ISSN 0141-9560

Natural Rubber Engineering Data Sheet

1980

EDS 16

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A Malaysian Rubber Research and Development Board Organization.

Natural Rubber engineering vulcanizate: 1·12MPa shear modulus (71 IRHD) Ref. no. MRPRA EDS 16

A conventional accelerated-sulphur vulcanizate containing 45 parts phr of HAF (N-330) carbon black. Suitable for most engineering applications at moderate and low temperatures.
EDS 17 and 18 have the same formulation but different mix preparations.

Formulation

	parts by weight
Natural rubber, SMR CV60	100
Zinc oxide	5
Stearic acid	2
Carbon black, HAF (ASTM N-330)	45
Process oil[1]	4·5
Antioxidant/antiozonant, HPPD[2]	3
Antiozonant wax[3]	2
CBS[4]	0·6
Sulphur	2·5

1. Low viscosity naphthenic oil; Fina Process Oil 2059 (Petrofina) was used.
2. N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine; Santoflex 13 (Monsanto) was used.
3. Sunproof Improved (Uniroyal) was used.
4. N-cyclohexylbenzothiazole-2-sulphenamide.

Where ingredients in MRPRA formulations are designated by trade names this indicates only that these were the materials used to develop the formulation and does not imply recommendation of specific trade materials. Chemically equivalent materials would normally be expected to give similar results.

Mix preparation and properties

Francis Shaw K1 Intermix, 3kg batch, 60°C, 45rev/min, 0·55MPa (80 lbf/in²) ram pressure. 0min: add rubber. 1min: add ZnO, StA, HPPD, wax. 2–13min: slow addition of black with oil added at 9min. 14min: sweep down. 15min: discharge. Mix finalized on cold mill.

Mooney viscosity (ISO/R289), ML1+4, 100°C	56·5
Mooney scorch (ISO 667), t_5, 120°C, min	22·1
Monsanto Rheometer (ISO 3417), 140°C	
scorch, t_{s1}, min	7·3
time to 95% crosslinking, min	28·0

Vulcanizate properties

for press cure 45min at 140°C

Density (ISO 2781), Mg/m³	1·104
Hardness (ISO 48), IRHD	71
Tensile strength (*TS*) (ISO 37), MPa	27
Elongation at break (*EB*) (ISO 37), %	550
Modulus at 300% elongation(*M300*)(ISO 37),MPa	10·8
Relaxed modulus (*MR100*), MPa	2·02
Compression set (ISO 815)	
22h at 23°C, %	8
22h at 70°C, %	29
22h at 100°C, %	48
22h at 125°C, %	71
22h at 150°C, %	94
7 days at 23°C, %	11
7 days at 70°C, %	46
3 days at 100°C, %	60
Resilience, Lüpke (ISO 4662), %	63
Stress relaxation, bonded disk 13mm dia × 6·3mm	
20% compression, % per decade	3·6
Tear strength (ISO 34)	
trouser, kN/m	24
angle, without nick, kN/m	112
angle, with 1mm nick, kN/m	52
crescent (with 1mm nick), kN/m	112

Tension fatigue, ring test pieces, kc to failure

strain range	minimum strain 0%	12½%	25%	37½%
50%	>2000	1234	1789	>2000
75%	700	359	594	1715
100%	218	187	238	489
125%	139	100	104	198
150%	57	60	49	89

Goodrich Flexometer (ISO 4666)	
static stress 1MPa, stroke 5·71mm, 30Hz, 100°C	
time to failure, min	121
Abrasion loss, Akron (BS 903:A9) dusted, mg/1000rev	48
Ozone resistance (ISO 1431), 40°C, 20% strain	
No cracks after 7 days at 100pphm ozone	
Resistance to liquids (ISO 1817), 70h at 100°C	
Oil No. 3, volume change, %	315
Water, volume change, %	5·3

Low temperature hardness (ISO 3387) IRHD

days	1	3	7	14	21	28
0°C	67	67	68	67	67	68
−10°C	71	73	70	72	71	72
−25°C	74	77	78	77	79	80
−40°C	74	75	70	75	74	76

Low temperature compression set (ISO 1653) lubricated small disks, set after 30min recovery, %

days	1	3	7	14	21	28
0°C	12	14	16	10	19	19
−10°C	13	14	17	17	19	19
−25°C	31	32	32	42	50	57
−40°C	21	29	43	42	53	69

Impact brittleness (ISO 812), −40°C	no failures
Air-oven ageing resistance (ISO 188)	
increase in IRH, deg	
decrease in *TS* and *EB*, %	
increase in *M300* and *MR100*, %	

	IRH	*TS*	*EB*	*M300*	*MR100*
3 days at 70°C	1	−1	0	12	9
4 ,, ,,	1	1	5	17	8
7 ,, ,,	3	2	9	25	13
14 ,, ,,	4	6	13	32	25
3 days at 100°C	3	46	47	—	36
4 ,, ,,	2	55	58	—	48
7 ,, ,,	4	68	71	—	82
14 ,, ,,	11	78	87	—	—
1 day(s) at 125°C	−6	81	75	—	28
3 ,, ,,	3	82	91	—	—
1 day at 150°C	2	—	—	—	—

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Stress-strain characteristics

Shear modulus	(0–2%)	2·39MPa
,,	(0–50%)	1·12MPa
Bulk modulus (calculated)		2140MPa

Static shear moduli

Chord modulus G_{ch} = stress/strain; tangent modulus G_{tan} = slope of stress-strain curve. Strain rate ~ 30%/min.

Strain, %		2	5	10	25	50	75	100	150	200	250	300	350
1st cycle	G_{ch}, MPa	1·85	1·96	1·78	1·45	1·23	1·14	1·11	—	—	—	—	—
	G_{tan}, MPa	2·02	1·77	1·46	1·11	0·97	1·00	1·41	—	—	—	—	—
10th cycle	G_{ch}, MPa	2·39	1·92	1·65	1·32	1·12	1·05	1·14	1·31	1·59	1·96	2·39	2·85
	G_{tan}, MPa	1·98	1·60	1·28	1·00	0·87	1·02	1·72	1·98	2·93	3·99	5·09	5·78

First nine cycles to 100% strain. Set at end of 9th cycle 7·2%.

Static compression moduli

Chord modulus E_{ch} = stress/strain; tangent modulus E_{tan} = slope of stress-strain curve. Strain rate 1–2%/min.

Diameter/thickness		2 (S = 0·5)				4 (S = 1)				8 (S = 2)			
Strain, %		5	10	15	20	5	10	15	20	5	10	15	20
1st cycle	E_{ch}, MPa	9·2	8·0	7·6	7·4	16·5	14·4	14·1	14·6	42	40	45	54
	E_{tan}, MPa	7·1	6·7	6·7	7·1	13·3	12·7	14·6	18·4	36	45	65	105
10th cycle	E_{ch}, MPa	8·1	7·4	7·1	7·1	13·9	12·7	12·5	13·1	35	32	34	38
	E_{tan}, MPa	7·1	6·6	6·8	7·6	11·9	11·8	13·2	17·7	31	32	42	69
Max strain on 1st cycle			26%				27%				27%		
Set at end of 9th cycle			1·8%				1·5%				3·0%		

Diameter/thickness		12 (S = 3)				20 (S = 5)				32 (S = 8)			
Strain, %		5	10	15	20	5	10	15	20	5	10	15	20
1st cycle	E_{ch}, MPa	80	83	103	150	185	225	360	—	440	—	—	—
	E_{tan}, MPa	69	111	185	330	194	415	720	—	570	—	—	—
10th cycle	E_{ch}, MPa	64	64	70	89	146	153	210	—	335	—	—	—
	E_{tan}, MPa	59	74	120	220	144	270	450	—	400	—	—	—
Max strain on 1st cycle			23%				16%				9%		
Set at end of 9th cycle			3·0%				2·1%				1·3%		

Dynamic shear moduli and phase angles

Shear modulus is the ratio of stress amplitude to strain amplitude. Mean strain is zero.

Frequency	0·1Hz			1Hz							15Hz		
Strain amplitude, %	2	10	50	1	2	5	10	20	50	100	2	5	10
Shear modulus, MPa													
150°C	—	—	—	—	—	—	—	—	—	—	—	—	—
125°C	1·54	1·32	1·07	1·77	1·63	1·47	1·38	1·26	1·11	1·07	1·75	1·55	1·46
100°C	1·56	1·33	1·10	1·85	1·68	1·50	1·40	1·29	1·15	1·09	1·81	1·58	1·48
70°C	1·91	1·49	1·11	2·34	2·03	1·73	1·48	1·33	1·15	1·09	2·17	1·79	1·63
50°C	2·09	1·59	1·15	2·59	2·23	1·86	1·57	1·37	1·18	1·14	2·38	1·95	1·75
23°C	2·43	1·77	1·17	3·13	2·68	2·19	1·77	1·49	1·23	1·17	2·89	2·30	2·00
0°C	2·96	2·06	1·27	3·84	3·24	2·60	2·06	1·65	1·33	1·26	3·76	2·92	2·45
–10°C	3·14	2·16	1·29	4·27	3·56	2·78	2·17	1·67	1·38	1·30	4·33	3·07	2·74
–25°C	3·72	2·49	1·37	5·23	4·57	3·60	2·66	1·92	1·55	1·46	7·52	4·72	4·42
–40°C	6·30	3·41	1·54	13·5	11·5	8·90	5·67	2·95	2·12	1·98	29·7	16·0	9·16
Phase angle, degrees													
150°C	—	—	—	—	—	—	—	—	—	—	—	—	—
125°C	5·3	4·2	3·0	4·7	5·0	5·2	4·3	3·5	3·3	3·2	4·5	5·0	4·5
100°C	6·3	4·8	3·2	5·7	6·2	6·0	5·0	4·0	3·3	2·8	5·3	5·5	4·8
70°C	7·5	6·0	3·8	6·5	7·5	6·8	6·0	4·7	3·8	3·0	7·0	7·0	5·7
50°C	8·2	6·5	4·0	6·8	7·5	7·3	6·5	5·3	4·0	3·5	7·7	8·2	7·0
23°C	8·8	7·7	4·8	8·0	8·8	9·2	7·8	6·7	5·3	4·8	9·2	9·8	9·0
0°C	10	9·3	6·3	9·5	11	12	11	9·0	7·2	6·3	13	14	14
–10°C	11	11	7·0	10	13	14	13	11	8·8	7·3	18	20	18
–25°C	14	14	9·2	15	18	20	18	15	14	13	30	33	32
–40°C	25	27	16	31	35	39	37	32	28	25	41	43	42

Further information

EDS 1 Test methods used for the natural rubber engineering vulcanizates in the EDS series
EDS 2 Properties given for the natural rubber engineering vulcanizates in the EDS series
EDS 3 Effect of compounding on the properties of natural rubber engineering vulcanizates