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CARBON BLACK STUDY IN ROYALENE® 512 AND 502

This study is designed to reveal the relative reinforcing nature of various types of carbon blacks in Royalene® EPDM and is meant to serve as a starting point for building black-filled compounds of EPDM. Table I provides a summary of the properties of the carbon blacks evaluated.

TABLE I – CARBON BLACKS EVALUATED

Filler	DBP Absorption, $cm^3/100g$	Iodine Absorption, g/kg	pH	Type
N-990	36	9	8.5	Medium Thermal (MT)
N-770	70	25	9.3	Semi-Reinforcing Furnace (SRF)
N-765	115	31	9.3	High Structure Semi-Reinforcing Furnace (SRF-HS)
N-550	121	43	9.0	Fast Extruding Furnace (FEF)
N-330	102	82	9.0	High Abrasion Furnace (FEF)
N-347	124	90	8.6	High Structure High Abrasion Furnace (FEF)

TABLE II – ROYALENE® 512 BASE FORMULA FOR DATA IN TABLE IV

ROYALENE® 512	100
Naphthenic Oil	100
Carbon Black	as shown
Zinc Oxide	5
Stearic Acid	1
ROYALAC® 133*	0.5
TUEX®	1.5
Sulfur	1.5

TABLE III – ROYALENE® 502 / 400 BASE FORMULA FOR DATA IN TABLE V

ROYALENE® 502	80
ROYALENE® 400	40
Naphthenic Oil	30
Carbon Black	as shown
Zinc Oxide	5
Stearic Acid	1
ROYALAC® 133*	0.5
TUEX®	1.5
Sulfur	1.5

* Data developed with ROYALAC® 133. METHAZATE® would be a current offset that could provide similar properties.

Table IV – EVALUATION OF CARBON BLACKS IN ROYALENE® 512

	N990			N770			N765			N550			N330			N347		
	200	350	500	100	175	250	100	175	250	100	150	200	100	150	200	100	150	200
Mooney at 100 ºC																		
Viscosity, ML(1+4)	19	31	48	17	29	47	20	46	114	22	46	89	24	47	107	33	79	
Mooney at 121 ºC																		
Scorch, t5, minutes	29.5	21.0	19.0	30.0	27.5	24.0	30.0	29.0	14.8	>30	28.2	20.2	29.0	22.2	12.2	29.0	17.8	---
Cured 20' at 160 ºC																		
Hardness, Shore A	47	64	75	44	60	74	48	69	83	51	69	79	55	70	80	58	75	83
200% Modulus, MPa	1.7	3.0	4.1	2.6	5.6	9.5	4.0	8.8	---	4.5	9.6	---	4.6	8.8	---	5.0	10.5	---
(psi)	240	430	600	380	810	1380	580	1280	---	650	1390	---	660	1270	---	730	1530	---
Tensile Strength, MPa	8.1	4.1	4.2	10.5	10.1	9.5	12.6	11.0	9.1	14.2	12.1	10.9	11.7	11.9	9.9	13.8	12.2	8.5
(psi)	1180	600	610	1520	1470	1380	1830	1590	1320	2060	1760	1580	1690	1720	1430	2000	1770	1240
Elongation, %	730	580	220	630	430	200	600	290	120	610	300	150	470	290	160	490	240	150
Tear Str., Die C, kN/m	17	20	21	26	34	28	33	33	25	36	36	26	36	33	25	28	29	20
(pli)	150	180	190	230	300	250	290	290	220	320	320	230	320	290	220	250	260	180
Aged 70 hours at 100 ºC																		
Hardness, Shore A	50	60	81	45	62	77	51	72	85	50	71	83	56	75	86	71	77	86
Tensile Strength, MPa	6.8	4.9	5.4	9.7	11.1	10.6	13.6	12.3	10.7	13.9	13.7	11.7	11.5	13.6	10.9	15.0	13.3	10.5
(psi)	980	710	780	1410	1610	1540	1970	1790	1550	2010	1990	1700	1670	1970	1580	2180	1930	1520
Elongation, %	570	310	190	430	300	150	450	200	110	410	210	120	290	190	110	310	150	110
Tensile, % change	-17	18	28	-7	10	12	8	13	17	-2	13	8	-1	15	10	9	9	23
Elongation, % change	-22	-47	-14	-32	-30	-25	-25	-31	-8	-33	-30	-20	-38	-34	-31	-37	-38	-27
Garvey Die Extrusion																		
Length, m	7.9	10.2	12.3	9.1	11.9	11.9	12.0	11.3	3.4	12.3	12.3	4.1	11.9	10.1	5.6	12.2	6.7	3.5
(ft)	26	33.5	40.5	30	39	39	39.5	37	11	40.5	40.5	13.5	39	33	18.5	40	22	11.5
Weight, g	585	640	720	550	650	560	620	490	140	610	565	165	625	435	225	605	260	140
Appearance Rating, ASTM D2230, Method B	16 (4444)	16 (4444)	16 (4444)	14 (3434)	16 (4444)	16 (4444)	16 (4444)	16 (4444)	16 (4444)	16 (4444)	16 (4444)	16 (4444)	14 (4433)	16 (4444)	16 (4444)	16 (4444)	16 (4444)	16 (4444)
Specific Gravity (calc.)	1.18	1.30	1.38	1.06	1.16	1.23	1.06	1.16	1.23	1.06	1.13	1.18	1.06	1.13	1.18	1.06	1.13	1.18

Table V – EVALUATION OF CARBON BLACKS IN ROYALENE® 502 / 400

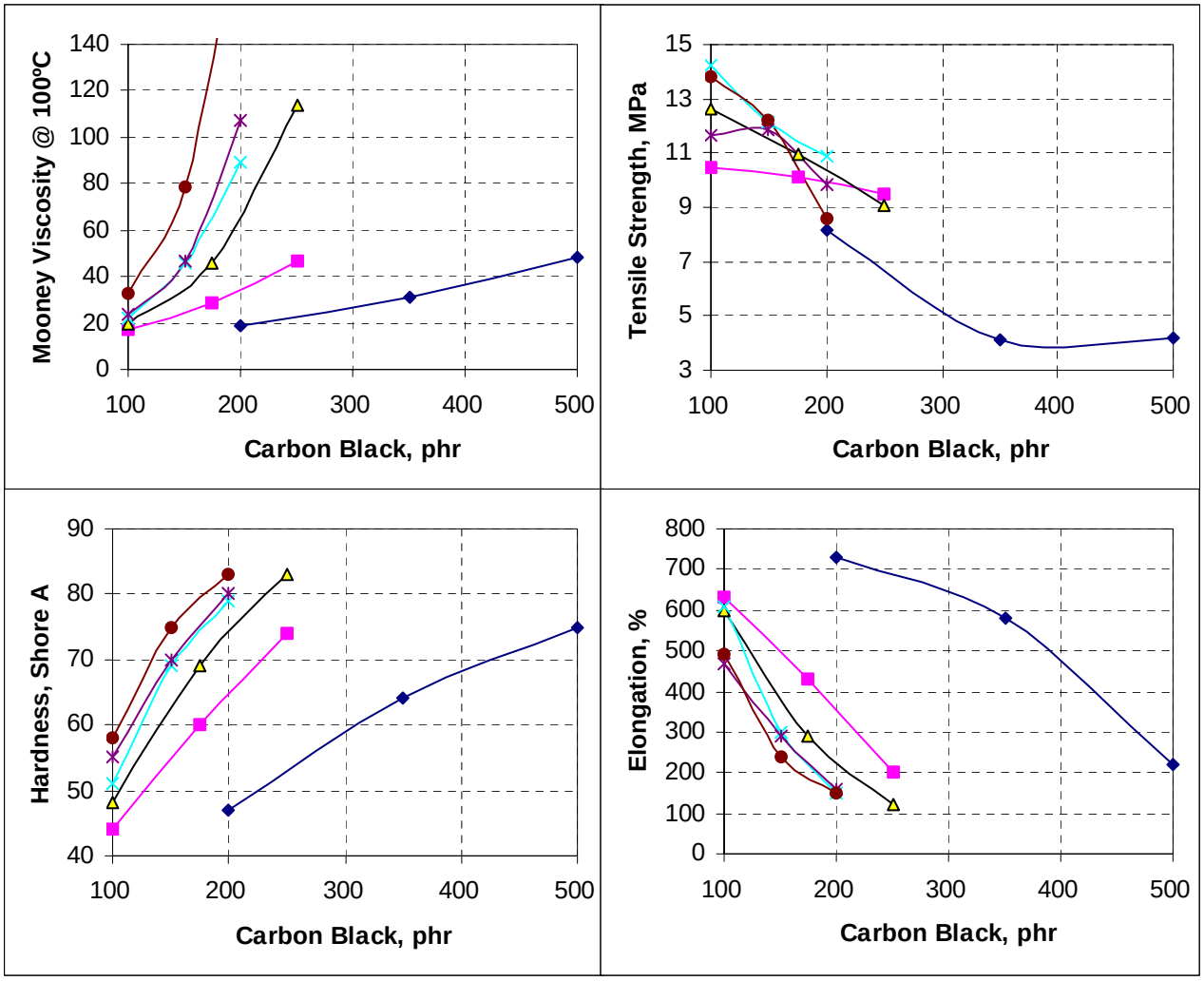
	N990			N770			N765			N550			N330			N347		
	100	250	400	50	125	200	50	125	200	50	100	150	50	100	150	50	100	150
Mooney at 100 ºC																		
Viscosity, ML(1+4)	43	73	123	47	83	>200	47	125	>200	47	73	124	43	68	>200	43	83	>200
Mooney at 121 ºC																		
Scorch, t5, minutes	24.5	18.5	15.5	26.0	23.2	10.3	>30	22.0	12.0	25.8	25.3	15.0	25.2	21.5	10.8	24.2	22.2	7.0
Cured 20' at 160 ºC																		
Hardness, Shore A	49	72	86	48	75	87	50	74	87	50	68	83	52	70	83	53	75	86
200% Modulus, MPa	2.3	4.9	---	4.1	14.3	---	4.2	14.5	---	4.1	11.1	---	4.1	11.2	---	4.7	14.3	---
(psi)	330	710	---	600	2080	---	610	2110	---	600	1610	---	590	1620	---	680	2070	---
Tensile Strength, MPa	6.5	5.6	6.1	12.4	15.1	11.7	10.7	15.4	11.1	14.2	15.1	13.7	14.5	19.4	12.7	16.5	20.1	11.9
(psi)	940	810	880	1800	2190	1700	1550	2230	1610	2060	2190	1990	2110	2810	1840	2400	2920	1720
Elongation, %	550	400	100	470	220	90	420	220	90	490	280	130	460	340	130	450	290	120
Tear Str., Die C, kN/m	16	24	24	32	41	26	32	36	24	35	40	31	35	42	27	40	40	24
(pli)	140	210	210	280	360	230	280	320	210	310	350	270	310	370	240	350	350	210
Aged 70 hours at 100 ºC																		
Tensile Strength, MPa	6.1	5.6	6.8	9.6	15.9	11.7	10.0	17.7	12.3	12.3	16.5	15.5	13.1	19.0	13.1	13.9	19.2	13.0
(psi)	880	810	990	1390	2310	1700	1450	2560	1790	1780	2400	2250	1900	2750	1900	2010	2790	1880
Elongation, %	500	230	80	340	200	90	370	200	170	380	250	120	390	280	190	390	210	110
Tensile, % change	-6	0	13	-23	5	0	-6	15	11	-14	10	13	-10	-2	3	-16	-4	9
Elongation, % change	-9	-43	-20	-28	-9	0	-12	-9	89	-22	-11	-8	-15	-18	46	-13	-28	-8
Garvey Die Extrusion																		
Length, m	3.4	4.0	6.4	4.9	9.0	3.7	4.4	8.7	2.6	4.6	7.9	3.7	4.3	7.9	3.8	4.9	10.4	1.7
(ft)	11	13	21	16	29.5	12	14.5	28.5	8.5	15	26	12	14	26	12.5	16	34	5.5
Weight, g	250	285	375	300	440	175	280	440	110	290	430	160	300	420	160	285	470	70
Appearance Rating, ASTM D2230, Method B	7 (3211)	14 (4343)	16 (4444)	13 (4333)	16 (4444)	16 (4444)	13 (4333)	16 (4444)	16 (4444)	13 (4333)	16 (4444)	16 (4444)	12 (3333)	16 (4444)	16 (4444)	13 (4333)	16 (4444)	16 (4444)
Specific Gravity (calc.)	1.12	1.30	1.40	1.03	1.16	1.25	1.03	1.16	1.25	1.03	1.12	1.19	1.03	1.12	1.19	1.03	1.12	1.19

Graphs 1 to 4

Formula

ROYALENE® 512	100
Naphthenic Oil	100
Carbon Black	as shown
Zinc Oxide	5
Stearic Acid	1
ROYALAC® 133	0.5
TUEX®	1.5
Sulfur	1.5

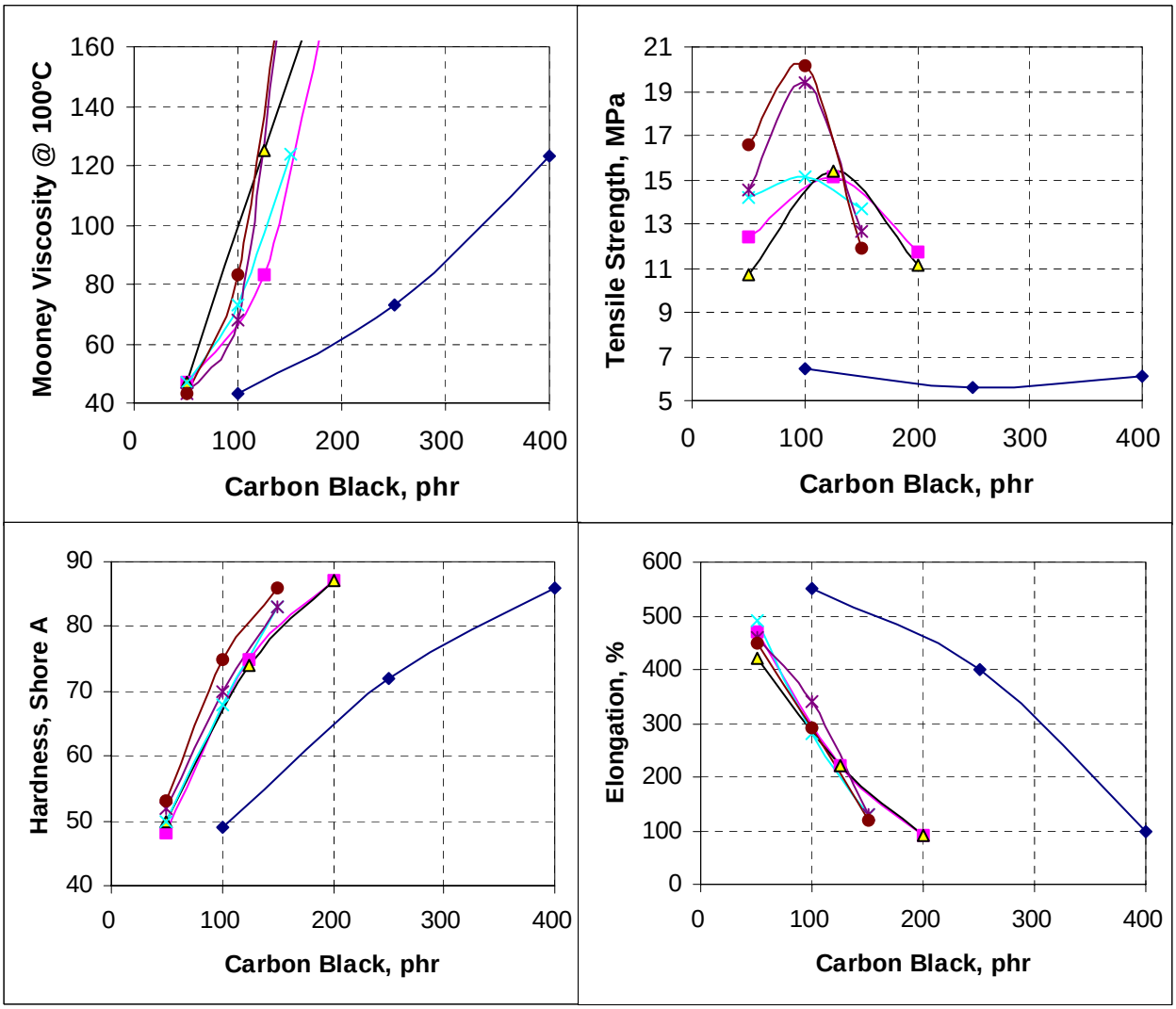
Key: N990, N770, N765, N550, N330, N347



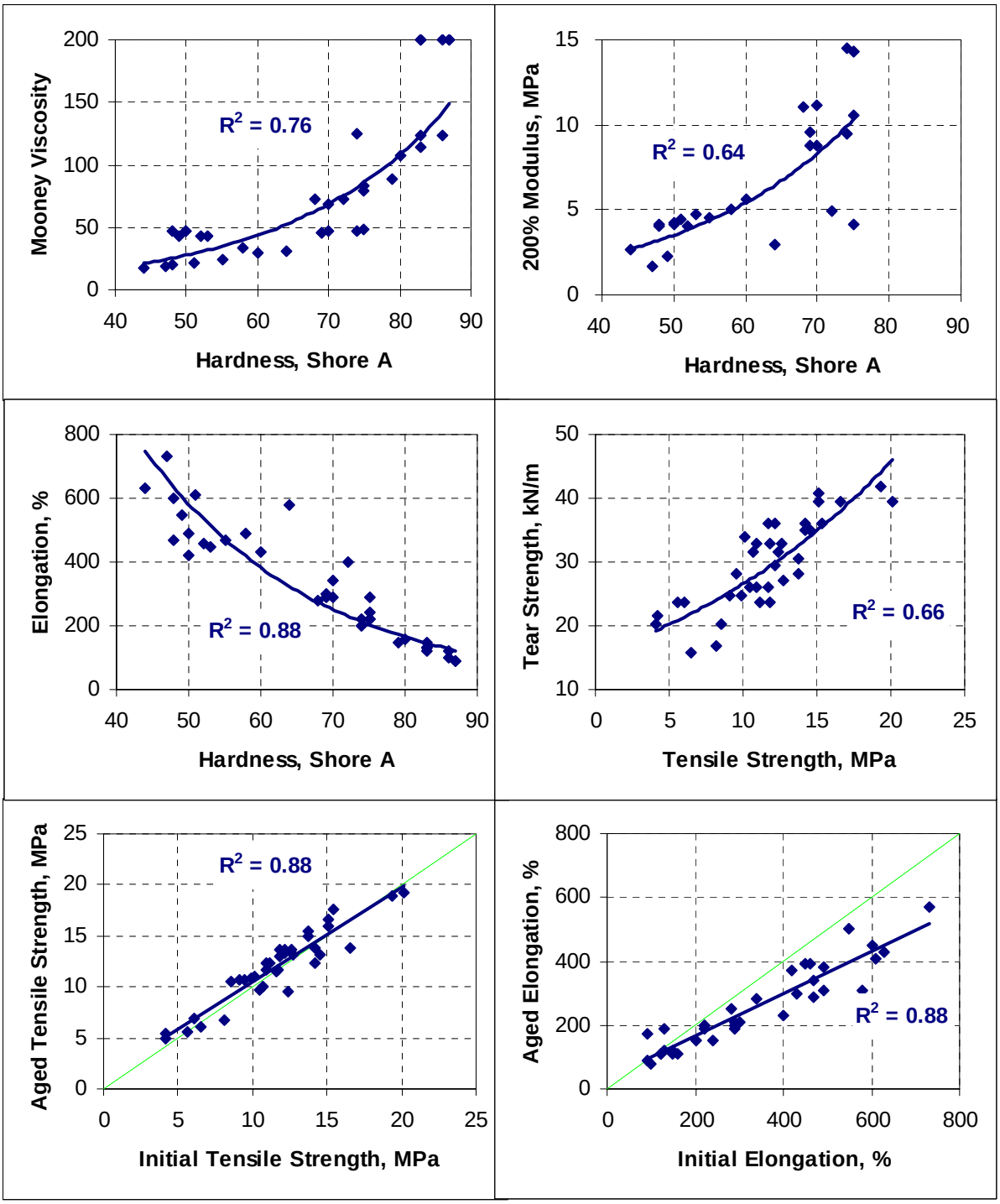
Graphs 5 to 8

Formula	
ROYALENE® 502	80
ROYALENE® 400	40
Naphthenic Oil	30
Carbon Black	as shown
Zinc Oxide	5
Stearic Acid	1
ROYALAC® 133	0.5
TUEX®	1.5
Sulfur	1.5

Key: N990, N770, N765, N550, N330, N347



Graphs 9 to 14
Pooled Data from Both Base Recipes



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