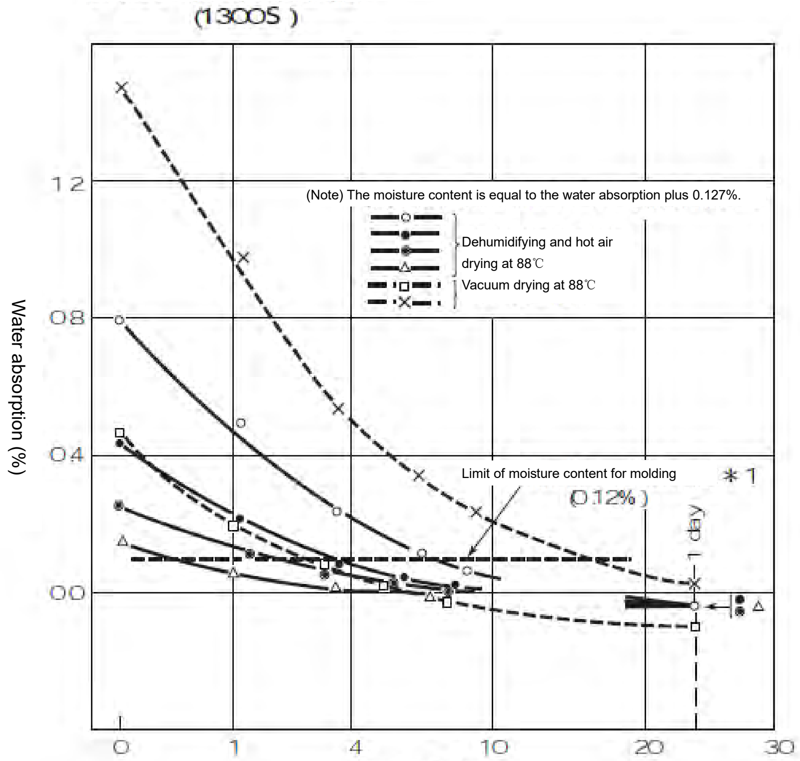
Water absorption: moisture rate of water absorbed by particles after unsealing

Moisture content: total moisture rate owned by particles

In this case, the moisture content at unsealing is 0.127%

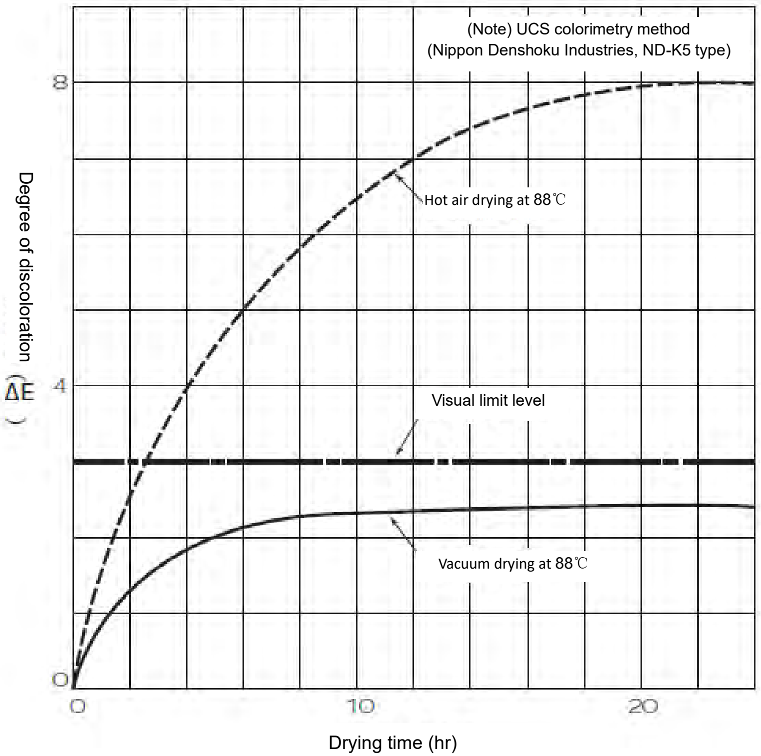
Then moisture content = 0.127 + water absorption

Figure-293 Moisture content and drying time



*1. Vary with the level.

Figure-294 Degree of discoloration and drying conditions



(Note) This case is for 1300S.

The degree of discoloration varies with the level.

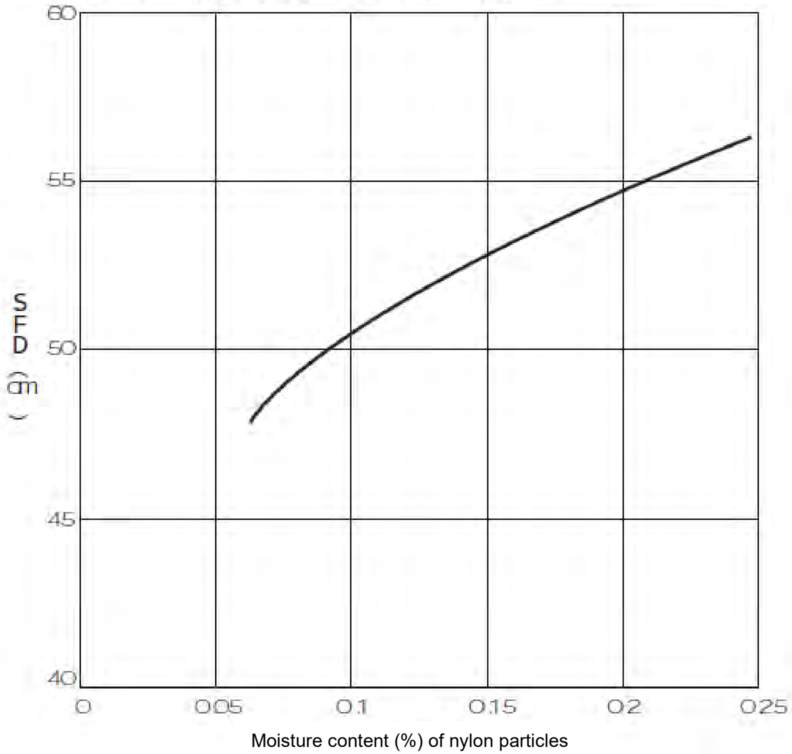
(2) Storage methods of LEONA particles

- Overlap the inside and outside of two polythene bags (about 100μ thick), bundle and seal the inner and outer bags.The moisture content is about 0.02% 10 days after storage by this method.
- Seal LEONA bag with a heat sealing machine for film,so that the bag has the same role with original bag of LEONA and the storage life is unlimited.
- The opening of the unsealed packaging bag is sealed by adhesive tape. The effect is poor in the summer.

(3) Liquidity changes caused by moisture content

The viscosity and liquidity of LEONA are changed after water absorption.

Figure-295 Viscosity and liquidity changes of nylon particles before molding



(4) Changes of physical properties caused by regeneration

The physical properties of unreinforced level (1300S) will not decline generally after regeneration, but the strength of the reinforced level of glass fiber (1300G) will decline due to glass fiber fracture.

Figure-296 Regeneration characteristics of 1300S

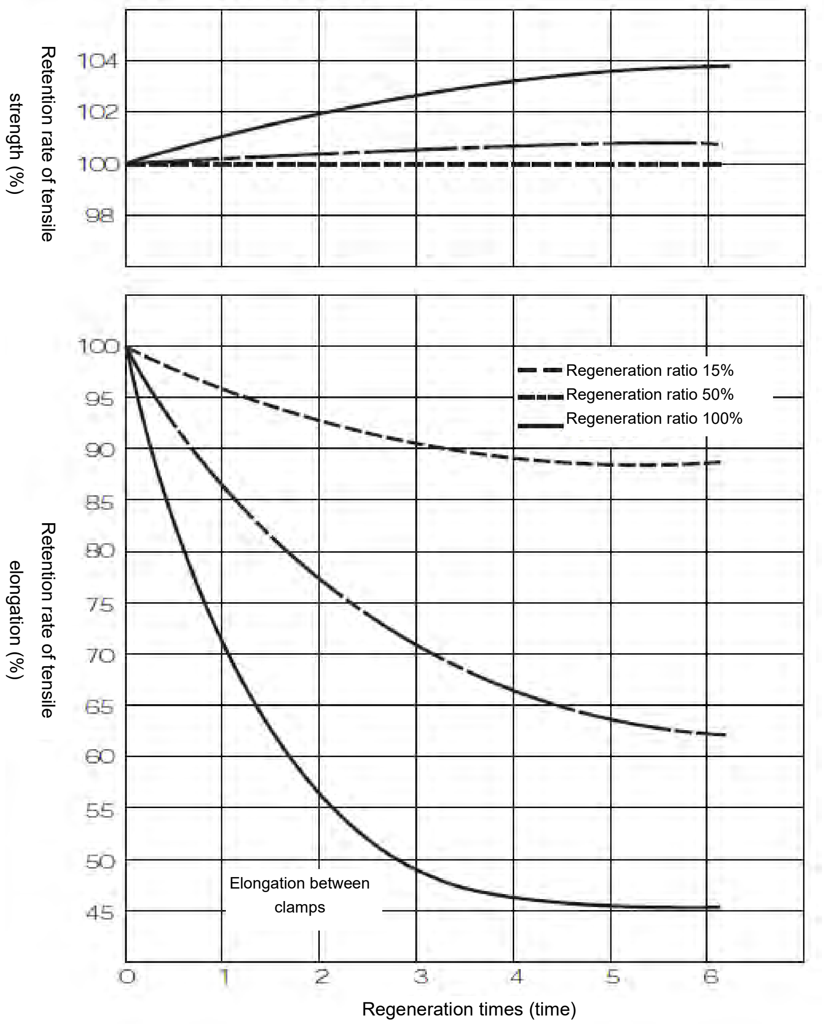


Figure-297 Regeneration characteristics of 1300G

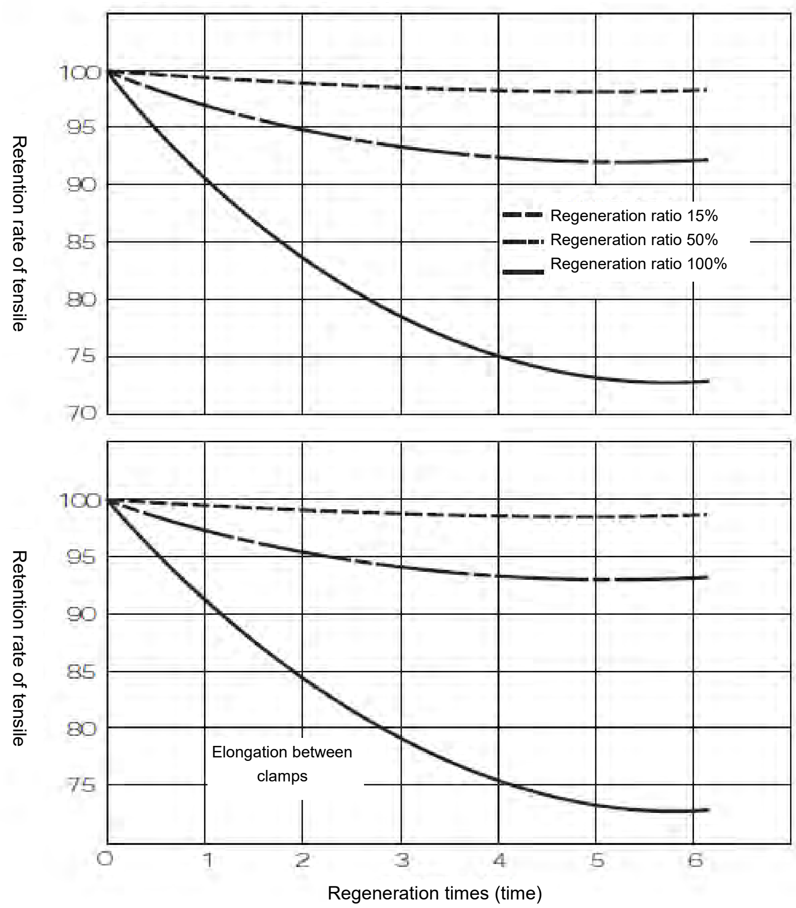


Figure-298 Regeneration characteristics of FR370 (regeneration ratio 100%)

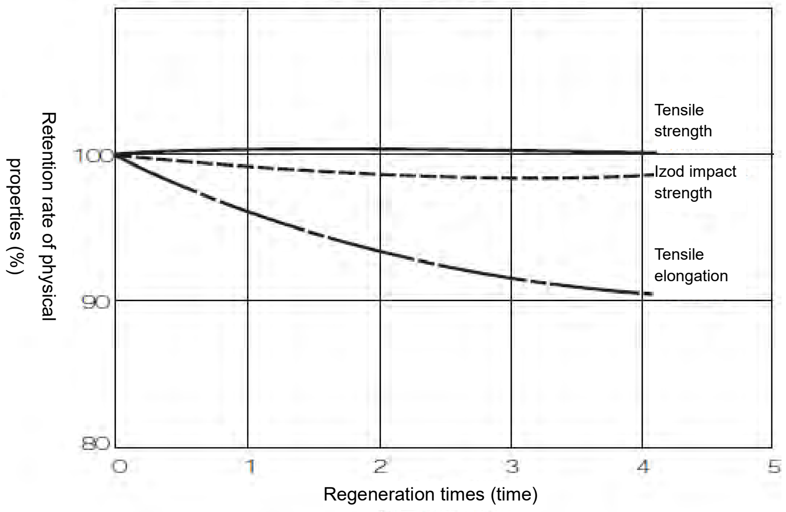
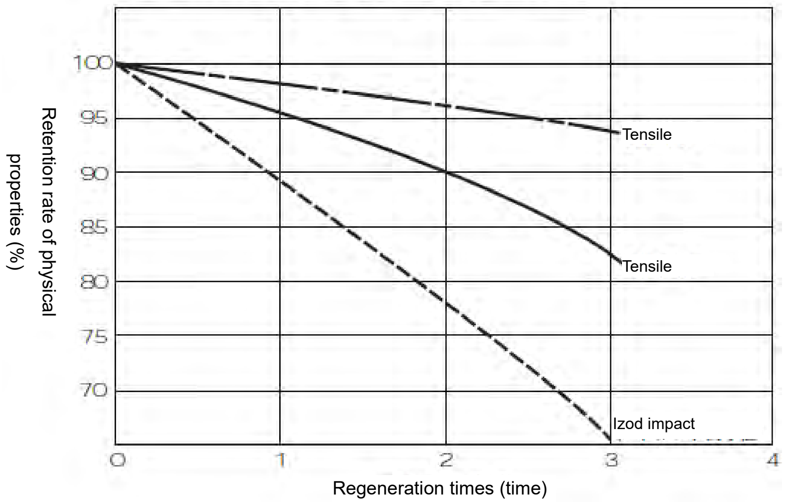


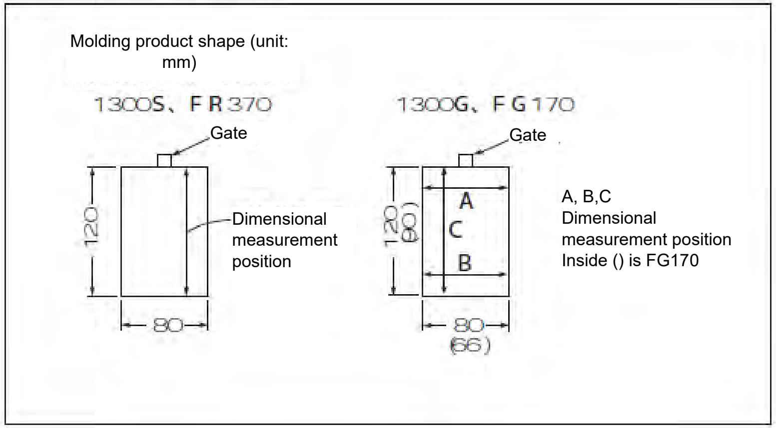
Figure-299 Regeneration characteristics of FG170 (regeneration ratio 100%)



(5) Molding shrinkage rate

Generally, the molding shrinkage rate will vary with the molding product thickness, mold temperature, injection molding pressure and other molding conditions.It shall be noted that the molding shrinkage rate of the glass fiber reinforced level 1300G and FG170 is anisotropic.

Molding product shape and dimensional measurement position



1) Thickness dependency

Figure-300 Dependency of molding shrinkage rate on product thickness

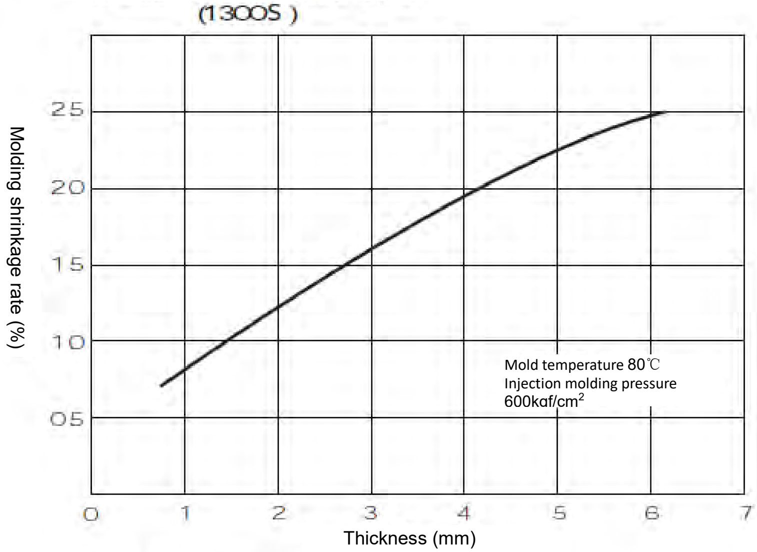


Figure-301 Dependency of molding shrinkage rate on product thickness

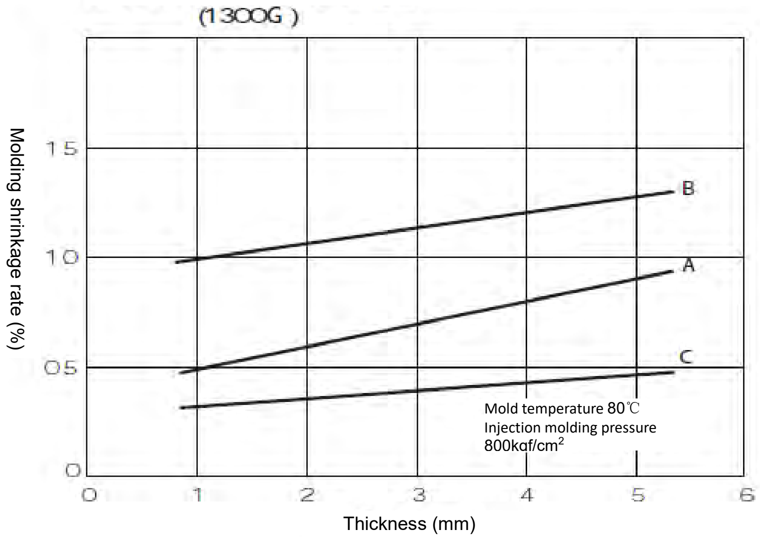


Figure-304 Dependency of molding shrinkage rate on product thickness

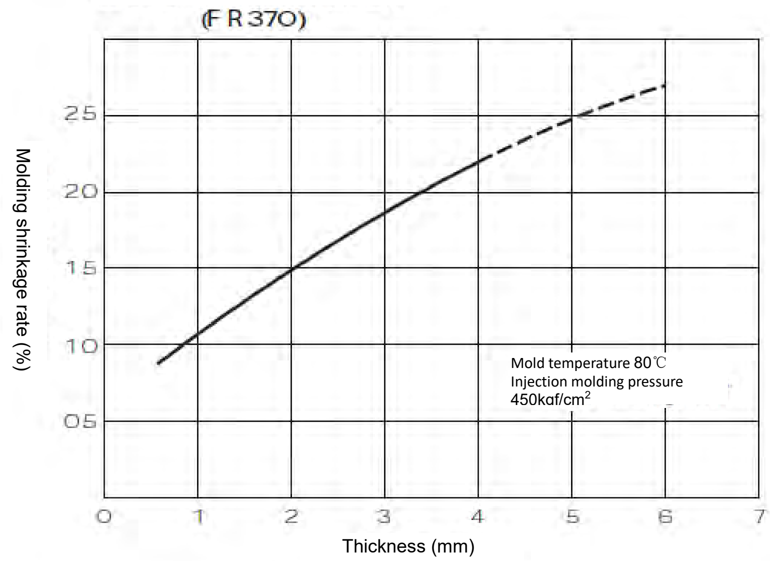
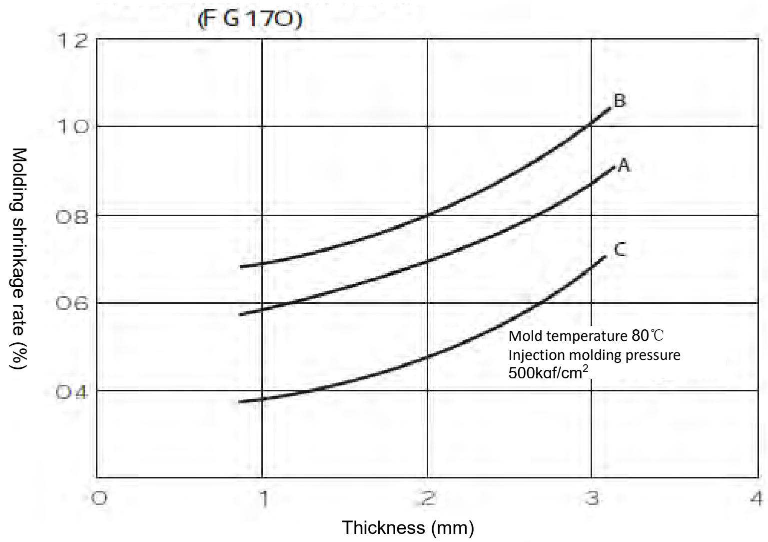


Figure-303 Dependency of molding shrinkage rate on product thickness



2) Mold temperature dependency

Figure-304 Dependency of molding shrinkage rate on product thickness

(1300S)

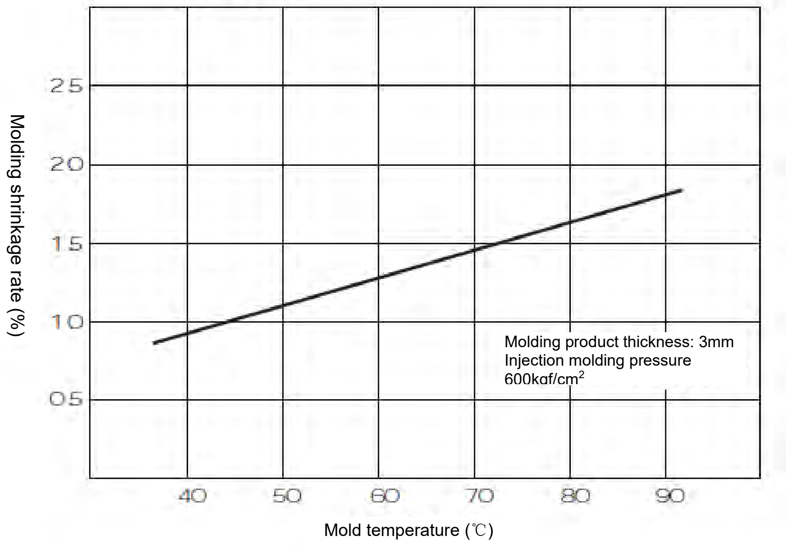


Figure-305 Dependency of molding shrinkage rate on product thickness

(FR370)

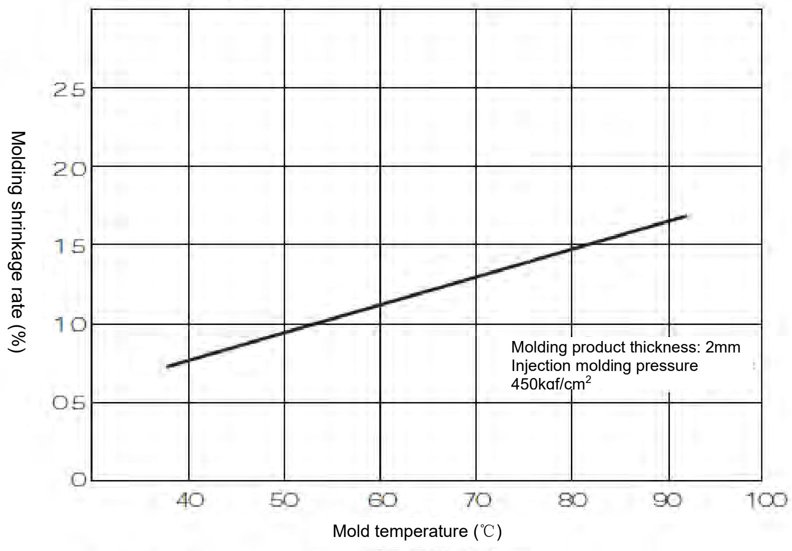
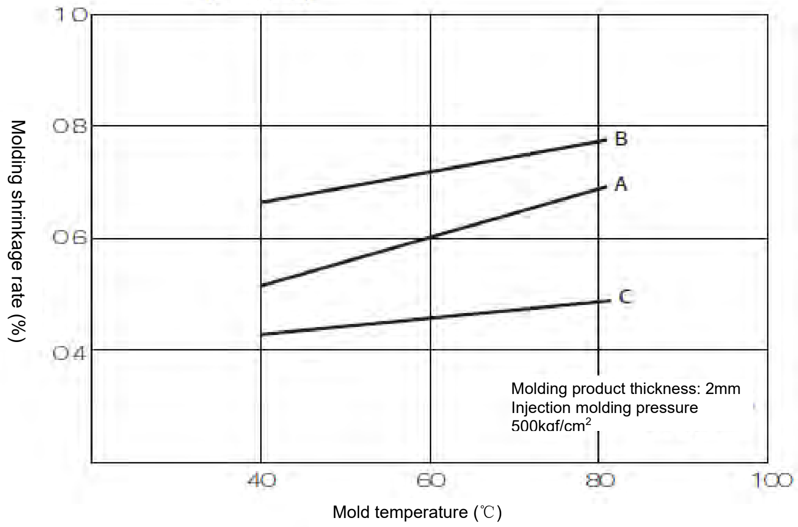


Figure-306 Dependency of molding shrinkage rate on product thickness

(FG170)



3) Injection molding pressure dependency

Figure-307 Dependency of molding shrinkage rate on injection molding pressure

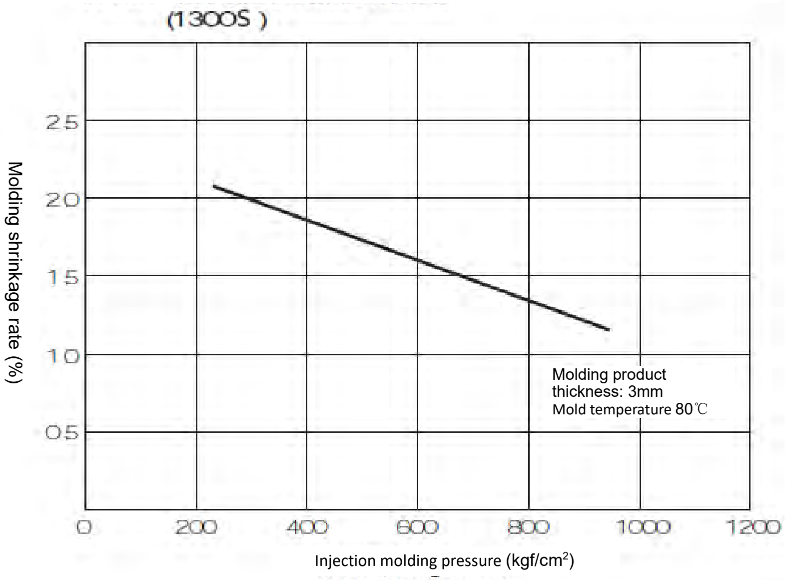


Figure-308 Dependency of molding shrinkage rate on injection molding pressure

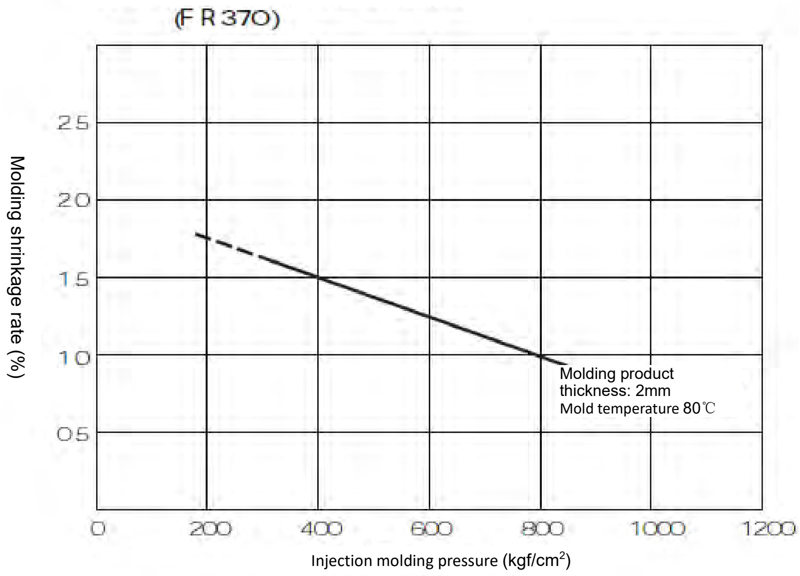
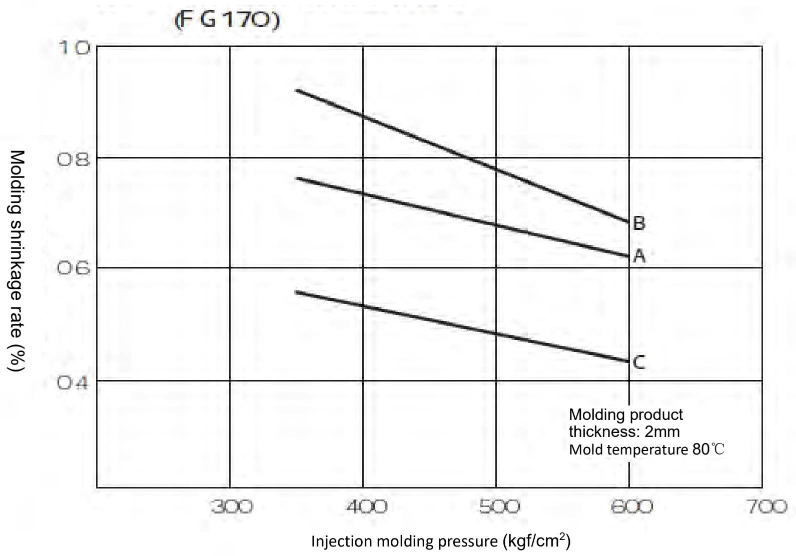


Figure-309 Dependency of molding shrinkage rate on injection molding pressure



(6) Liquidity

The spiral flow mold for measurement is shown below:

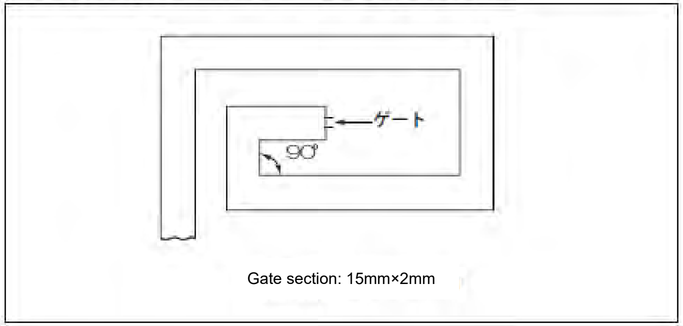
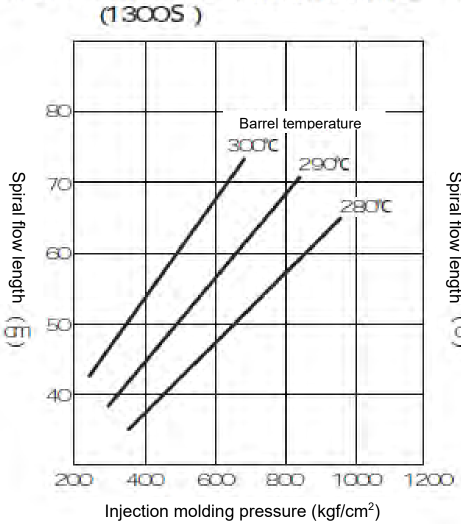
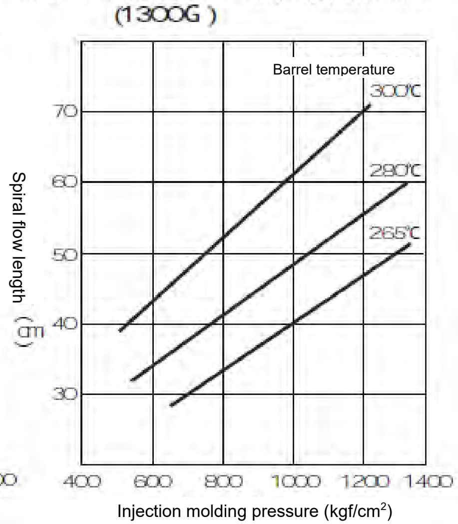


Figure-310 Dependency of liquidity on molding temperature and injection molding pressure



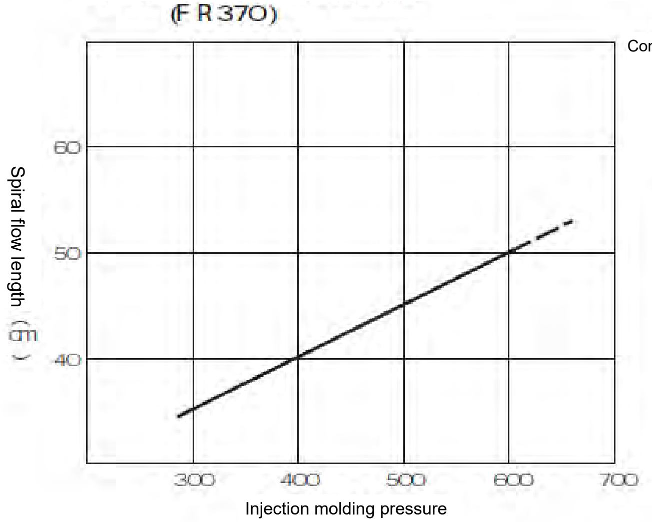
Conditions
- Mold temperature: 80℃
- Gate section: 4mm×2mm

Figure-311 Dependency of liquidity on molding temperature and injection molding pressure



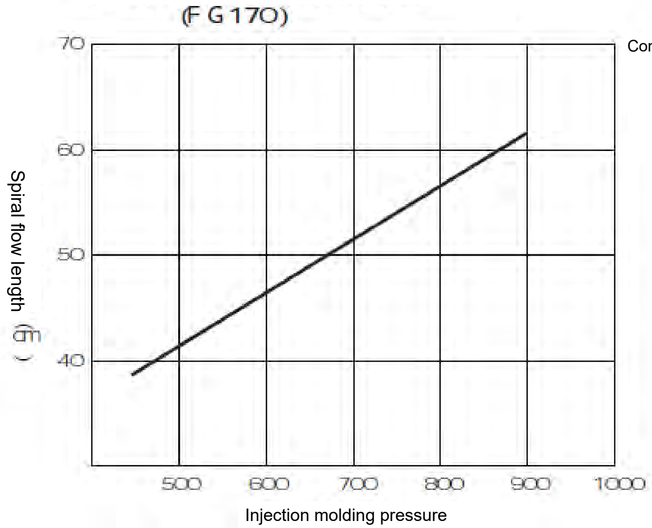
Conditions
- Mold temperature: 80℃
- Gate section: 2mm×2mm

Figure-312 Dependency of liquidity on injection molding pressure



Conditions
- Resin temperature: 265℃
- Mold temperature 80℃
- Gate section: 2 mm×2 mm

Figure-313 Dependency of liquidity on injection molding pressure



Conditions
- Resin temperature: 275℃
- Mold temperature 80℃
- Gate section: 4 mm×2 mm

11-5 Prevention of scorches and dark spots and injection molding conditions

(1) Prevention and removal of scorches and dark spots in molding machine

The mold problems and molding problems result in molding interrupt sometimes in LEONA molding process.The molding machine shall be turned off at the end of molding.It is difficult to eliminate the scorches and inferior substances (dark brown gel and black spots) caused by operation error and restart during and after molding.The nylon resin may be oxidized, degraded and gelated sometimes in the molding machine barrel due to heat and oxygen and form dark brown gel and black spots.So the following shall be noted:

1) Short-time shutdown and restart methods

◆ Fitness

Mold replacement and other circumstances within 1h after molding stop

◆ Shutdown operation

① Fully circulate the hopper cooling water.

* Cool the lower part of the hopper to the degree that can be touched with bare hands.(Touch with bare hands with caution.)

② Set the barrel temperature to about 250℃.

③ Turn off the molding machine when the hopper and the barrel are filled with resin.

* Cleaning results in hopper and barrel voidance, air involvement and formation of inferior substances (dark brown gel and black spots).

◆ Restart operation

① Recover the hopper cooling water volume and barrel temperature to original set values.

② Do not set back pressure. Maximize the plasticization stroke and plasticize and clean the LEONA material to be molded.

* Plasticize and clean repeatedly until there are no black spots in the cleaning substances.

(Clean at least 5 times)

③ Return the back pressure and plasticization stroke to the setting conditions and start molding,

* The products from the 30th batch to the 50th batch after start of molding may not be used due to instable conditions.

(Remark)

Shut down under the setting conditions within extremely short time (5min) and start molding directly after restart.But the products from several batches to the 20th batch after start of molding may not be used.

2) Long-term shutdown and restart methods

◆ Fitness

Molding machine shutdown for more than 1hr.

◆ Shutdown operation

① Do not apply back pressure. Minimize the plasticization stroke and implement plasticizing and cleaning by PE (SANTEC HD J-240).

* Purify at least five times.

② Turn off the heater when the charging barrel is filled with PE

◆ Restart operation

① Set the barrel temperature and open the heater.

② Do not set back pressure. Maximize the plasticization stroke and plasticize and clean with PE.

* Plasticize and purify repeatedly until there are no black spots in the cleaning substances.

③ Plasticize and clean the LEONA material to be molded.

* Switch from PE to LEONA material continuously and do not make the charging barrel empty.

* Plasticize and clean repeatedly until LEONA material ejected from the nozzle is fully transparent.

④ Return the back pressure and plasticization stroke to the setting conditions and start molding.

* The products from the 30th batch to the 50th batch after start of molding may not be used due to instable conditions.

(Short cut method)

◆ Shutdown operation

Stop molding when the charging barrel is filled with LEONA material under molding.Keep circulating the hopper cooling water.

◆ Restart operation

① Set the barrel temperature and open the heater.

③ Implement plasticizing and cleaning in above ③ and set ④ conditions through LEONA material for molding from the start and then start molding.

3) Removal method of inferior substances (dark brown gel and black spots) in barrel

◆ Fitness

A lot of cracking matters (dark brown gel and black spots) due to empty charging barrel by cleaning cannot be removed by general cleaning procedures.

(Method-1)

② Set the barrel temperature.

② Do not set back pressure. Maximize the plasticization stroke and plasticize and clean with ASACLEAN EG (cleaning agent for molding machine, or LEONA1300G).

* Operate repeatedly until no cracking matters are mixed.

③ Implement plasticizing and cleaning with PE (SANTEC HD J240).

* Switch from ASACLEAN to PE continuously and avoid empty barrel.

* Clean repeatedly until PE injected from the nozzle is transparent.

④ Then plasticize and clean with LEONA material to be molded.

* Switch from PE to LEONA material continuously and do not make the barrel empty.

*   Plasticize and clean repeatedly until LEONA material ejected from the nozzle is fully transparent

.

⑤ Return the back pressure and plasticization stroke to the setting conditions and start molding,

* The products from the 30th batch to the 50th batch after start of molding may not be used due to instable conditions.

(Method-2): When the cracking matters (black spots) cannot be removed through method-1.

① Set the barrel temperature to 300℃.

* Set the temperature in the rear of the charging barrel according to the setting conditions.

② Do not set back pressure. Maximize the plasticization stroke and plasticize and clean with ASACLEAN (cleaning agent for molding machine,or LEONA1300G).

Reduce the temperature to 250 ℃ while plasticizing and cleaning.

* Reduce the barrel temperature to the reachable minimum temperature if it cannot be reduced to 250℃ due to shear heat.

* The cleaning effect is better if the back pressure is applied and changed at any time.

③ Then increase the barrel temperature to 300℃ while plasticizing and cleaning with PE.

④ Then plasticize and clean with the LEONA material to be molded while reducing the barrel temperature to the set temperature.

*   Plasticize and clean repeatedly until LEONA material ejected from the nozzle is fully transparent.

③ Return the back pressure and plasticization stroke to the setting conditions and start molding.

* The products from the 30th batch to the 50th batch after start of molding may not be used due to instable conditions.

(Remark)

a) Perform ② to ⑤ continuously and do not make the barrel empty.

b) Set the barrel temperature to about 270℃ when unplugging the screw from the charging barrel and then clean with ASACLEAN cleaning agent.

(2) Other precautions for molding conditions

1) Injection speed: medium speed or a little fast.

2) Injection time: set the gate confinement time to ＋1～2sec.

3) Screw speed: It will be changed depending on the molding machine size and shall be as slow as possible.

Example: 100t molding machine: 80~120rpm

40t molding machine: 150~200rpm

4) Sucking back...amount not generating salivation.

Low melt viscosity of LEONA will result in salivation, so sucking back is required.

It is generally 2~3mm and excessive sucking back will result in discoloring and scorch.

5) Back pressure

To avoid uneven melting, 0~25kgf/cm² back pressure is generally applied.

To eliminate color spots in the use of color master batch, 50kgf/cm² back pressure shall ve applied.

—

(2) Standard table of molding conditions

Class		Unreinforced	Unreinforced/fire retardant		GF reinforced/fire retardant
Level		1300S 1302S 1402S 1500 1502(S) 1700S 1702 9400S	FR200	FR370	FG170 FG172 FG171 FG173
Pre-drying	Temperature (℃)	80～90	80～90	80～90	80～90
	Time (HR)	2~3	2~3	2~3	2~3
Molding conditions	Resin temperature (℃)	270～290	250～260	265～275	270～280
	Mold temperature (℃)	75～85	75～85	75～85	75～85

Class		GF reinforced	GF reinforced/special PA66	Impact-resistant and GF reinforced	Special and composite
Level		13G15 14G15 1300G 1402G 13G43 13G25 14G25 14G33 14G43 13G50 14G50	90G33 90G50 90G55 90G60 91G40 91G55 91G60	TR161 TR382 53G33 54G33 54G43 93G33	CR101 CR301 CR302 MR001 1330G
Pre-drying	Temperature (℃)	80～90	80～90	80～90	80～90
	Time (HR)	2~3	2~3	2~3	2~3
Molding conditions	Resin temperature (℃)	275～295	275～295	270～290	275～295
	Mold temperature (℃)	75～85	85～95	75～85	75～85

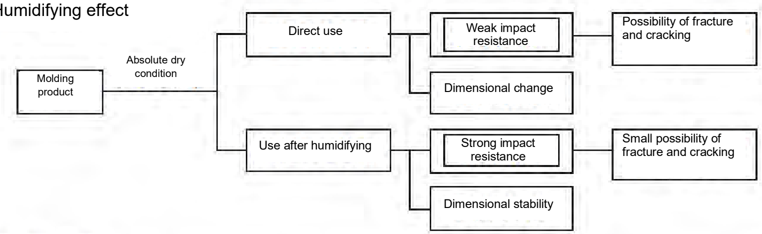
Other precautions	1. The pre-drying condition is the hot air drying condition.Please note that the material will be discolored sometimes after long-time drying at high temperature. The sealed new material may be directly used without drying after unsealingand shall be used up within 3hr after unsealing. If the material is affected with much damp, vacuum drying (90℃, 24hr) is recommended. 2. The mold temperature of LEONA90G series is a little higher than that of general nylon 66 (recommended temperature 90℃).

11-6 Humidifying method and annealing heat treatment method of LEONA injection molding products

(1) Humidifying method of LEONA injection molding products

The water absorption of LEONA is as large as other nylon resins. When the molding products are placed in the atmosphere, the water absorption is different depending on the level. The maximum water absorption of unreinforced standard level is about 2.5% and the maximum water absorption of LEONA placed in the water is 8%.Water absorption results in changes of physical properties, especially rigidity and dimensions. In terms of rigidity, the rigidity is reduced and the impact resistance is improved; in terms of dimensions, the dimensional change is small and the dimensions start to be stable after absorption of certain water.The molding product just after molding does not contain moisture basically and is in dry condition.(It is called absolute dry condition). In this case, the softness is slightly insufficient and the impact resistance is weak, resulting in break sometimes.To prevent these problems, humidifying shall be implemented to forcibly absorb water, so as to keep softness of molding product.

1) Humidifying effect



2) Humidifying methods

Humidifying methods include steam fumigation method and water impregnation method, in which, the former is commonly used.Please select according to the needs.

The water absorption curve of LEONA is very important during humidifying and is introduced in detail in the water absorption part of LEONA.

① Application method of humidifying machine (steam fumigation method)

Use a constant temperature humidity chamber to control the temperature (generally 60~100℃) and humidity (generally 90~100%).

② Water impregnation method

Water impregnation method is the most efficient method and the hot water (generally 60~95℃) is more effective.

③ Short cut method

Put the molding products in a sealed plastic bag and plastic container, inject the stipulated amount of water and seal.

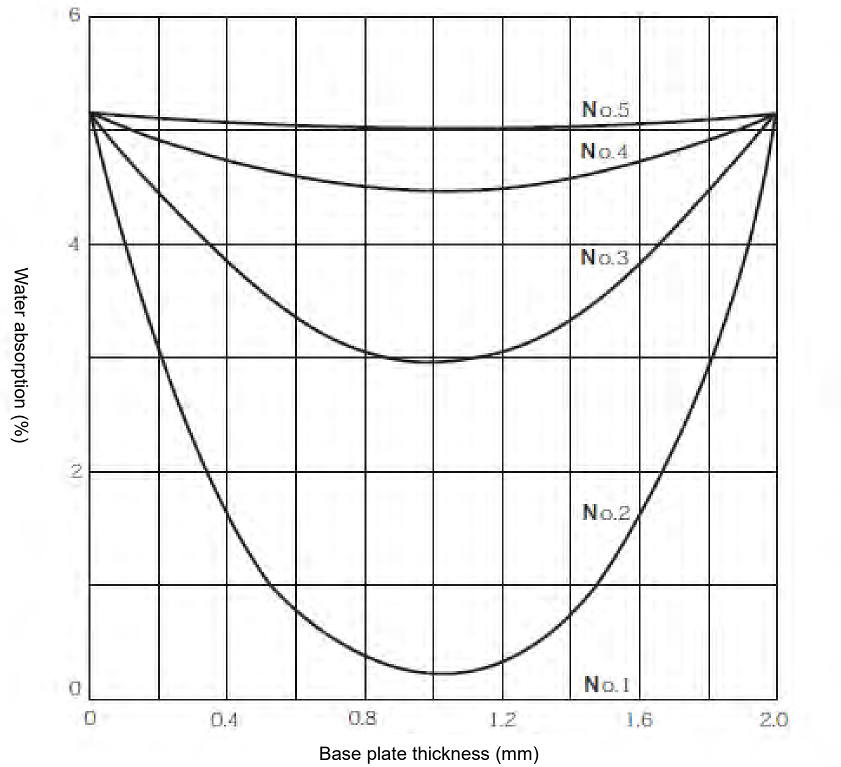
The steam formed from water during transportation and storage of the molding products plays the role of moisture absorption and humidifying in the molding products.

3) Precautions for humidifying

The moisture content is different on the surface and in the center of the part with thick wall of the molding product.(Refer to Figure-298) The product is humidified uniformly and shall be placed in the atmosphere for short time.

(The moisture content will be uniform during product and storage actually, so the standing time is not set specially.)

Figure-314 Water absorption distribution diagram of LEONA molding products (14G43 slab)



The above figure is the water absorption distribution diagram of the slab in absolute dry condition placed under the conditions of 23°C and 100%RH.The water absorption in the center of the slab is less than that in both sides within short time after water absorption and is uniform after long time.

No.	Humidifying time (hr)	Average water absorption (%)
1	0	0
2	100.6	1.666
3	500.2	3.716
4	1000	4.638
5	19000	5.021

(2) Dimensional changes caused by water absorption

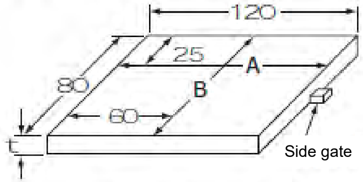
The dimensions of the molding product are changed due to water absorption.The dimensions (dimensional change rate based on the mold dimensions; the rate with the symbol changed to positive is molding shrinkage rate) of the molding product just molded are in ● position in the figure. The annealing effect (then shrinkage) will generate after humidifying of the product, trending to the straight line in the figure.

The bold line labeled by the arrow in the straight line represents the measured value range of the relationship between the water absorption and dimensions when the humidified molding product is placed outdoors (in shutter box) and indoors naturally. The change of these values with the environment is consistent with the straight line.

The sample for measurement is the slab object as shown below.

Molding product shape and dimensional measurement position

Molding product shape (unit: mm)



Dimensional measurement method

Use micrometer

Dimensions of A part (in flow direction) and B part (in vertical direction of flow)

.

t: Thickness (1, 2, 3 and 5mm)

Humidifying conditions: in 100℃ water

5.5~7.5hr

Environmental changes in outdoor placement

(In shutter box)

Temperature 0~30℃

Humidity 35～85％RH

Environmental changes in indoor placement

Temperature 20~30℃

Humidity 30～60％RH

Figure-315 Dependency of dimensions on water absorption after slab humidifying

(1300S)

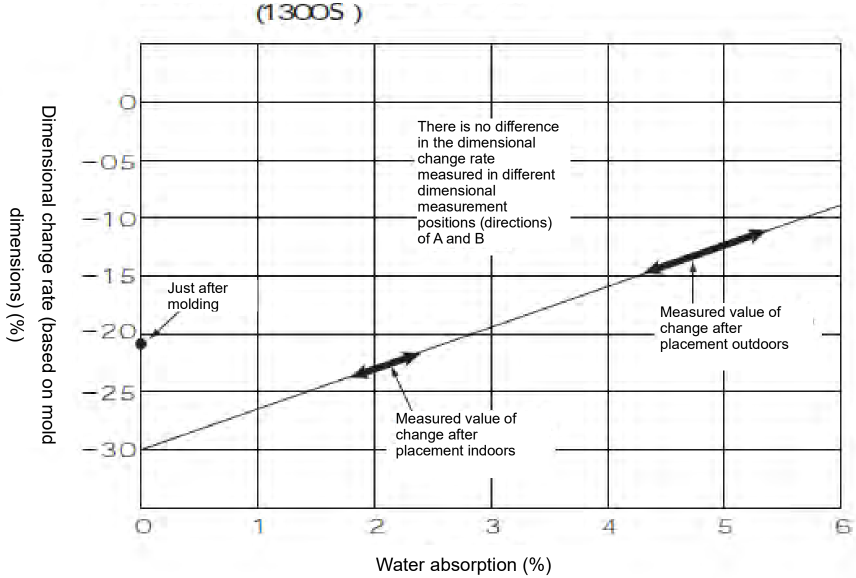
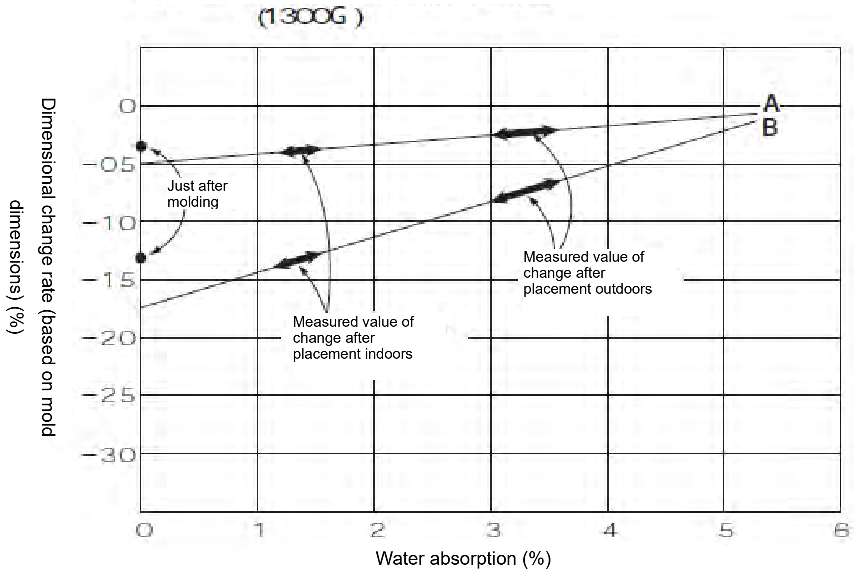


Figure-316 Dependency of dimensions on water absorption after

(1300G)



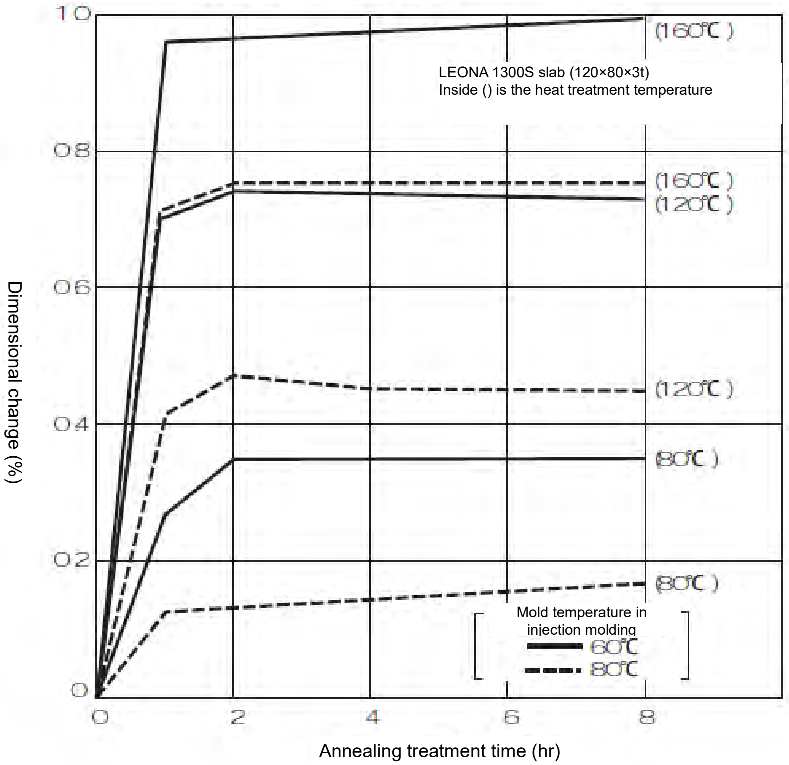
(3) Annealing treatment method of LEONA injection molding products

LEONA is crystalline resin, so the noncrystalline part of the molding product is gradually crystallized during long-term use and the volume change results in dimensional change.Moreover, the molding stress relaxation will also result in dimensional change.The product with high requirement for dimensional change is subject to annealing heat treatment. It is preferable to forcibly promote crystallization, relieve molding stress and stabilize the dimensions.

Annealing treatment is generally humidifying in high-temperature room or high temperature and humidity chamber.

The annealing treatment temperature is 20~30℃ higher than the actual operating temperature and the annealing heat treatment time varies with the product thickness and is 15~60min.

Figure-317 Annealing treatment and dimensional change
(Heat treatment temperature and heat shrinkage rate)



11-7 List of countermeasures for LEONA injection molding problems

(1) Molding problems (the serial number of the main reasons is one-to-one corresponding to that of the main countermeasures)

Problem	Main reasons
① Poor resin feed	1. The particle size of nylon particles and smashed product is greater than the screw groove depth. 2. The barrel temperature is too low and the resin is not melted. 3. The screw in the lower part of the hopper is stuck with cured resin (sometimes, the hopper is not cooled but the molding will occur)
② The nozzle cannot eject resin	1. It is speculated that the unmelted resin is blocked at the nozzle. 2. It is speculated that the melted resin is cured at the nozzle, resulting in blockage. 3. It is speculated that the foreign matters are blocked at the nozzle.
③ Foaming resin flows out at the nozzle	1. It is speculated that the resin is decomposed due to excessive barrel temperature. 2. It is speculated that the much moisture is gasified or the resin is decomposed.
④ Nozzle salivation	1. The polyamide resin with low melt viscosity is prone to salivation 2. It is speculated that the resin is hydrolyzed and the melt viscosity is reduced due to much moisture.
⑤ The melted resin ejected from the nozzle contains hard resin lumps	1. It is speculated that the resin is not melted fully 2. The screw speed is too fast, so the heat conduction in the barrel wall is poor 3. It is speculated that the other types of resin are mixed.
⑥ Poor demolding of molding product	1. Damaged mold 2. Excess filling 3. Too small draft
⑦ The main runner remains in the fixed side mold	1. Bushing damage (pay particular attention to the part in contact with the nozzle) 2. Core shift at the center of the nozzle and mold gate 3. Failure to fully cure due to short cooling time
⑧ The charging barrel cannot be filled with resin	1. The polyamide resin with low melt viscosity is prone to salivation 2. It is speculated that the resin is hydrolyzed and the melt viscosity is reduced due to much moisture.
⑨ Residual quantity of resin is not available	1. It is speculated that the check valve is abnormal (wear) 2. It is speculated that the resin is leaky at the nozzle contact part
⑩ Main runner drawing	1. The resin at the nozzle contact part is of great viscosity and is not solidified, resulting in constant drawing in mold opening.
⑪ Gate blockage	1. The resin is cured at the gate before full filling of the cavity. 2. The cold slug well is too shallow and the cold slug is blocked at the gate 3. The nylon particles or feed back is mixed with other types of resin with high melting point, resulting in gate blockage.

Main countermeasures
1. Process the nylon particles or smashed product to smaller size or replace the screw of the molding machine 2. Increase the barrel temperature 3. Remove the cured resin
1. Increase the barrel temperature 2. Increase the nozzle temperature 3. Remove and sweep the nozzle and take the countermeasures to prevent the foreign matters from being mixed
1. Reduce the barrel temperature 2. Dry the nylon particles and feed back
1. Properly adjust the screw sucking back 2. Dry the nylon particles and feed back
1. Increase the barrel temperature 2. Reduce the screw speed or increase the back pressure to delay the resin passing time 3. Confirm whether the resin with the melting point higher than LEONA melting point is mixed
1. Repair the damage 2. Reduce the injection molding pressure 3.Increase the draft
1. Repair the damage 2. Reinstall the mold and align at the center 3. Extend the cooling time
1-① Rotate the screw when the nozzle contacts the mold for resin filling. -② Reduce the nozzle temperature -③ Reduce the back pressure 2. Dry the resin
1. Replace the check valve 2. Use appropriate method to prevent resin leakage (is the curvature at the nozzle contact part correct?)
1-① Reduce the nozzle temperature to cure the resin at the nozzle contact part -② Extend the cooling time -③ Property set the sucking back
1. Increase the barrel temperature and mold temperature and accelerate the injection speed 2. Deepen the cold slug well 3. Remove other types of resin

(2) Molding product problems (the serial number of the main reasons is one-to-one corresponding to that of the main countermeasures)

Problem	Main reasons	Main countermeasures
① Small dimensions	1. Low injection molding pressure results in increase in molding shrinkage rate and decrease in dimensions 2. The mold temperature is too high, resulting in increase in crystalline degree in curing and molding shrinkage rate and decrease in dimensions 3. The molding product is exposed at high temperature, so the crystallization is accelerated and the dimensions are reduced.	1. Increase the injection molding pressure 2. Reduce the mold temperature 3. It is not exposed at high temperature if it is not necessary
② Deformation (warping and distortion)	1. Uneven mold cooling results in changes 2. Anisotropic level has large changes	1. Improve the cooling water circuit position or adjust the cooling water volume and temperature 2-① Select the resin with small anisotropy (the resin with reinforced level of glass fiber is of large anisortropy and the resin added inorganic fillers is of small anisortropy) -② Modify the product shape, mold shape and cooling water circuit position Product shape: shape of molten resin to achieve balanced flow horizontally and transversely;uniform thickness and symmetrical shape (large polymer orientation in thin part) Mold shape - determine the gate position, so that the molten resin flows from the long direction of the product.The gate shall be made as flat seam gate as far as possible and the resin flow shall be parallel and wide Cooling water circuit position: determine the cooling tank position to unify the mold surface temperature.It is effective to use CAE. Molding conditions: low mold temperature and long cooling time
③ Poor appearance a.Hard spot	1. Due to low mold temperature, the resin is directly cured rather than clinging to the mold surface 2. Due to low injection molding pressure, the resin is directly cured rather than clinging to the mold surface 3. Due to low barrel temperature and resin temperature, the resin is directly cured rather than clinging to the mold surface 4. Improper use of feed back (mixed with foreign matters, insufficient melting)	1. Increase the mold temperature 2. Increase the injection pressure 3. Increase the barrel temperature 4. Modify the feed back application method.
b.Weld line	1. During confluence of resin with decreased temperature at the front end of flow, confluence part is not fully fused and the line marks are left on the confluence surface.	1-① Increase the mold temperature and accelerate the injection speed. －② Product shape: easy flow shape of resin. Minimize confluence and properly increase the number of gates to prevent excessive decrease of the resin temperature in the confluence part.The confluence part shall not be designed in the position with load. Mold design: fully set air holes to ensure good resin flow and design overflow lugs occasionally to extrude the low-temperature resin from the product
c.Spray line	1. Snakelike traces left by part of cured resin pushed forward by the melten resin from the rear of the mold	1. Slow down the injection speed 2. Increase the gate size
d.Short shot	1. Low injection pressure and insufficient resin flow 2. Low mold temperature, rapid resin curing and insufficient flow 3. Low resin temperature, rapid curing and insufficient flow 4. Due to slow injection speed, the resin has started to be cured before reaching the end of the cavity 5. Too short injection time 6. Product shape: the resin at the extremely thin part of the product is cured due to poor flow 7. Mold shape: short shot in the cavity due to poor runner balance and gate balance of molds taken in large quantity 8. Excessive resin viscosity and poor flow 9. Poor check valve will sometimes result in failure of the injection molding pressure to rise 10. The resin cannot reach the front end of the cavity due to poor exhaust	1. Increase the injection pressure 2. Increase the mold temperature 3. Increase the barrel temperature 4. Increase the injection speed 5. Extend the injection time 6. Eliminate the extremely thin position 7. Improve the runner balance and gate balance 8. Select the resin of proper viscosity 9. Replace the check valve 10. Exhaust gas sufficiently

Problem	Main reasons	Main countermeasures
e. Craze	1. Contain vaporized moisture, decomposed gas and air	1-① Fully dry nylon particles -② Reduce the barrel temperature to prevent resin decomposition (molten resin shall not retain in the barrel) -③ Reduce the injection speed or change the shape to ensure easy flow and prevent the air from being involved
f.Carry-over	1. Resin flying at the sharp corners 2. Cold slug flying in the product 3. Fast injection speed	1. Eliminate sharp corners 2. Fully set the cold slug well 3.Slow down the injection speed
g.Flow line	1. Formed by the cooled and cured resin on the mold surface pushed forward by the rear melted resin 2. Flow lines easily appear at the sharp corners, extremely thin part and thick part of product(Flow lines easily appear at the flow end in the extremely thin part and near the gate in the extremely thick part)	1-① Increase the mold temperature to delay curing time -② Slow down the injection speed 2. Eliminate sharp corners and make thickness appropriate
h.Turnup	1. Open the mold before full curing of the thick part in case of extreme thickness difference 2. Mold opening before the resin after short cooling time will sometimes result in resin stuck to the mold and turnup 3. Other types of resin with poor intermiscibility are mixed	1-① Minimize the thickness difference -② Extend the cooling time 2-① Extend the cooling time -② Reduce the mold temperature 3. Clean fully to prevent other types of resin from being mixed
i.Irregular color	1. Insufficient mixing 2. Retention in the charging barrel results in discoloration and irregular color 3. Unbalanced filling when a number of gates are fetched	1-① The screw L/D shall be above 18 -② Improve the screw back pressure and reduce the speed -③ Minimize the feed back particles and reduce the mixing ratio 2. Do not leave retention part 3. Make gate position and size appropriate and ensure filling simultaneously
j.Stain	1. If the stains are black or dark brown, it is speculated that the substances generated in the charging barrel peel off and are mixed in the product 2. If the stains are white, it is speculated that the unmelted resin or melted resin is cured	1. Disassemble and sweep the charging barrel or clean fully 2-① Increase the barrel temperature for full melting -② Fully deepen the cold slug well
k.Bubble	1. The air in the die cavity is involved in high-speed resin flow and forms bubbles on the surface of the molding product. 2. The local thickness difference of the product is large and the air is involved when the resin flows at high speed from thin part to thick part of the product	1. Slow down the injection speed 2. Prevent sudden change of flow path in design
l.Cloud points or low gloss	1. When the resin temperature is low, the molten resin does not closely cling to the mold surface 2. When the mold temperature is low, the molten resin does not closely cling to the mold surface 3. The gas in the cavity is attached to the product surface, resulting in cloud points 4. The pollutants on the mold surface form cloud points 5. When the injection pressure is low, the molten resin does not closely cling to the mold surface 6. Poor injection switch position, resulting in the phenomenon in item 5 7. Small gate size, resulting in the phenomenon in item 5	1. Increase the barrel temperature 2. Increase the mold temperature 3. Improve the exhaust status or set shallow leather 4. Make the mold surface clean 5. Increase the injection pressure 6. Adjust the switch position 7. Increase the gate size
m.Wrinkle	1. The injection pressure is low and the molten resin does not closely cling to the mold surface 2. The injection speed is low and the molten resin is cured before fully clinging to the mold surface 3. The wrinkles are sometimes caused by pollution on the mold surface 4. Small gate size, resulting in the phenomenon in item 1	1. Increase the injection pressure 2. Increase the injection speed 3. Make the mold surface clean 4. Increase the gate size

Problem	Main reasons
n.Whitening	1. Mold surface pollution 2. Small gate size 3. Poor exhaust 4. Excessive mixing results in decomposition, gas and whitening 5. The resin contains the gas causing whitening 6. Forcibly unplug the molding product from the mold, resulting in whitening
o.Stripping	1. Contain other types of resin with poor intermiscibility 2. Salivation, drawing and mixed with cold slug
p.Scorch	1. Local resin retention in charging barrel 2. Poor exhaust and gas compression heat result in resin scorch 3. Excessive resin temperature results in dark brown
q.Expansion	1. Open the mold before full curing of resin 2. The thick part of the product is not fully cured
r.Trimming	1. The molten resin flows to the parting surface gaps of the mold
s.Sink mark	1. The volume of the molten resin shrinks during curing.The sink mark degree of crystalline resin is large generally.Curing shrinkage in thick part of the product results in drawing of product surface to the thick part, forming sink marks.
④ Insufficient strength of molding product a.Fracture at the corner	1. Easy break at the corner due to stress concentration 2. Small thickness 3. Damage results in stress concentration and easy break
b.Air holes in the fracture surface	1. It is speculated that the air holes result in stress concentration Air holes are caused by resin shrinkage and air involvement
c.Fixed fracture and break position	1. Fracture and break in the damaged part of the mold 2. Fracture and break in the part with weak strength
d.Fracture and break in the product part with poor appearance	1. It is speculated that the cold slug is mixed 2. Fracture and break in the wrinkle part due to insufficient injection pressure
e.Foreign matters found on the fracture surface	1. The foreign matters are in the stress concentration part. 2. It is speculated that the cold slug is mixed

Main countermeasures
1. Make the mold surface clean 2. Increase the gate size 3. Improve the exhaust status 4. Reduce the screw speed and back pressure 5. Fully dry the resin 6-① Fully make the draft -② Increase R angle at the corner of the molding product and at the root of the shaft sleeve and reinforcing rib
1-① Select other types of resin with good intermiscibility -② Clean the machine and increase the rejected quantity -③ Increase the resin temperature 2. Prevent salivation and drawing and modify the cold slug well
1. Remove and sweep the charging barrel and eliminate local retention part 2-① Ensure sufficient mold exhaust -② Reduce the injection speed 3. Reduce the barrel temperature
1-① Extend the cooling time -② Reduce the mold temperature 2.As thin as possible
1-① Increase the clamping force -② Reduce the injection molding pressure -③ Decrease the resin temperature and mold temperature -④ Correct the flatness of the parting surface -⑤ Improve the runner and gate balance to prevent resin pressure from biasing to a place
1-① Extend the holding time -② Reduce the mold temperature -③ Extend the cooling time -④ Decrease the product thickness (the maximum thickness is about 5mm) -⑤ Set gates near the position prone to sink marks and increase the gate size -⑥ Pay adequate attention in the design of reinforcing rib and shaft sleeve
1. Set R angle at the corner 2. Properly increase the thickness 3. Investigate and prevent the reasons for damage
1-① Reduce the thickness ② Extend the holding time Change the gate position and size Reduce the injection speed to avoid sharp flow path changes in design
1. Repair the mold damage 2.Properly increase the thickness
1. Fully deepen the cold slug well 2. Increase the injection pressure, mold temperature and resin temperature
1-① Disassemble and sweep the charging barrel or clean fully -② Take measures if other foreign matters are mixed 2. Fully deepen the cold slug well

12-1 Reasons and countermeasures for break and cracking

[Outline]

LEONA is crystalline thermoplastic resin and has extremely high toughness in the resin, so it is widely used for electrical, electronic, automobile and other functional components. There are few break and cracking phenomena in the market.

Therefore, the analysis results show that the break and fracture of LEONA molding products in the market are mostly caused by the following two reasons:

1) Poor crystalline status of molding product
2) Poor design (acute angle)

Main points of countermeasures:

1) Use the molding temperature suitable for LEONA
2) Set R angle for acute angle of the molding product

(1) First

The engineering plastic is used for gear, connector and other multi-functional components, but has less break and fracture in the market.There is no exception for LEONA, especially in the winter.

We have analyzed the true reasons for break • fracture of LEONA molding products in the market in the past and discussed how to solve the countermeasures.

(2) Reasons for break • fracture of LEONA molding products

The general reasons for break • fracture of LEONA molding products are as follows:

Table 45: General reasons for break • fracture

Break • fracture status	Reasons for break • fracture
(A) Ductile failure (Neck shape deformation)	① Abnormal external force load
(B) Brittle failure	① Poor design (stress concentration in sharp edge) ② Mixing of metal powder, gravel and other foreign matters (stress concentration caused by foreign matters) ③ Poor molding (insufficient gate confinement, poor weld lines, flow marks, unmelted resin and poor crystalline state) ④ Decreased molecular weight (use moisture absorbing materials, resulting in polymer decomposition).

(3) Analysis results of reasons for break • fracture of LEONA molding products

Analysis of the reasons for break • fracture of LEONA in the market recently shows that "poor crystalline state" and "poor design" (with sharp edges) are the main reasons.

Table-46 Analysis results of reasons for break • fracture of LEONA molding products

No.	Level name	Use name	Reasons		
			Poor crystalline state	Poor design	Exceptional external force
1	1300S	Socket part	○	○	
2	1300S	Connector		○	
3	1300S	Threaded part			○
4	1402S	Gear	○		
5	1402S	Fuse block	○		
6	1402S	Fixed part	○		
7	1402S	Cover	○		
8	1402S	Connector	○	○	
9	FR200	Connector	○	○	

(○ represents relevant reason)

1) Crystalline state and break • fracture

It is found that the break • fracture of LEONA molding products are closely related to the molding temperature (barrel setting temperature).That is, when the barrel setting temperature (especially the middle temperature) is below 275℃ of general level (resin melting point of +10℃), the molding product is in poor crystalline state, resulting in break and fracture.

The following ① and ② are enumerated based on such data.

① Crystals are not visible and the resin is mixed with unmelted nylon particles at low resin temperature. The screw speed is too high and the crystalline state is uneven.

② When the resin temperature is below LEONA melting point, the breaking strain drops suddenly.

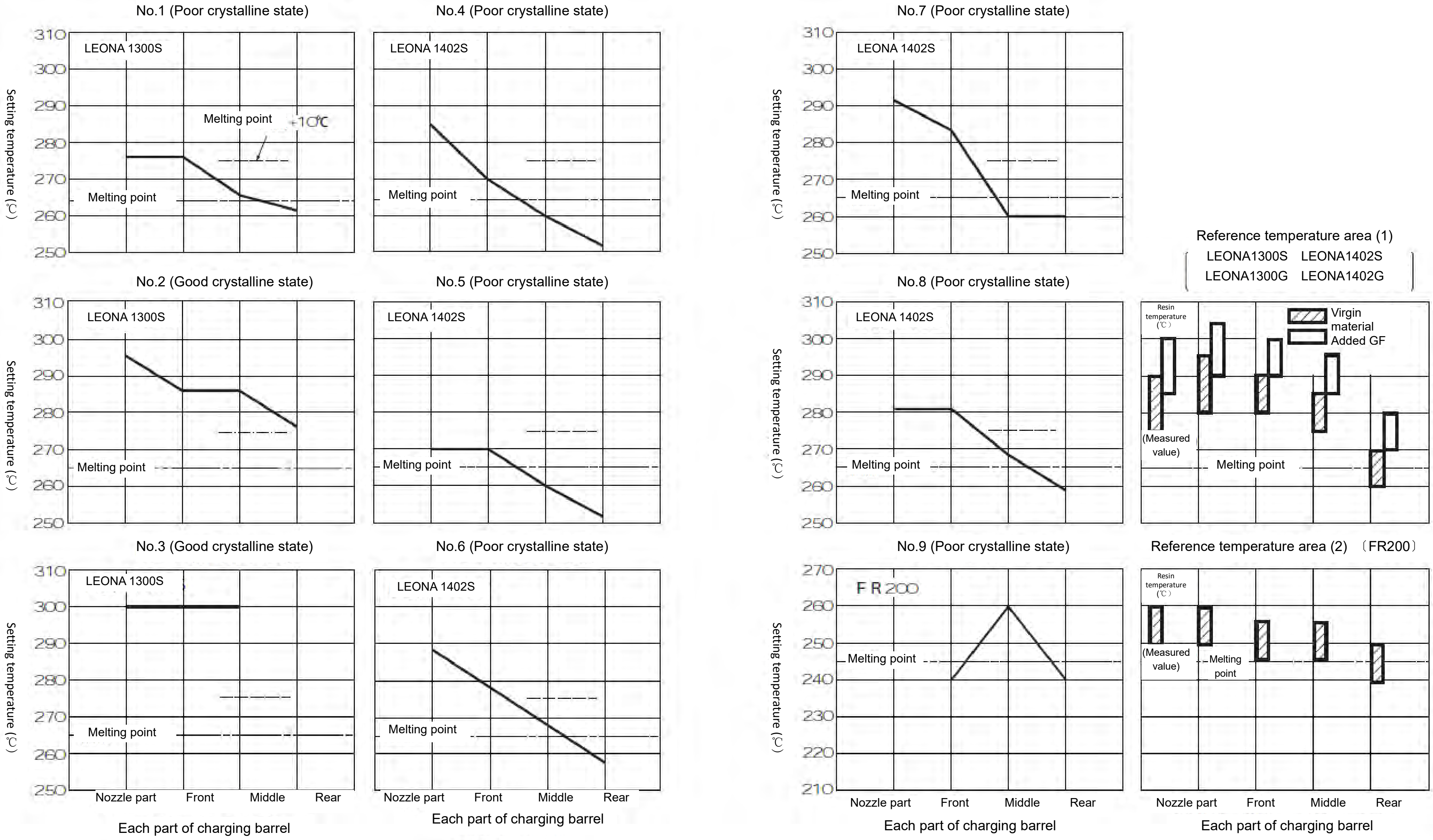
So the low resin temperature or high screw speed will result in insufficient resin plasticizing, poor crystalline state (unmelted resin, incomplete spherulite and flow marks),strain decrease and break and fracture.

2) Relationship between design and break • fracture

The break and fracture of molding products are mostly caused by acurate angle in terms of design.

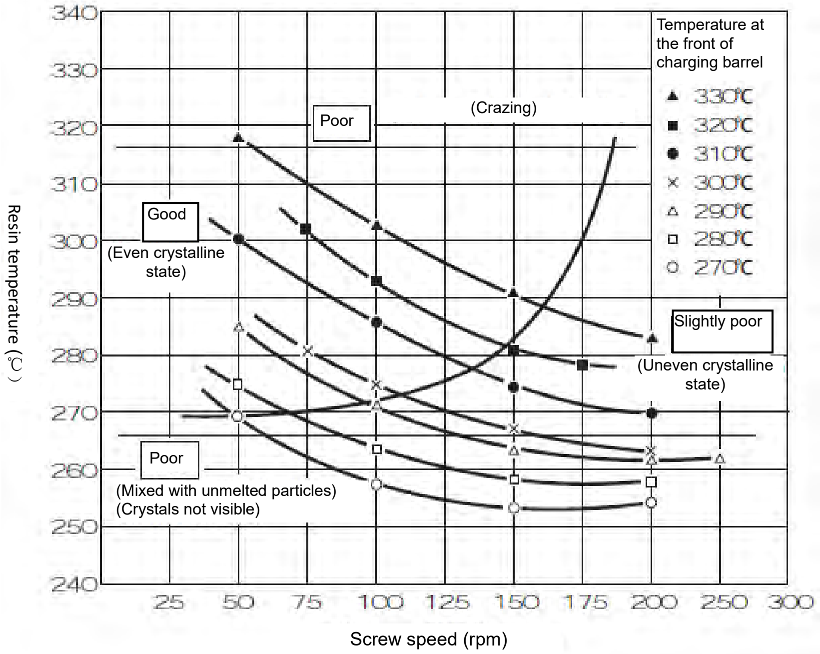
Figure-318 Analysis of reasons for break • fracture of LEONA

(Relationship between molding temperature and crystalline state)



General specification
Water absorption characteristics
Moisture dependency
Temperature dependency
Evaluation methods
Specifications and acts
Long-term characteristics
When replacing the metal
Product design
Mold for injection molding
Injection molding technology
Fault cases and countermeasures of molding products

Figure-319 Relationship between plasticization conditions and crystalline state

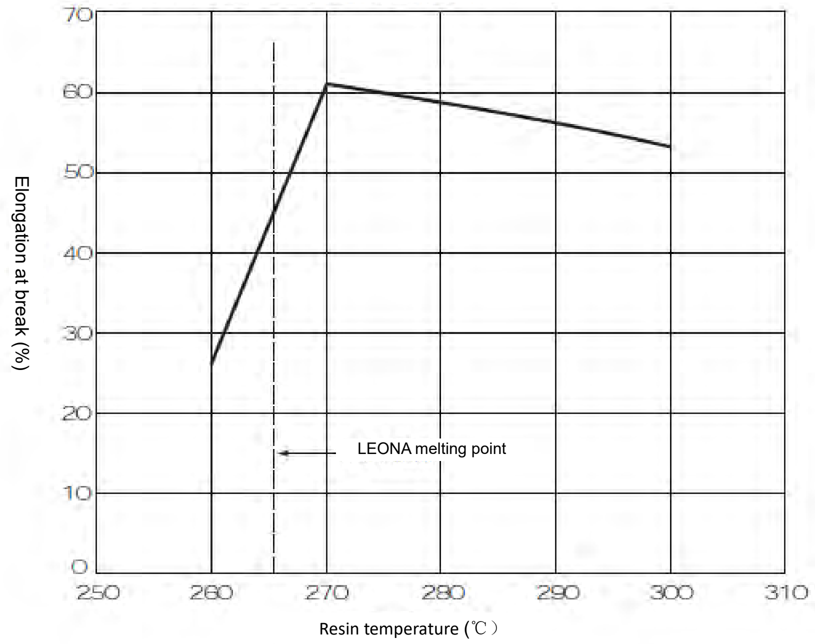


Condition: resin LEONA 1300S

Molding machine IS90B

(Note) The above data is for good and poor areas distinguished by observation of the crystalline state of the polymer strips continuously extruded when the molding cycle is 0.

Figure-320 Relationship between resin temperature and tensile elongation



Condition: resin LEONA 1300S

Molding machine	NETSTAL（10Z）
Mold	ASTM #1 dumbbell-shaped sample
Mold temperature	80℃
Screw speed	100RPM

(4) Countermeasures for break • fracture of LEONA molding products

The above analysis results show that the break and fracture are mostly caused by poor crystalline state and poor design of molding products.Therefore, the following measures shall be taken for break and fracture:

1) Measures taken to obtain the molding products in good crystalline state

① The resin temperature in LEONA molding is controlled in the management range according to the following table.

Resin		Resin temperature (℃) (measured value)	Barrel temperature (set value) (℃)			
			Nozzle part	Front	Middle	Rear
LEONA	Virgin material	275～290	280～295	280～290	275～285	260～270
	Added GF	285～300	290～305	290～300	285～295	270～280
	FR200	250～260	250～260	245～255	245～255	240～250

It shall be noted that there are many cases of low setting temperature in the middle and rear of the charging barrel.

The resin temperature is affected by the molding machine type and molding conditions and the resin temperature at the nozzle shall be measured and confirmed.

② If the screw speed is too high even though the barrel temperature is set to the stipulated temperature, the molding product will be in crystalline state. So the screw speed shall be set to 80~100rpm.

③ The feed back particles with excessive size are not easy to melt in the charging barrel, resulting in unmelted resin, so the feed back particles shall be uniformly smashed into nylon particles before use.

④ Excessive injection volume injected once relative to the molding machine capacity will result in poor plasticizing, so the molding shall be achieved within 30%~60% injection capacity of the molding machine.

2) Design countermeasures

Acute angles result in stress concentration and break • fracture, so it is required to set R angle for the acute angles of the molding products.

3) Other countermeasures

① Mixing of gravel, metal powder and other foreign matters in the molding products will result in stress concentration and break • fracture, so the foreign matters shall be fully managed.

② Insufficient gate confinement, poor weld lines, flow marks and bubbles result in break and fracture, so the mold temperature and injection time shall be molded under appropriate molding conditions.

④ Molding at high moisture content of nylon particles will result in molecular weight decrease of LEONA and break • fracture, so the moisture in the nylon particles shall be strictly managed.

For example, the remaining nylon particles are put in a bag for LEONA and sealed by heat or adhesive tape; or two thick plastic bags are overlapped and the inner bag and the outer bag are bundled by rope.Moreover, the particles may also be stored in a sealed metal container with a washer.

When the feed back is used, the smashed product is subject to hot air drying or vacuum drying before molding. (Refer to 11-4 (1) Drying of LEONA particles for the drying conditions.)

In the environment with low temperature and low moisture content, the nylon materials including LEONA have high rigidity, resulting in stress concentration and strain decrease, and the molding products are prone to break and fracture. In such environment, break and fracture easily appear close to the area with poor crystalline state, so the resin temperature shall be controlled in the area with good crystalline state of molding products.

Picture 1: Relationship between plasticization conditions and crystalline state (through polarizing microscope)
Test of samples continuously extruded from LEONA 1300S

Screw revolution (RPM)	Barrel setting temperature (front) (℃) (Toshiba IS90B) (Below the picture is the resin temperature (℃))					
	270	280	290	300	310	320
40	 (268)	 (274)				
100	 (257)	 (262)		 (275)		 (290)
120			 (263)		 (278)	
160	 (253)	 (258)		 (265)		 (279)
180			 (260)		 (269)	

Picture 2: Crystalline state case of LEONA 1402S

Poor	Slightly poor	Good
		

Poor — Barrel setting temperature

Nozzle part	285(℃)
Front	275
Middle	260
Rear (Below the hopper)	250

Slightly poor — Barrel setting temperature

Nozzle part	285(℃)
Front	280
Middle	280
Rear (Below the hopper)	260

Good — Barrel setting temperature

Nozzle part	285(℃)
Front	290
Middle	290
Rear (Below the hopper)	265

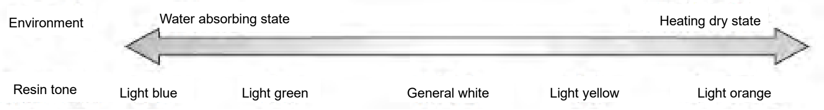
12-2 Heat discoloration and water absorbing discoloration of heat-proof aging grade

[Phenomena]

LEONA particles with the heat-proof aging level of 1402S, 1402G and 14G25 are approximately white naturally, but the particles will turn light blue or orange after unsealing from 25kg bag and water absorption or after heating drying in an oven.

This phenomenon is changed and reversible depending on the water absorption and heating status of particles.

The same phenomenon will also occur in the molding products.



[Reasons]

For heat-proof aging, the above LEONA levels are mixed with heat stabilizer of copper compound.Affected by moisture and heat, the copper compound will be discolored due to change in the junction state of copper ions, so the tone of the resin particles will be changed based on above principle.

Even in case of discoloring, the copper compound as the heat stabilizer still has the same effect and will not affect the mechanical properties of the molding product according to the experience so far.

12-3 White attachments on the surface of unreinforced flame retardant grade molding products

[Phenomena]

White attachments may generate on the surface of the molding products with the unreinforced flame retardant grade of FR200 and FR370 after long-term exposure to high temperature and humidity environment.

[Reasons]

The white attachments may be regarded to be precipitated to the surface of the molding product by polyamide 66 oligomer (LMW components) and flame retardant components in the molding product resin.

[Countermeasures]

Try not to store the molding products in high temperature and humidity environment for long time.

The white attachments, as part of the resin components, will not affect the mechanical physical properties and flame retardance of the molding product.

12-4 Corrugated case discoloration of LEONA molding products

[Phenomena]

Yellow spots will appear on the surface of LEONA molding product sometimes after the molding product is stored in a corrugated case for long time.This yellowing phenomenon will accelerate in high temperature and humidity environment.

[Reasons]

It is believed that the compound generated by property changes of lignin as one of corrugated case components in high temperature and humidity environment has chemical reactions with polyamide molecules, resulting in yellowing.

[Countermeasures]

For storage in a corrugated case, it is recommended to use a corrugated case with coated inner surface or place a sealed bag with good air barrier property in a corrugated case.

13. Precautions for use of LEONA

■ Precautions

The content recorded in this material is based on the current materials, information and data mastered and may be revised based in new findings and understanding.The information provided is not guaranteed value.Therefore, please fully consider the operating environment and design before use at your risk based on your judgment of no problem in the product.

(1) Precautions for use

The following precautions shall be noted for the use of LEONA provided for you.Please effectively follow the precautions for safe use of LEONA!An MSDS has been made separately for precautions for use of LEONA.Please contact us!Investigate the safety of additives other than LEONA by yourself.

①Precautions for safety and sanitation

Do not make your eyes and skin in contact with gas from LEONA drying and melting and do not inhale the gas.

Do not directly touch high-temperature resin!It is recommended to set local exhaust device and wear protective appliances (protective goggles and protective gloves) during drying, melting and other operations.

②Precautions for burning

LEONA is flammable, so it shall be used and stored away from fire!In case of burning, poisonous gases and asphyxiating gases may generate.For extinguishment,water base extinguisher, foam extinguishing agent and powder extinguishing agent may be used.

③Precautions for waste

LEONA may be handled through burning or landfill by recognized industrial waste disposer or local public body according to *Relevant Regulations for Waste Treatment and Cleaning*.For handling by yourself, please use combustion equipment and comply with the decrees such as law on prevention of atmospheric pollution!Carbon monoxide and other poisonous gases and asphyxiating gases may generate during combustion.

④Precautions for storage

Absolutely avoid resin pollution and moisture absorption!Store the resin in a cold and dark place without moisture and immediately start molding after unsealing.

The bag containing the product shall not be opened or immersed in water!The resin falling out shall not be loaded back to the bag!

⑤Precautions for molding

The appropriate resin temperature for LEONA molding is 270～310℃.At a lower temperature, the local biological property may be reduced due to uneven plasticity;at a higher temperature, the gas may generate or crazing and other poor appearance may appear due to decomposition.However, there are individual exceptions,such as FR200 and FR360.Be sure to refer to the product manual of each product before molding.Do not make LEONA stay in the cylinder of the molding machine for long time in melted status!

The resin will be decomposed, resulting in discoloration or degradation of the molding product.In this case, please use polyethylene for displacement in the charging barrel before molding!

(2) Applicable specification

Consult us on whether each level meets the requirements in electrical appliance management law, UL specifications and CSA specifications.Do not use them for food packaging containers and other purposes in contact with foodor for medical purposes!Consult us for details! Contact us for other special purposes and we will negotiate with your.

(3) Other

Pay attention to the industrial property right before use.