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1.Introduction

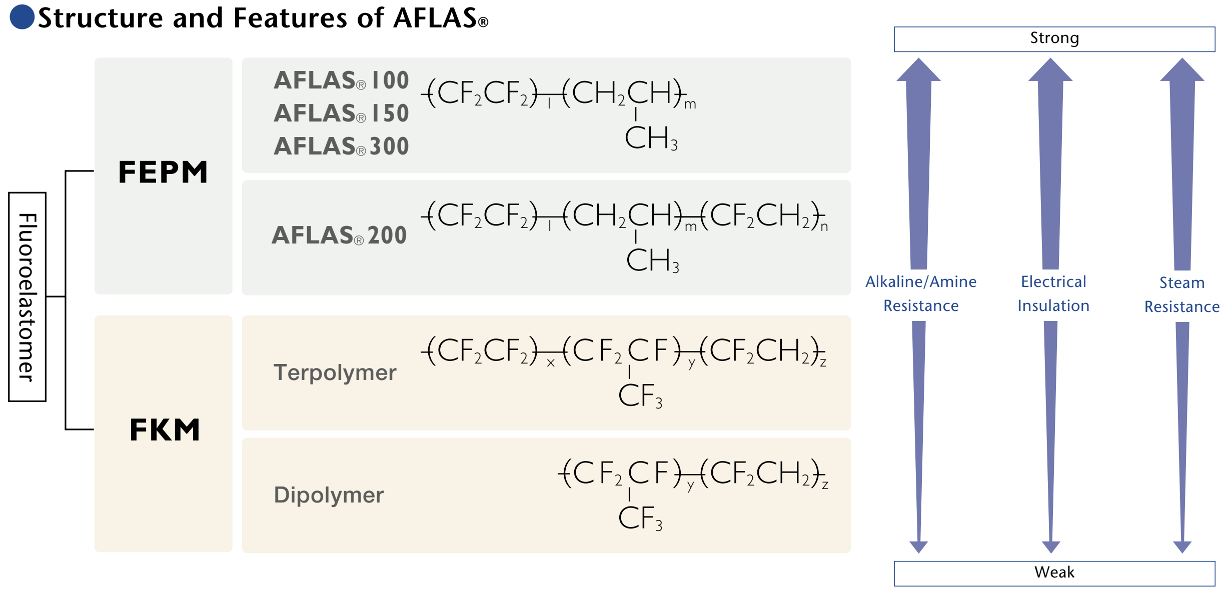
Since the arrival of VdF-HFP based elastomer (FKM) in the 1950s, a variety of fluoroelastomers have been developed and commercialized. In 1975 a new fluoroelastomer family, based on an alternating copolymer of TFE and propylene (FEPM) was introduced by Asahi Glass Co., Ltd, under the trade name AFLAS®.

The polymer structure of AFLAS® gives unique properties in that it offers excellent heat resistance with a continuous service temperature of 200℃ and a maximum peak exposure temperature of 250℃, outstanding chemical resistance with no or little deterioration even in contact with strong acids and bases at high temperatures and high electrical resistivity of the order of $10^{15} \sim 10^{16}\,\Omega\cdot$cm. AFLAS® is used worldwide in many industrial fields where rubber components come into contact with harsh environments.

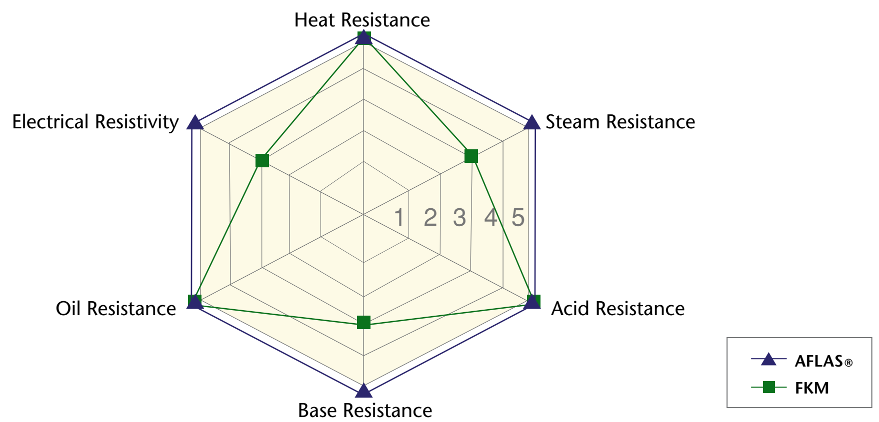
Reflecting the recent trend of increasing power in automotive engines, the use of high performance engine oils is now essential to cope with increasing engine temperatures. These engine oils are heavily formulated with amine-based additives and therefore elastomer components are now required to have greater heat and engine oil resistance than previously experienced. Therefore AFLAS® has been attracting more attention as a material which can survive in such harsh conditions.

AFLAS® has been finding new applications in wire & cable industries as an elastomeric insulating material with the highest heat resistance.

●Structure and Features of AFLAS®



●Overview of Properties



2.Commercial Polymer Types and AFLAS® Grades

Commercial AFLAS® polymers are classified into three types; TFE-P dipolymer type (AFLAS®100 and 150 grades), TFE-P-VdF terpolymer type (AFLAS®200 grade) and TFE-P-CSM terpolymer type (AFLAS®300 grade).

AFLAS®100 and 150 grades are high performance fluoroelastomers with excellent base resistance and electrical resistivity due to the polymer structure which is totally different from FKM. AFLAS®200 has improved low-temperature properties. AFLAS®300 has improved curability and extrusion processability with its special termonomer. It also gives low die-swell, good dimensional stability of moulded parts and smooth surface finish.

Below are the polymer grades currently available. These are mainly classified according to Storage Modulus, G'(as determined by a rubber process analyser) which is representative of molecular weight. Each AFLAS® grade is suited to a particular type of application such as wire insulation and oil seals.

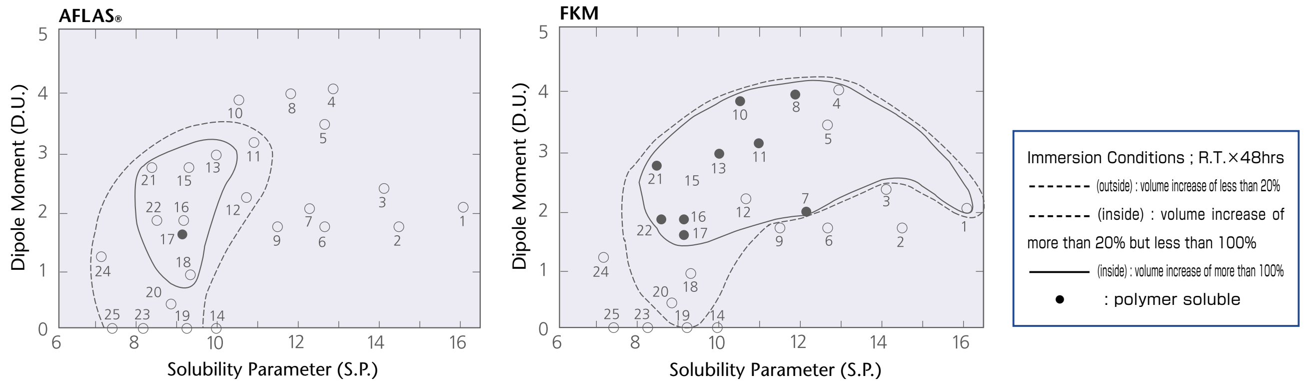
●Grade Range

Polymer Structure	TFE-P							TFE-P-VdF	TFE-P-CSM
Grade	100H	100S	150P	150E	150L	150C	150CS	200P	300S
Specific Gravity	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.60	1.55
Fluorine Content (%)	57	57	57	57	57	57	57	60	57
Storage Modulus, G' (RPA 100℃, 50cpm)	500	340	240	160	80	490	390	220	380
Mooney Viscosity (ML1+10, 100℃)	—	160	95	60	35	—	140	90	—
Mooney Viscosity (ML1+10, 121℃)	—	115	70	45	—	—	100	65	120
Glass Transition Point (℃)	-3	-3	-3	-3	-3	-3	-3	-13	-3
Appearance	Brown	Brown	Brown	Brown	Brown	White	White	Yellow	White
Cure Type	Peroxide Cure	Peroxide Cure	Peroxide Cure	Peroxide Cure	Peroxide Cure	Electron Beam Cure	Electron Beam Cure	Peroxide Cure	Peroxide Cure
Features	High Strength	High Strength	General	Extrusion	Lining	Extrusion	Extrusion	For Low Temp	Extrusion

3.Properties

●Solubility of AFLAS® Raw Polymer

Working and stirring the polymer above room temperature makes AFLAS® soluble in tetrahydrofuran (17). Although the polymer swells in low-polar chlorine or aromatic solvents, it swells only negligibly in solvents with a solubility parameter of more than 10. AFLAS®200P polymer swells and dissolves in both methylethylketone (15) and acetonitrile (8).



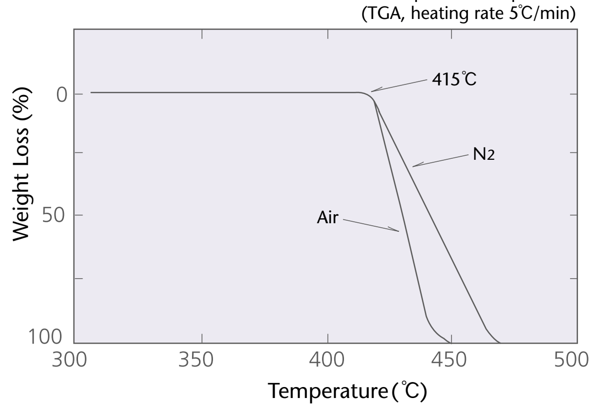
1 CH_3CONH_2 Acetamide	**6** C_2H_5OH Ethanol	**11** $CH_3COCH_2COCH_3$ Acetylacetone	**16** $CH_3COOC_2H_5$ Ethylacetate	**21** $CH_3(i\text{-}C_4H_9)CO$ 4-Methyl,2-Pentanone
2 CH_3OH Methanol	**7** $HCON(CH_3)_2$ N,N-Dimethylformamide	**12** C_5H_5N Pyridine	**17** C_4H_8O Tetrahydrofuran	**22** CH_3CCl_3 1,1,1-Trichloroethane
3 HOC_2H_4OH Ethylene Glycol	**8** CH_3CN Acetonitrile	**13** $(CH_3)_2CO$ Acetone	**18** C_2HCl_3 Trichloroethylene	**23** $c\text{-}C_6H_{12}$ Cyclohexane
4 $(CH_3)_2SO$ Dimethylsulfoxide	**9** $n\text{-}C_4H_9OH$ 1-Buthanol	**14** CS_2 Carbondisulphate	**19** C_6H_6 Benzene	**24** $(i\text{-}C_3H_7)_2O$ Diisopropylether
5 CH_3NO_2 Nitromethane	**10** CH_2CHCN Acrylonitrile	**15** $CH_3(C_2H_5)CO$ Methylethylketone	**20** $C_6H_5CH_3$ Toluene	**25** $n\text{-}C_7H_{16}$ Heptane

●Heat Resistance

AFLAS® provides excellent thermal stability. The copolymer only starts to decompose in open-air or nitrogen gas at 400℃. The composition ratio of the copolymer is TFE/P=55/45. This is why AFLAS® has excellent heat stability.

■Typical Thermogravimetric Curves

Thermal decomposition temperature (TGA, heating rate 5℃/min)



4.Standard Formulation and Vulcanisation

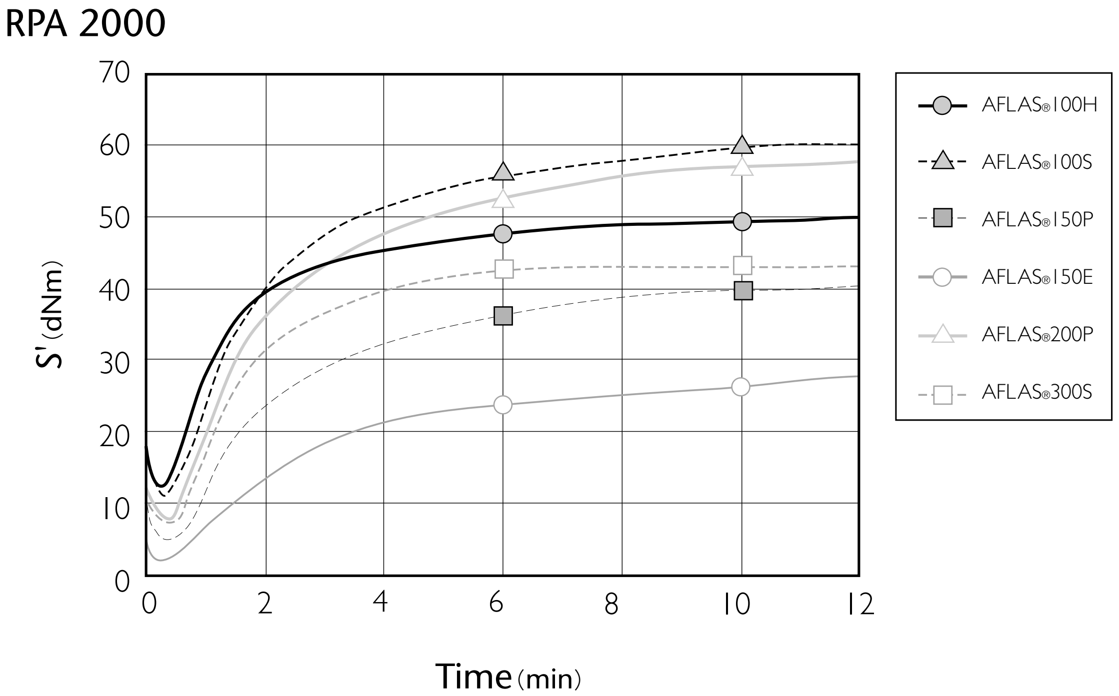
AFLAS® can be compounded by conventional processing equipment, such as Banbury mixers and open 2-roll mills. Various articles can be produced by means of compression moulding, extrusion, injection moulding and calendaring. AFLAS®100, 150, 200 and 300 are vulcanised by organic peroxides with the aid of an appropriate co-agent, such as TAIC (triallylisocyanurate).

●Standard Formulations and Properties

		AFLAS®100H	AFLAS®100S	AFLAS®150P	AFLAS®150E	AFLAS®200P	AFLAS®300S
Formulation	Polymer	100	100	100	100	100	100
	MT-Carbon (N990)	30	30	30	30	25	25
	TAIC*	5	5	5	5	5	3
	Peroxide A**	1	1	1	1	1	—
	Peroxide B***	—	—	—	—	—	1.5
	MgO (highly active)	—	—	—	—	3	—
	Sodium Stearate	1	1	1	1	1	—
	Zinc Stearate	—	—	—	—	—	1
Mooney Viscosity (121℃)	ML1+4	122	93	58	38	79	99
	ML1+10	114	85	51	35	74	97
Cure Condition	Press Cure	170℃/20min	170℃/20min	170℃/20min	170℃/20min	170℃/20min	170℃/20min
	Post Cure	200℃/4hrs	200℃/4hrs	200℃/4hrs	200℃/4hrs	230℃/24hrs	230℃/16hrs
Properties	Tensile Strength (MPa)	21	20	17	13	18	13
	Tensile Elongation (%)	300	230	280	360	270	220
	100% Modulus (MPa)	6	7	5	5	5	4
	Hardness (ShoreA)	72	72	70	70	69	67
	Compression Set (%, 200℃×70hrs)	35	26	29	32	23	29

* triallylisocyanurate (100%liquid)
** 1,3Bis (t-buthylperoxy isopropyl) benzene (100%active)
*** Di t-buthylperoxide (100%active)

●Cure Curve by Rubber Process Analyser



●MT-Carbon Loading vs. Physical Properties

		Carbon 10phr	Carbon 20phr	AFLAS®150P Standard Formulation	Carbon 40phr	Carbon 50phr
Formulation	AFLAS® 150P	100	100	100	100	100
	MT-Carbon(N990)	10	20	30	40	50
	TAIC*	5	5	5	5	5
	Peroxide A**	1	1	1	1	1
	Sodium Stearate	1	1	1	1	1
Mooney Viscosity (121℃)	ML1+4	49	54	58	61	69
	ML1+10	43	47	51	56	64
RPA (177℃×12min, Frequency:3)	t10(min)	0.9	0.9	0.9	0.9	0.9
	t90(min)	6.8	6.8	6.9	7.0	7.0
	MH(dNm)	34.8	38.5	40.3	43.4	46.3
	ML(dNm)	4.6	5.1	5.6	5.9	6.4
Properties***	Tensile Strength (MPa)	16	17	17	17	17
	Tensile Elongation (%)	360	320	280	260	210
	100% Modulus (MPa)	2.3	3.8	5.0	7.5	9.5
	Hardness (ShoreA)	63	67	70	75	80
	Specific Gravity	1.54	1.57	1.59	1.60	1.62
	Compression Set (%, 200℃×70hrs)	29	29	29	28	29
	Compression Set (%, 200℃×22hrs)	20	21	19	18	17

* triallylisocyanurate (100%liquid)
** 1,3Bis (t-buthylperoxy isopropyl) benzene (100%active)
*** Cure condition : 170℃×20min press cure + 200℃×4hrs post cure

●Suitable Co-agents and Peroxides

A number of peroxides and co-agents can be used to obtain the desired properties.

		AFLAS®150P Standard Formulation (Example1)	AFLAS®150P Standard Formulation (Example2)	AFLAS®150P Standard Formulation (Example3)	Not Suitable (Example1)	Not Suitable (Example2)
Formulation	AFLAS®150P	100	100	100	100	100
	MT-Carbon (N990)	30	30	30	30	30
	TAIC*	5	5	—	5	5
	TAIC 60% Active Powder**	—	—	8.3	—	—
	Peroxide A***	1	—	1	—	—
	Peroxide A 40%active****	—	2.5	—	1	—
	Peroxide C*****	—	—	—	—	2
	Sodium Stearate	1	1	1	1	1
Cure Condition	Press Cure	170℃/20min	170℃/20min	170℃/20min	170℃/20min	170℃/20min
	Post Cure	200℃/4hrs	200℃/4hrs	200℃/4hrs	200℃/4hrs	200℃/4hrs
Properties***	Tensile Strength (MPa)	17	←Equivalent	←Equivalent	13	14
	Tensile Elongation (%)	280	←Equivalent	←Equivalent	350	350
	100% Modulus (MPa)	5	←Equivalent	←Equivalent	4.5	4.6
	Hardness (ShoreA)	70	←Equivalent	←Equivalent	72	71
	Compression Set (%, 200℃×70hrs)	29	←Equivalent	←Equivalent	41	39

* triallylisocyanurate (100%liquid)
** triallylisocyanurate (60%powder)
*** 1,3Bis (t-buthylperoxy isopropyl) benzene (100%active)
**** 1,3Bis (t-buthylperoxy isopropyl) benzene (40%active)
***** 2,3 dimethyl 2,5 di(t-buthylperoxy) hexane

5.Heat Resistance

AFLAS® has excellent heat resistance with a continuous service temperature of 200℃ and a maximum peak exposure temperature of 250℃.

●Heat Resistance

				AFLAS®100S	AFLAS®150P	AFLAS®200P	AFLAS®300S	2-FKM*
Formulation	Polymer			100	100	100	100	100
	MT-Carbon(N990)			30	30	25	25	30
	TAIC**			5	5	5	3	—
	Peroxide A***			1	1	1	—	—
	Peroxide B****			—	—	—	1	—
	Sodium Stearate			1	1	1	—	—
	Zinc Stearate			—	—	—	1	—
	MgO			—	—	3	—	3
	$Ca(OH)_2$			—	—	—	—	6
Properties	Tensile Strength (MPa)			20	17	19	13	14
	Tensile Elongation (%)			230	280	270	220	180
	100% Modulus (MPa)			7	5	5	4	8
	Hardness (ShoreA)			72	70	69	67	86
	Specific Gravity			1.59	1.59	1.68	1.59	1.83
Heat Resistance	200℃	200hrs	Retention of Tensile Strength(%)	95	96	100	111	97
			Retention of Tensile Elongation(%)	88	93	84	97	98
			Change in Hardness (points)	+1	+1	+1	+1	+2
		500hrs	Retention of Tensile Strength(%)	110	114	90	112	99
			Retention of Tensile Elongation(%)	87	93	72	96	101
			Change in Hardness (points)	+5	+5	+1	0	+2
		1000hrs	Retention of Tensile Strength(%)	101	102	90	119	81
			Retention of Tensile Elongation(%)	91	93	72	106	116
			Change in Hardness (points)	+3	+2	+1	+1	+1
	230℃	200hrs	Retention of Tensile Strength(%)	88	89	83	105	93
			Retention of Tensile Elongation(%)	107	114	77	119	113
			Change in Hardness (points)	-1	0	+1	-2	-1
		500hrs	Retention of Tensile Strength(%)	74	72	51	92	57
			Retention of Tensile Elongation(%)	122	132	53	144	154
			Change in Hardness (points)	-4	-3	+1	-5	0
	250℃	96hrs	Retention of Tensile Strength(%)	78	73	80	108	81
			Retention of Tensile Elongation(%)	106	116	81	117	128
			Change in Hardness (points)	0	0	+1	-4	+1

* Cure promoters are incorporated into the polymer ** triallylisocyanurate (100% liquid) *** 1,3Bis (t-buthylperoxy isopropyl) benzene (100% active)
**** Di t-buthylperoxide (100% active)

※Heat Resistance Performance If a polymer meets the following criteria at a particular temperature it is said to have good heat resistance at that temperature. After 70hrs heat aging, ①±30% retention of tensile strength ②±30% retention of tensile elongation ③±5 points change of hardness
※ In order to determine the continuous service temperature of a polymer the following test criteria must be met at the temperature in question. After 1000hrs heat aging, ①±30% retention of tensile strength ②±30% retention of tensile elongation ③±5 points change of hardness

6.Acid and Base Resistance

AFLAS® has excellent resistance to high concentrations of acids, bases and oxidants at high temperatures. AFLAS® is superior in this respect to FKM elastomers.

●Effect on Volume of Acids and Bases

Chemical		Immersion Conditions Temp (℃)	Immersion Conditions Time (day)	AFLAS®	FKM	Silicone rubber	EPDM	CR	IIR	NBR	CSM
Sulphuric Acid	Fuming	25	7	A	C	×	×	×	×	×	×
	96%	100	3	A	D	×	×	×	×	×	×
		70	3	A	C	×	×	×	×	×	×
		40	3	A	B	×	D	×	×	×	D
		25	7	A	B	×	C	×	×	×	D
	60%	100	3	A	A	A	A	A	A	C	B
		25	7	A	A	A	A	A	A	A	A
	20%	100	3	A	A	A	A	A	A	B	A
Nitric Acid	Fuming	25	7	C	C	×	×	×	×	×	×
	98%	25	7	C	D	D	×	×	×	×	×
	60%	100	3	C	×	×	×	×	×	×	×
		70	3	B	×	×	×	×	×	×	×
		40	3	A	C	B	×	×	×	×	×
		25	7	A	B	B	D	×	×	×	×
	20%	100	3	C	D	×	×	×	×	×	×
		70	3	B	D	×	×	×	×	×	×
		25	7	A	A	C	B	B	B	B	B
Hydrochloric Acid	37%	70	3	B	D	×	C	D	C	D	D
		40	3	A	C	C	B	C	B	B	B
		25	7	A	B	C	A	B	A	B	A
	20%	100	3	B	D	×	C	D	D	D	D
		70	3	B	D	×	D	D	D	D	D
		25	7	A	A	B	A	A	A	B	A
Sodium Hydroxide	50%	100	3	A	×	B	A	B	A	A	B
		70	3	A	A	A	A	A	A	A	B
		25	7	A	A	B	A	A	A	A	A
	20%	100	3	A	D	A	A	A	A	A	A
		70	3	A	A	A	A	A	A	A	A
Fluoric Acid	50%	25	7	A	B	×	B	D	A	D	A
Aqueous Ammonia	28%	70	3	A	B	A	A	B	A	A	C
		25	7	A	A	A	A	A	A	A	A

A: Volume change ≦5%, B: Volume change <15%, C: Volume change <40%
D: Volume change >40%, ×: disintegration or dissolution

Acid Resistance (AFLAS®150P Basic Formulation, JIS3 Dumbbell)

Chemical Volume		Immersion Conditions		Retention(%)			Hardness Change (points)	Hardness Change (%)
		Temp(℃)	Time(day)	Tensile Strength	Tensile Elongation	100% Modulus		
Sulphuric Acid	Fuming	R.T.	7	76	98	115	-2	4.2
		R.T.	30	—	—	—	+1	0.7
		R.T.	90	—	—	—	—	5.1
		R.T.	180	—	—	—	—	7.4
	96%	100	3	99	101	73	-3	4.4
		R.T.	7	98	99	92	-3	0.4
		R.T.	30	—	—	—	+1	0.2
		R.T.	90	—	—	—	—	1.1
		R.T.	180	—	—	—	—	2.3
	60%	100	3	107	104	116	+1	0.4
		R.T.	7	103	98	102	-1	0.1
		R.T.	30	—	—	—	+1	0.3
		R.T.	90	—	—	—	—	0.2
		R.T.	180	—	—	—	—	0.4
	20%	100	3	99	98	103	-3	0.4
		R.T.	7	102	105	93	-1	-0.5
		R.T.	30	—	—	—	+1	0.4
Nitric Acid	Fuming	R.T.	7	42	126	49	-7	19
		R.T.	30	—	—	—	-2	15.8
		R.T.	90	—	—	—	—	14.8
		R.T.	180	—	—	—	—	14.9
	98%	R.T.	7	—	—	—	—	—
		R.T.	30	—	—	—	-10	21.4
		R.T.	90	—	—	—	—	20.6
		R.T.	180	—	—	—	—	23.1
	60%	100	3	—	—	—	-18	34
		70	3	44	107	61	-3	10
		40	3	—	—	—	+1	1.2
		R.T.	7	94	95	91	-1	1.3
		R.T.	30	—	—	—	0	1.0
		R.T.	90	—	—	—	—	2.0
		R.T.	180	—	—	—	—	5.1
	20%	100	3	43	93	50	-10	23
		70	3	42	90	58	-13	25
		40	7	105	114	111	-1	-5.0
		R.T.	30	—	—	—	+1	0.4
		R.T.	90	—	—	—	—	0.5
		R.T.	180	—	—	—	—	1.3
Hydrochloric Acid	37%	70	3	57	112	74	-2	7.0
		40	3	77	88	108	-4	2.3
		R.T.	7	100	107	118	+1	0.2
		R.T.	30	—	—	—	+1	0.7
		R.T.	90	—	—	—	—	1.8
		R.T.	180	—	—	—	—	4.5
	20%	100	3	67	98	92	-7	6.5
		70	3	58	85	92	-6	7.4
		R.T.	7	103	107	112	-1	-4.6
		R.T.	30	—	—	—	+1	0.7
Fluoric Acid	50%	R.T.	7	63	117	100	+6	1.5
		R.T.	30	—	—	—	0	1.7
		R.T.	90	—	—	—	—	2.9
		R.T.	180	—	—	—	—	4.1
Chromic Acid	62%	R.T.	7	90	98	92	-2	1.7
5% Fluoric Acid + 25% Nitric Acid		100	7	70	84	105	-6	3.5
46% Chromic Acid + 25% Sulphuric Acid		R.T.	7	115	117	100	-1	2.6

Base Resistance (AFLAS®150P Basic Formulation, JIS3 Dumbbell)

Chemical Volume		Immersion Conditions		Retention(%)			Hardness Change (points)	Hardness Change (%)
		Temp(℃)	Time(day)	Tensile Strength	Tensile Elongation	100% Modulus		
Sodium Hydroxide	50%	180	3	102	91	86	+1	1.5
		180	7	96	94	81	0	-0.3
		180	30	117	81	126	+2	-0.1
		100	3	101	116	96	-1	1.1
		70	7	103	90	112	0	0.0
		70	30	105	84	123	0	0.1
		R.T.	7	108	116	75	+2	1.2
		R.T.	30	—	—	—	-1	0.3
		R.T.	90	—	—	—	—	0.7
		R.T.	180	—	—	—	—	0.5
	20%	100	3	95	117	92	-3	2.0
		R.T.	7	85	104	100	-1	-0.3
		R.T.	30	—	—	—	+1	-0.1
Aqueous Ammonia	28%	70	3	82	116	116	-1	3.2
		70	7	100	88	94	-2	1.5
		70	30	105	81	100	-1	2.0
		R.T.	7	—	—	—	0	1.3
		R.T.	30	—	—	—	+1	0.8
		R.T.	90	—	—	—	—	1.0
		R.T.	180	—	—	—	—	2.5
	7%	140	30	87	107	68	-8	16.1
Urea Solution	30%	100	7	107	94	94	0	2.8
Ethylene Diamine		25	7	105	108	108	+5	1.0

7.Excellent Chemical Resistance

AFLAS® has excellent chemical resistance, examples of which are in the table below.

●Chemical Resistance (AFLAS®150P Basic Formulation, JIS3 Dumbbell)

Chemical Volume	Immersion Conditions		Retention(%)			Hardness Change (points)	Hardness Change (%)
	Temp(℃)	Time(day)	Tensile Strength	Tensile Elongation	100% Modulus		
Hot Water	100	3	89	117	117	0	1.1
Steam (6.2atm)	160	7	91	84	110	-3	4.6
Bromine	R.T.	7	54	136	—	—	6.2
32% Bromine + 18% Hydrochloric Acid + 25% Sulphuric Acid	100	1	66	112	95	-8	6.0
Chlorine Solution (Saturated)	100	4	22	28	87	-10	169
Chlorine Solution(Saturated) + 35% Sodium Chloride + Sodium Hypochlorite (pH9.6)	100	2.5	69	78	86	-9	5.9
10% Bleaching Liquor $Ca(ClO)_2$	100	7	112	89	148	-2	0
10% Sodium Hypochlorite	100	7	100	95	114	-1	1.0
10% Sodium Chlorite	100	7	80	93	57	-12	22
10% Sodium Chlorite + Acetic Acid(pH3.5)	100	1	67	105	39	-16	24
10% Sodium Chlorite + 5% Sodium Hydroxide	100	7	88	85	108	0	0.6
5% Sulphur Dioxide (Continuously Blown)	40	2	69	84	86	-4	7.8
30% Hydrogen Peroxide	100	7	105	99	110	0	-1.1
15% Hydrogen Peroxide + 3% Sodium Hydroxide	100	7	107	111	96	-2	-1.8
Lithium Bromide (53-63%) (Lithium Bromide Acid Stabilizer)	160	11	106	106	113	+1	-0.3
	200	11	99	110	87	+1	-0.3
Lithium Bromide (53-63%) (Stabilizer for Organics)	160	11	108	119	100	+1	-0.3
	200	11	95	118	90	+3	-0.2
Potassium Fluoride + Fluoric Acid (1:1.8)	85	3	94	111	109	-3	0.4
Triethylene Glycohol	230	3	88	148	—	-5	7.7
		10	84	169	—	-6	8.8
		20	74	145	—	-9	8.5

●Solvent Resistance (AFLAS®150P Basic Formulation)

Solvent	Volume Change(%)	Solvent	Volume Change(%)
Isoamyl alcohol	0	Toluene	41
Carbitol	0	Acetone	50
Methanol	0.2	Methylethylketone	58
Aniline	0.7	Acetic Acid	71
Methyl Cellosolve	1.4	Carbon Tetrachloride	86
Ethanol	2.3	Ethyl Acetate	88
Oil of Turpentine	2.9	Methyl Isobuthyl Ketone	95
Nitrobenzene	5.6	Trichloroethylene	95
NMP	9	Chloroform	112
Mono-ethanol Amine(120℃)	16	Methyl Chloroform	125
n-Hexane	24	Trichlorotrifluoroethane	249
Benzene	40		

(Immersion ; R.T.×7days)

●Hot Water, Steam, Base Resistance (Standard Formulations - see page 4, JIS3 Dumbbell)

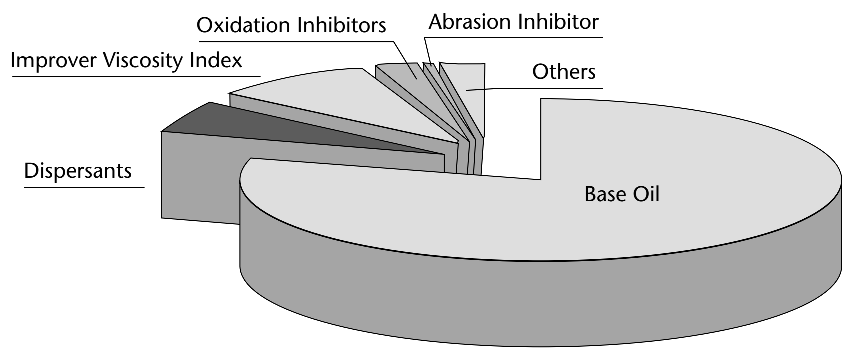
			AFLAS®100S	AFLAS®150P	AFLAS®200P	AFLAS®300S	2-FKM*
Hot Water (180℃)	168hrs	Retention of Tensile Strength (%)	88	97	29	70	53
		Retention of Tensile Elongation (%)	104	105	42	88	124
		Change in Hardness (points)	-4	-4	-14	-3	-16
		Volume Change (%)	14	15	105	4	24
	720hrs	Retention of Tensile Strength (%)	85	91	11	60	17
		Retention of Tensile Elongation (%)	100	103	25	104	58
		Change in Hardness (points)	-5	-5	-29	-4	-28
		Volume Change (%)	16	20	120	6	103
Steam (180℃)	168hrs	Retention of Tensile Strength (%)	90	91	41	84	66
		Retention of Tensile Elongation (%)	107	99	62	90	146
		Change in Hardness (points)	-3	-3	-13	-4	-11
		Volume Change (%)	8	10	72	2	15
	720hrs	Retention of Tensile Strength (%)	92	92	28	73	51
		Retention of Tensile Elongation (%)	88	111	42	88	147
		Change in Hardness (points)	-3	-3	-16	-6	-15
		Volume Change (%)	10	11	91	3	20
50% Sodium Hydroxide (70℃)	168hrs	Retention of Tensile Strength (%)	102	103	99	101	36
		Retention of Tensile Elongation (%)	100	90	90	102	84
		Change in Hardness (points)	+1	0	0	-2	-12
		Volume Change (%)	0	0	0	-1	-34
	720hrs	Retention of Tensile Strength (%)	100	105	98	111	Disintegration
		Retention of Tensile Elongation (%)	100	84	89	95	
		Change in Hardness (points)	0	0	-1	0	
		Volume Change (%)	-1	0	1	-1	
28% Aqueous Ammonia (70℃)	168hrs	Retention of Tensile Strength (%)	96	100	106	91	Disintegration
		Retention of Tensile Elongation (%)	98	88	81	93	
		Change in Hardness (points)	-1	-2	-1	0	
		Volume Change (%)	1	2	7	3	
	720hrs	Retention of Tensile Strength (%)	99	105	84	83	Disintegration
		Retention of Tensile Elongation (%)	94	81	62	89	
		Change in Hardness (points)	-1	-1	-3	0	
		Volume Change (%)	1	2	32	5	

* Cure promoters are incorporated into the polymer

8.Oil Resistance

Due to its excellent resistance to amines, AFLAS® performs exceptionally well in engine oil & gear lubricant applications.

●An Example of Engine Oil Component



●Application for Automotive Fluids : AFLAS® vs. FKM

Oil	Component	Application	Temperature (℃)	AFLAS®	FKM
Engine Oil		Crank Shaft Seal	160	◎	△
		Valve Stem Seal	—	—	—
AT Fluids		Transmission Seal	160	◎	△
Gear Oil		Pinion Seal	135	◎	×
		Axle Seal	—	—	—
		Differential Gear Seal	—	—	—
Brake Fluids	Polyglycolether		135	○	○
Coolants	Glycol-H_2O	Cylinder Liner Seal	135	○	△
		Water Pump Seal	—	—	—
		Cylinder Head Gasket	—	—	—
Operating Oils	Glycol-H_2O	Shock Absorber Seal	110	○	△
	Phosphate		—	○	○
	Silicone Oil		—	○	◎
Fuels	Gasoline		110	×	◎
	Light Oil		—	×	◎
	Heavy Oil		—	◎	△
	100% Methanol		—	◎	△

◎:Suitable, ○:Applicable, △:Caution, ×:Not applicable

●Oil Resistance (Standard Formulations - see page 4, JIS3 Dumbbell)

			AFLAS®100S	AFLAS®150P	AFLAS®200P	AFLAS®300S	2-FKM*
Engine Oil (SJ) 175℃	70hrs	Retention of Tensile Strength (%)	76	71	—	—	96
		Retention of Tensile Elongation (%)	105	116	—	—	78
		Change in Hardness (points)	-1	-1	—	—	+1
		Volume Change (%)	—	—	—	—	—
	168hrs	Retention of Tensile Strength (%)	87	82	—	—	46
		Retention of Tensile Elongation (%)	90	91	—	—	35
		Change in Hardness (points)	-6	-5	—	—	0
		Volume Change (%)	9	9	—	—	1
	500hrs	Retention of Tensile Strength (%)	92	85	—	—	41
		Retention of Tensile Elongation (%)	95	93	—	—	35
		Change in Hardness (points)	-6	-6	—	—	+1
		Volume Change (%)	10	9	—	—	1
	1000hrs	Retention of Tensile Strength (%)	92	88	—	—	35
		Retention of Tensile Elongation (%)	95	99	—	—	35
		Change in Hardness (points)	-5	-5	—	—	+3
		Volume Change (%)	7	7	—	—	0
Diesel Oil (CD) 175℃	200hrs	Retention of Tensile Strength (%)	88	84	—	—	69
		Retention of Tensile Elongation (%)	90	93	—	—	59
		Change in Hardness (points)	-3	-3	—	—	—
		Volume Change (%)	8	7	—	—	4
	500hrs	Retention of Tensile Strength (%)	96	89	—	—	73
		Retention of Tensile Elongation (%)	90	94	—	—	51
		Change in Hardness (points)	-7	-5	—	—	+1
		Volume Change (%)	8	7	—	—	1
Automatic Transmission Oil 175℃	200hrs	Retention of Tensile Strength (%)	86	82	—	—	61
		Retention of Tensile Elongation (%)	86	96	—	—	54
		Change in Hardness (points)	-3	-4	—	—	+1
		Volume Change (%)	14	9	—	—	1
	500hrs	Retention of Tensile Strength (%)	84	87	—	—	62
		Retention of Tensile Elongation (%)	81	93	—	—	48
		Change in Hardness (points)	-6	-5	—	—	-1
		Volume Change (%)	8	9	—	—	9
	1000hrs	Retention of Tensile Strength (%)	86	88	—	—	52
		Retention of Tensile Elongation (%)	82	96	—	—	41
		Change in Hardness (points)	-8	0	—	—	-1
		Volume Change (%)	10	10	—	—	3

* Cure promoters are incorporated into the polymer

●Oil Resistance (Standard Formulations - see page4, JIS3 Dumbbell)

			AFLAS®100S	AFLAS®150P	AFLAS®200P	AFLAS®300S	2-FKM*
Gear Oil A 175℃	70hrs	Retention of Tensile Strength (%)	—	67	—	—	53
		Retention of Tensile Elongation (%)	—	93	—	—	34
		Change in Hardness (points)	—	-11	—	—	+5
		Volume Change (%)	—	8	—	—	1
	168hrs	Retention of Tensile Strength (%)	70	—	—	88	41
		Retention of Tensile Elongation (%)	84	—	—	98	33
		Change in Hardness (points)	-11	—	—	-4	-1
		Volume Change (%)	9	—	—	4	—
	500hrs	Retention of Tensile Strength (%)	—	78	—	—	42
		Retention of Tensile Elongation (%)	—	101	—	—	37
		Change in Hardness (points)	—	-6	—	—	0
		Volume Change (%)	—	5	—	—	—
	1000hrs	Retention of Tensile Strength (%)	79	65	—	—	—
		Retention of Tensile Elongation (%)	86	85	—	—	—
		Change in Hardness (points)	-6	-14	—	—	—
		Volume Change (%)	6	21	—	—	—
Gear Oil B 175℃	200hrs	Retention of Tensile Strength (%)	65	66	—	—	73
		Retention of Tensile Elongation (%)	82	88	—	—	86
		Change in Hardness (points)	-17	-15	—	—	-11
		Volume Change (%)	22	22	—	—	15
	500hrs	Retention of Tensile Strength (%)	66	64	—	—	74
		Retention of Tensile Elongation (%)	88	102	—	—	85
		Change in Hardness (points)	-14	-23	—	—	-11
		Volume Change (%)	21	21	—	—	17
	1000hrs	Retention of Tensile Strength (%)	62	—	—	—	64
		Retention of Tensile Elongation (%)	89	—	—	—	89
		Change in Hardness (points)	-18	—	—	—	-19
		Volume Change (%)	20	—	—	—	24
50% LLC 160℃	70hrs	Retention of Tensile Strength (%)	81	82	—	—	67
		Retention of Tensile Elongation (%)	94	104	—	—	72
		Change in Hardness (points)	-6	-6	—	—	-4
		Volume Change (%)	4	5	—	—	10

* Cure promoters are incorporated into the polymer

●Oil Resistance (Standard Formulations - see page 4, JIS3 Dumbbell)

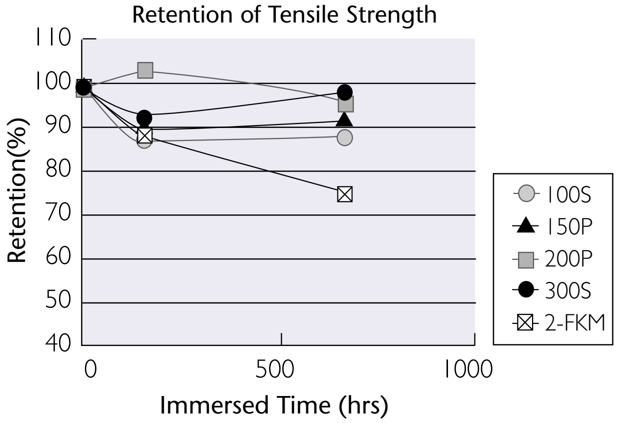
			AFLAS®100S	AFLAS®150P	AFLAS®200P	AFLAS®300S	2-FKM*
Heavy Oil C 140℃×72hrs	100 %	Retention of Tensile Strength (%)	85	84	—	—	87
		Retention of Tensile Elongation (%)	92	98	—	—	88
		Change in Hardness (points)	-8	-6	—	—	-1
		Volume Change (%)	8	9	—	—	3
	60 %	Retention of Tensile Strength (%)	68	69	—	—	83
		Retention of Tensile Elongation (%)	87	101	—	—	93
		Change in Hardness (points)	-9	-6	—	—	-5
		Volume Change (%)	9	10	—	—	8
CNG Oil 175℃	168hrs	Retention of Tensile Strength (%)	87	92	89	91	65
		Retention of Tensile Elongation (%)	99	100	75	90	61
		Change in Hardness (points)	-8	-7	-4	-6	0
		Volume Change (%)	6	8	3	7	1
	720hrs	Retention of Tensile Strength (%)	85	94	88	87	52
		Retention of Tensile Elongation (%)	99	96	68	93	42
		Change in Hardness (points)	-7	-9	-3	-8	0
		Volume Change (%)	9	9	4	6	1
ASTM No.3 Oil 175℃	168hrs	Retention of Tensile Strength (%)	—	84	—	80	—
		Retention of Tensile Elongation (%)	—	105	—	83	—
		Change in Hardness (points)	—	-11	—	-9	—
		Volume Change (%)	—	15	—	12	—
	720hrs	Retention of Tensile Strength (%)	—	87	—	79	—
		Retention of Tensile Elongation (%)	—	95	—	87	—
		Change in Hardness (points)	—	-10	—	-7	—
		Volume Change (%)	—	16	—	12	—
Engine Oil (SM) 175℃	168hrs	Retention of Tensile Strength (%)	87	90	102	92	88
		Retention of Tensile Elongation (%)	98	92	82	84	89
		Change in Hardness (points)	-8	-7	-4	-6	0
		Volume Change (%)	6	7	2	7	1
	720hrs	Retention of Tensile Strength (%)	88	91	95	97	73
		Retention of Tensile Elongation (%)	102	92	72	98	65
		Change in Hardness (points)	-6	-7	-2	-4	+2
		Volume Change (%)	6	7	3	6	0
Ethylene Diamine 25℃	168hrs	Retention of Tensile Strength (%)	105	105	—	—	Disintegration
		Retention of Tensile Elongation (%)	93	108	—	—	
		Change in Hardness (points)	+1	5	—	—	
		Volume Change (%)	0	1	—	—	

* Cure promoters are incorporated into the polymer

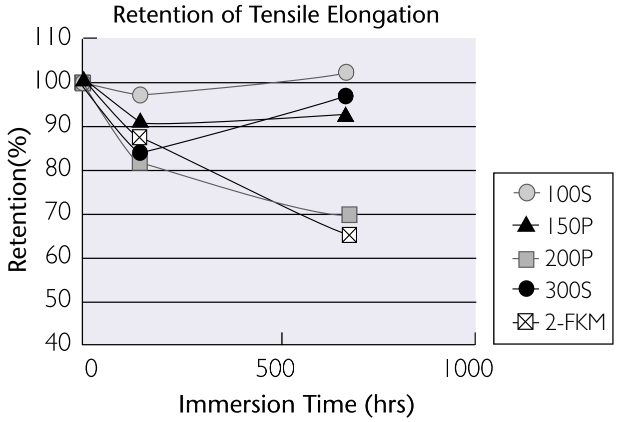
●Oil Resistance

■Engine Oil (SM, Immersed at 175℃)

Retention of Tensile Strength

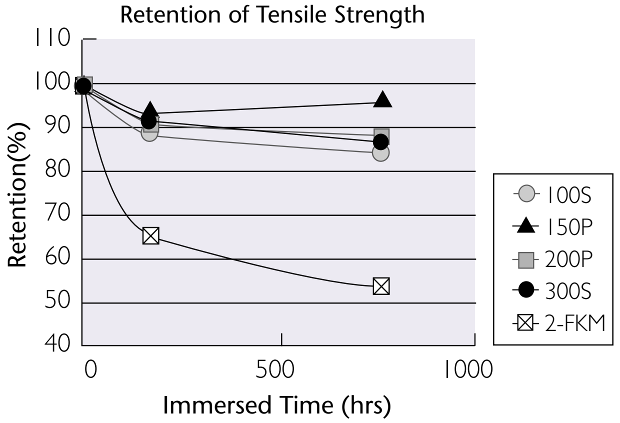


Retention of Tensile Elongation

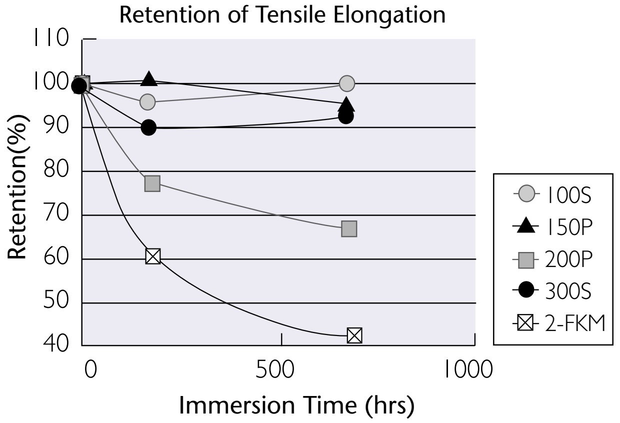


■CNG Automotive Engine Oil (Immersed at 175℃)

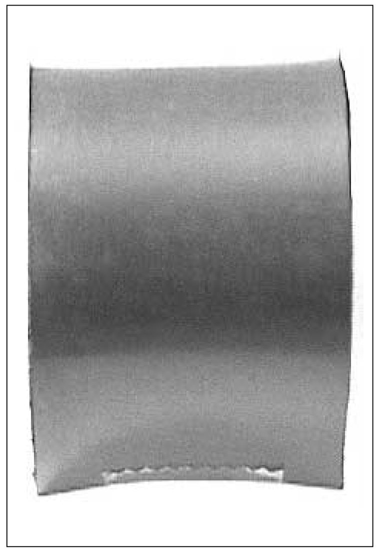
Retention of Tensile Strength



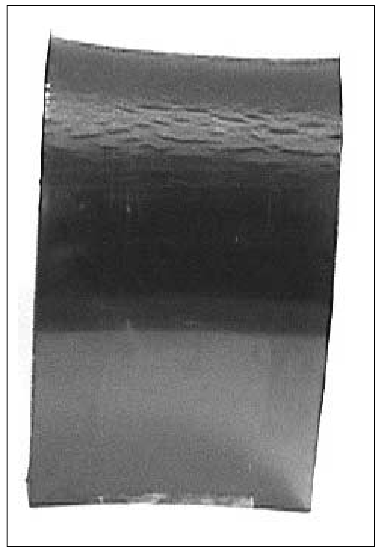
Retention of Tensile Elongation



●Examples After Immersion Test in Engine Oil



AFLAS® 150P
(No cracking)



2-FKM
(Cracking)

SJ,175℃×240hrs

9.Electrical Properties

AFLAS® has superior electrical properties compared to FKM elastomers.

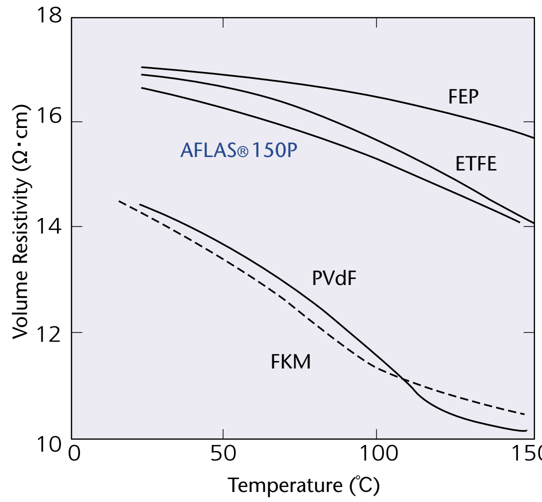
●Electrical Properties

	Volume Resistivity(Ω·cm)	Dielectric Constant(1kHz)	Dielectric Loss(1kHz)	Dielectric Breakdown(kV/mm)
AFLAS® (100,150,300S)	3×10^{16}	2.8	0.03	23
AFLAS® (200P)	4×10^{15}	5.9	0.03	16
FKM	2×10^{13}	17	0.03	20
EPDM	5×10^{16}	2	0.0015	40
Silicone Rubber	5×10^{15}	3~4	0.007	25
IIR	1×10^{15}	3	0.005	30
SBR	1×10^{15}	2~3	0.006	25
Chloroprene Rubber	2×10^{13}	7	0.04	15

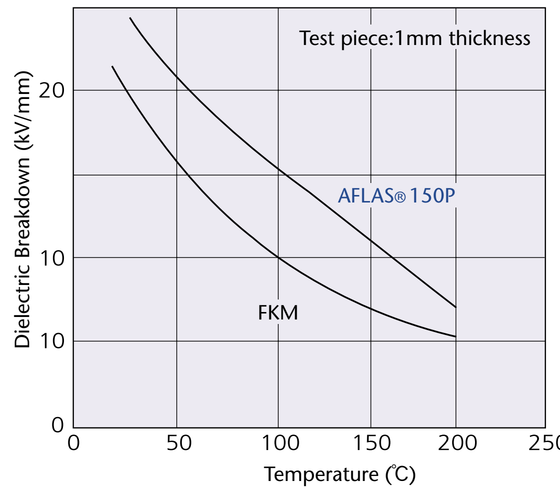
Pure rubber compound at R.T.

●Electrical Resistivity vs. Temperature

■Volume Resistivity vs. Temperature (pure rubber compound)



■Dielectric Breakdown vs. Temperature (pure rubber compound)



●Fundamental Properties of AFLAS® Vulcanised by Electron Beam

	AFLAS® 100S	AFLAS® 150E	AFLAS® 150C	AFLAS® 150CS
Specific Gravity	1.55	1.55	1.55	1.55
Hardness (Shore A)	50	39	52	51
100%Modulus (MPa)	1.5	1.1	1.5	1.4
Tensile Strength (MPa)	18	9	19	17
Tensile Elongation (%)	330	460	400	360
Volume Resistivity (Ω·cm)	$>10^{16}$	$>10^{16}$	$>10^{16}$	$>10^{16}$
Dielectric Constant at 1kHz	2.8	2.8	2.8	2.8
Dielectric Break Down (kV/mm)	25	23	24	23

Cured in its raw state by 100kGy of electron beam (EB) irradiation.

10.Other Properties

●Radiation Resistance

AFLAS® is stable against γ-rays of up to 2000kGy.

γ-ray (kGy)		0	100	200	500	1000	2000
AFLAS®150P*	Tensile Strength (MPa) Tensile Elongation (%)	17 280	18 260	19 250	18 130	18 100	18 50
2-FKM	Tensile Strength (MPa) Tensile Elongation (%)	16 440	15 200	12 170	12 110	14 60	17 20
PTFE	Tensile Strength (MPa) Tensile Elongation (%)	30 320	Disintegration Disintegration	Disintegration Disintegration	— —	— —	— —

*Standard formulation, JIS3 dumbbell

●Gas Permeability

AFLAS® is impermeable to various gases.

	Nitrogen	Oxygen	CO_2
AFLAS®150P	7	23	29
2-FKM	4	15	78
Epichlorohydrine Rubber	—	5	—
Butyl Rubber	3	10	39
CSM Rubber	12	28	210
Chloroprene Rubber	9	30	200
SBR	50	130	940
Natural Rubber	60	180	1,000
EPDM	60	190	820
Silicone Rubber	2000	4000	16000

Pure rubber compound, $(cc \cdot mm/cm^2 \cdot s \cdot cmHg) \times 10^{-10}$, R.T.

●Flame Resistance

AFLAS® burns in a flame but stops burning when the flame is removed.

●Weatherability

AFLAS® has very good weathering characteristics and shows almost no change in properties after a one year exposure test.

●Ozone Resistance

No change in properties after one-month exposure in 50ppm of ozone at 40℃.

●Flexibility at Low Temperature

In terms of compression set, rigidity modulus and TR-10 AFLAS®100, 150 and 300 retain elasticity to approximately 0℃ and AFLAS®200 to approximately -10℃. However since the brittle point of AFLAS®100S and AFLAS®150P is -40℃, AFLAS® is usable at low temperatures, depending upon application method and purpose.

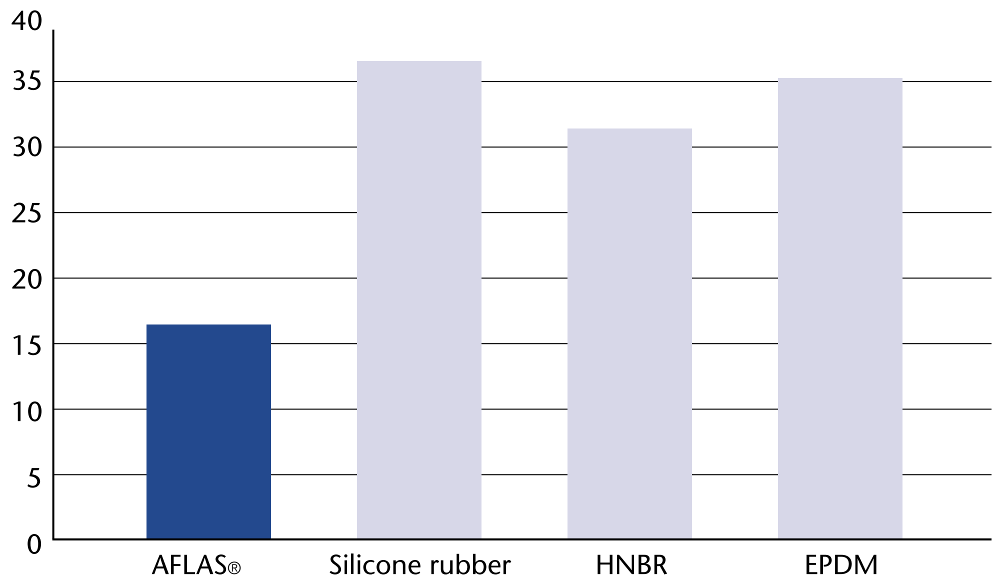
(Brittle point may change relating to the formulation.)

	AFLAS®100S	AFLAS®150P	AFLAS®200P	AFLAS®300S	2-FKM	3-FKM
Tg(℃)	-3	-3	-13	-3	-22	-6
TR-10	3	3	-8	3	-17	-7

●Odour Retention

AFLAS® has extremely low odour retention and is resistant to chemicals, steam and ultraviolet ray sterilisation. AFLAS® conforms to Japanese food contact regulations and AFLAS®100S conforms to the American USP Class VI regulation.

■Odour Index



※The odour index indicates the level of odour which can be detected by smell. An odour index of 10 indicates an odour level requiring dilution 10 times before it is undetectable whereas an odour index of 20 must be diluted 100 times and an odour index of 30 requires 1000 times dilution.

※ Data is based on an immersion test with orange juice at 80℃ for 24hrs and subsequent washing in water for 30min.

※ Facility : Shimadzu FF-2A

11.Typical Applications

AFLAS® is used in a range of applications including, thermal power plants, the oil and gas industry, ocean development, chemical and nuclear plants, the automotive industry, electronics and machinery.

1. Packings and O-rings

AFLAS® has excellent heat resistance and chemical resistance and is used in chemical plants, downhole applications.

2. Engine Gaskets

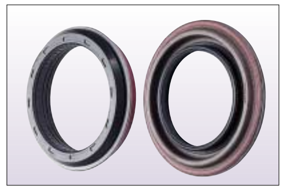
AFLAS® has excellent resistance to both engine oils and engine coolants.

3. Wire & Cable

AFLAS®100,150 and 300 have excellent electrical properties and therefore are suitable for insulation jacketing of cables.

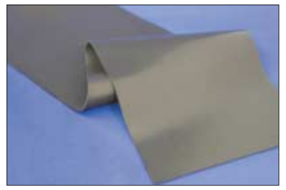
4. Shaft Seals

AFLAS® has excellent chemical resistance to engine oil additives, for example, dispersants, oxidation inhibitors and abrasion inhibitors.



5. Thin Sheet

AFLAS®150E and AFLAS®300S are suitable for extrusion and calendaring for the manufacture of extremely thin sheet.



6. AFLAS® Sponge

AFLAS® can be moulded into a sponge which means it can be used in an even greater variety of applications.

7. AFLAS® Latex

AFLAS® latex is an aqueous dispersion of AFLAS® polymer suitable for use as a binder or coating material.

AFLAS®
FLUOROELASTOMERS