



MILLATHANE DIVISION

TECHNICAL REPORT

DATE: June 16, 2004

EXPERIMENT NUMBER: XP-3126

TITLE: Effect Carbon Blacks on Properties of Sulfur Cured Millable Polyurethane Rubber

PURPOSE: Compound various carbon blacks for equal loading, equal hardness in millable polyurethane rubber with emphasis on Thermax[®] N990 carbon black.

DETAILS: Millathane 76 a polyester based polyurethane rubber and Millathane E34 a polyether polyurethane rubber were used in this carbon black study. All carbon black was supplied by Cancarb Ltd. Both Millathane E34 and Millathane 76 were sulfur cured.

Part I Thermax Physical Properties in Millathane[®] Polyurethane Rubber
Part II Effect of Various Carbon Blacks on Millathane E34 and Millathane 76

RESULTS & CONCLUSIONS: The effects of various loadings of Thermax N990 and other carbon blacks can be seen on the following charts and tables.

RECOMMENDATION (S): The data found in this study is very useful for predicting amounts of carbon black to achieve desired hardness for various abrasion resistant applications.

Part I Thermax Physical Properties in Millathane Polyurethane Rubber

In the following charts and we will evaluate the effects of Thermax N990 black on the physical properties of both Millathane E34 and Millathane 76. Millathane E34 and Millathane 76 have a base hardness of 45A to 50A. As expected, the addition of 20 phr Thermax N990 has an initial 10 point rise in hardness but subsequent additions do not add significant hardness points. Thermax N990 at various loadings in both Millathane E34 and 76 has nearly the same hardness response. At 80 phr Thermax N990 yields 75A hardness in both Millathane 76 and E34.

From Figure 1: Effect of Thermax N990 on Abrasion Resistance of Millathane E34 and Figure 2: Effect of Thermax N990 on Abrasion Resistance of Millathane 76, we find DIN abrasion results are worse as higher amounts of Thermax N990 are used. The DIN abrasion results for Millathane 76 are better for all loading than for Millathane E34.

This improvement in abrasion resistance correlates to improved tear strength of polyester compared to polyether PU rubber as seen in Figure 3: Tear Strength Millathane E34 vs. Millathane 76 with Thermax N990.

Figure 1: Effect of Thermax N990 on Abrasion Resistance of Millathane E34

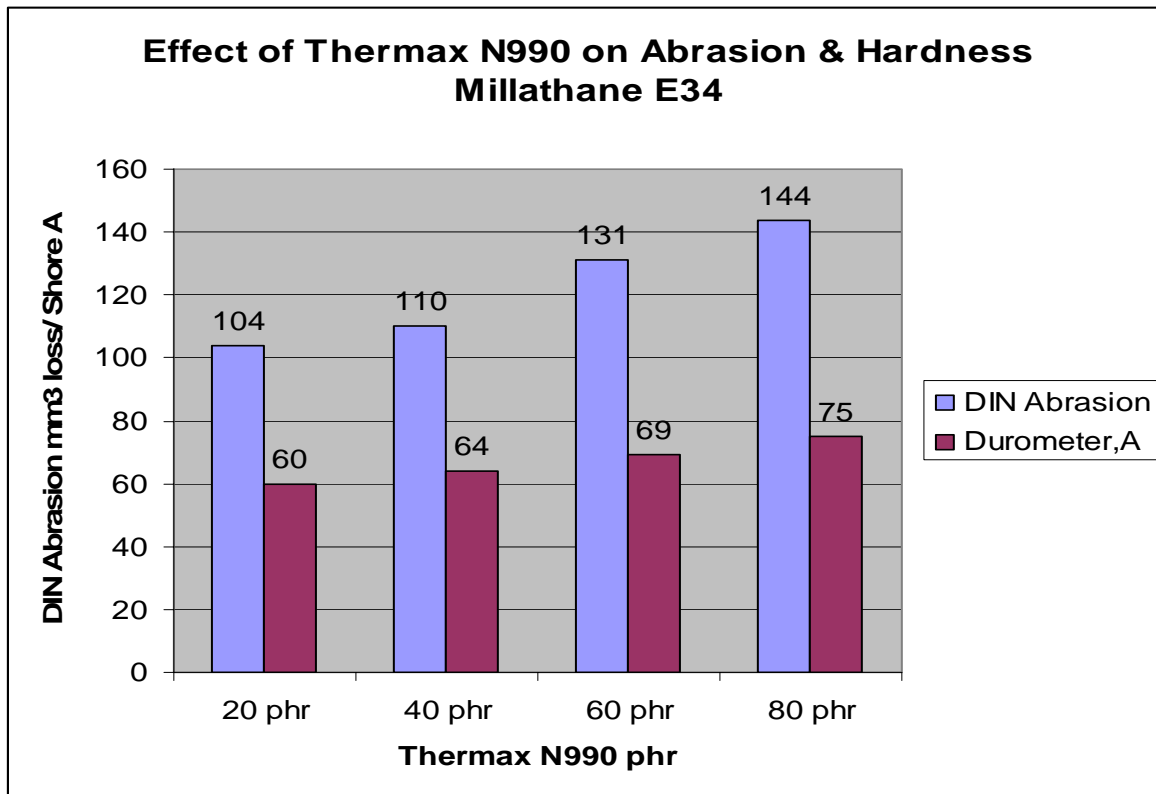


Figure 2: Effect of Thermax N990 on Abrasion Resistance of Millathane 76

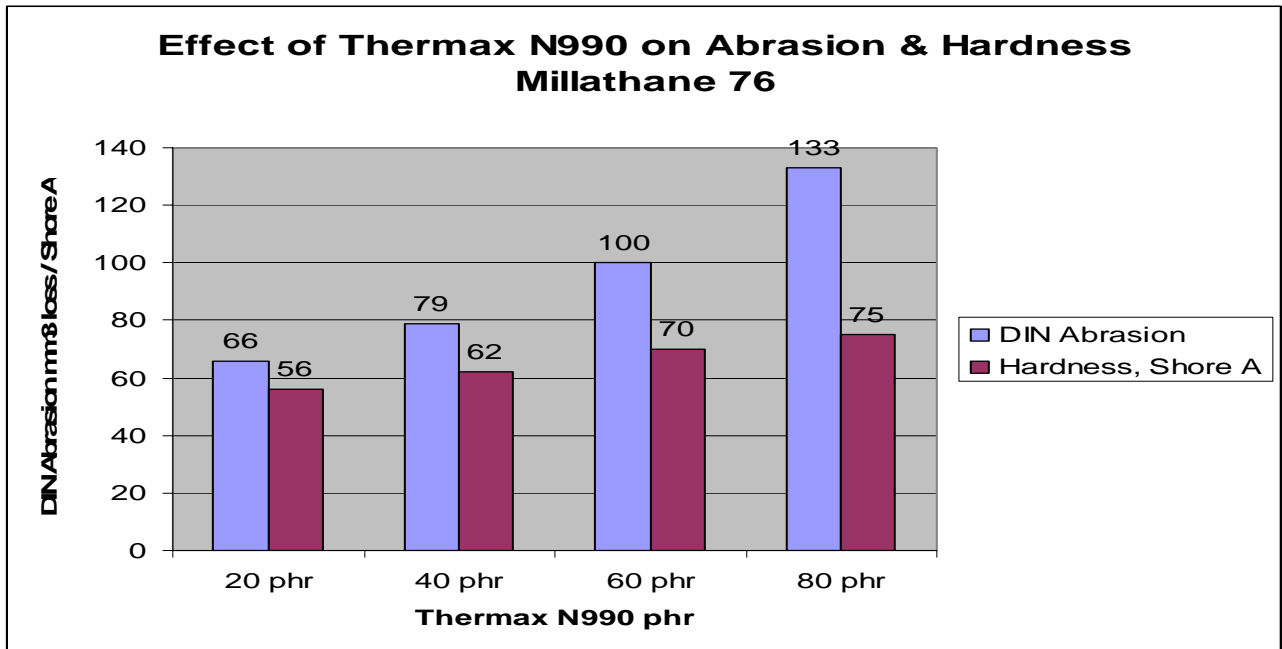


Figure 3: Tear Strength Millathane E34 vs. Millathane 76 with Thermax N990

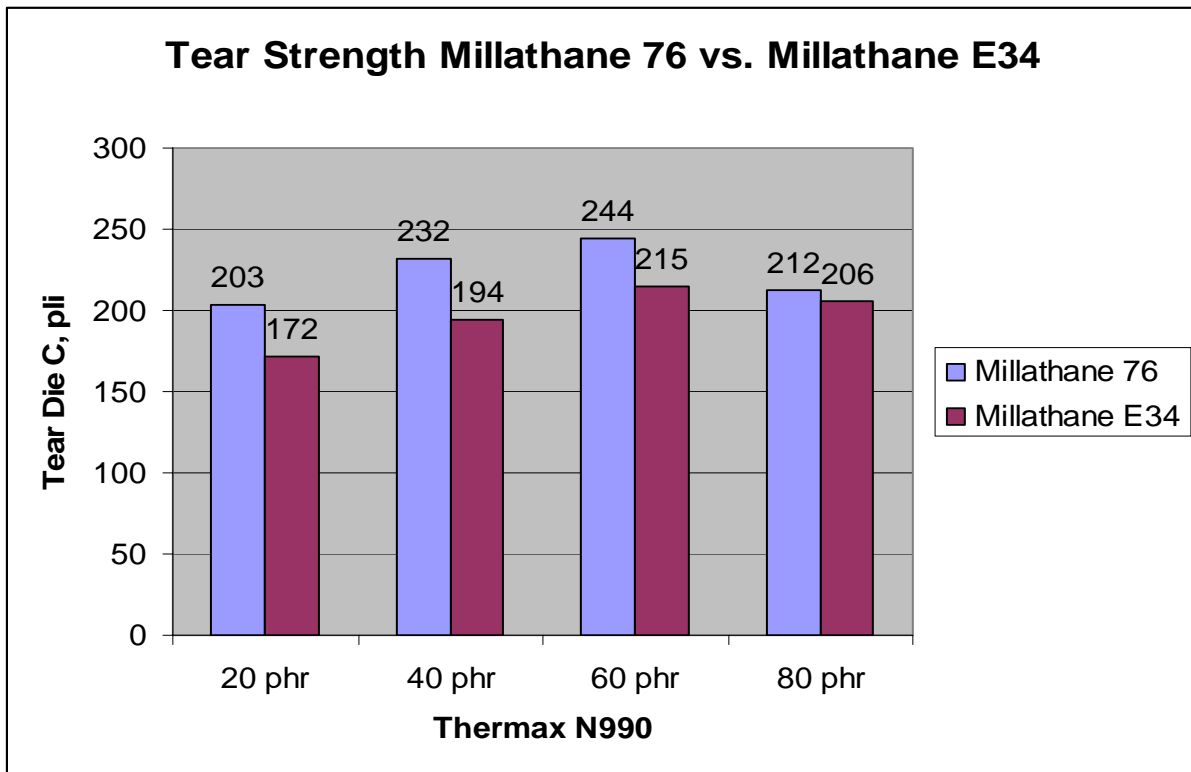


Table 1: VARIOUS LOADING THERMAX N990 CARBON BLACK

FORMULATION	PHR		PHR		PHR		PHR	
Millathane E34	100.0		100.0		100.0		100.0	
Zinc stearate	0.5		0.5		0.5		0.5	
Struktol WB222	1.0		1.0		1.0		1.0	
TP-95	5.0		5.0		5.0		5.0	
Thermax N-990	20.0		40.0		60.0		80.0	
MBTS	4.0		4.0		4.0		4.0	
MBT	2.0		2.0		2.0		2.0	
Thanecure ZM	1.0		1.0		1.0		1.0	
Sulfur	1.5		1.5		1.5		1.5	
TOTAL	135.0		155.0		175.0		195.0	
PERFORMANCE PROPERTIES								
Rheometer 310°F/155°C								
Cure Time, minutes, T90	12		12		12		12	
Cure Temp. 310°F/155°C								
Durometer, A	60		64		69		75	
Tensile, psi, MPa	3503	24.2	2947	20.3	3005	20.7	2109	14.5
100% Modulus, psi, MPa	239	1.6	307	2.1	428	3.0	610	4.2
200% Modulus, psi, MPa	419	2.9	645	4.4	960	6.6	1333	9.2
300% Modulus, psi, MPa	789	5.4	1180	8.1	1562	10.8	1871	12.9
Elongation, %	556		531		528		442	
Tear, pli, kN/m	172	30.1	194	34.0	215	37.7	206	36.1
Density	1.13		1.19		1.24		1.28	
Resilience, %	58		54		52		50	
DIN Abrasion, mm ³ Loss	104		110		131		144	
Compression set, % (22h @ 158°F 70°C)	35		42		39		36	

Table 2: VARIOUS LOADING THERMAX N990 CARBON BLACK IN MILLATHANE 76

FORMULATION	PHR	PHR	PHR	PHR
Millathane 76	100.0	100.0	100.0	100.0
Zinc Stearate	0.5	0.5	0.5	0.5
Struktol WB222	1.0	1.0	1.0	1.0
TP-95	5.0	5.0	5.0	5.0
Thermax N-990	20.0	40.0	60.0	80.0
MBTS	4.0	4.0	4.0	4.0
MBT	2.0	2.0	2.0	2.0
Thanecure ZM	1.0	1.0	1.0	1.0
Sulfur	1.5	1.5	1.5	1.5
TOTAL	135.0	155.0	175.0	195.0
PERFORMANCE PROPERTIES				
Rheometer 310°F/155°C				
Cure Time, minutes, T90	7.5	7.5	7.5	7.5
Cure Temp. 310°F/155°C				
Durometer, A	56	62	70	75
Tensile, psi, MPa	3879 26.7	3555 24.5	3178 21.9	2588 17.8
100% Modulus, psi, MPa	194 1.3	286 2.0	410 2.8	593 4.1
200% Modulus, psi, MPa	355 2.4	635 4.4	953 6.6	1305 9.0
300% Modulus, psi, MPa	685 4.7	1218 8.4	1701 11.7	2024 14.0
Elongation, %	583	574	536	503
Tear, pli, kN/m	203 35.6	232 40.6	244 42.7	212 37.1
Density	1.29	1.34	1.38	1.42
Resilience, %	17	15	15	12
DIN Abrasion, mm ³ Loss	66	79	100	133
Compression set, % (22h @ 158°F 70°C)	43	39	39	39

Part II Effect of Various Carbon Blacks on Millathane E34 and Millathane 76

The following charts show the response of N990, N774, N550 and N330 on physical properties of Millathane E34 and Millathane 76 to equal loading and compounding for equal hardness. We were surprised to find abrasion resistance at equal hardness in Millathane 76 was independent of carbon black type. Whereas in Millathane E34 we found improved abrasion resistance as carbon black particle size decreased. That is we obtained much better abrasion resistance with N330 black in Millathane E34 compounds.

Compression set results can be analyzed in Figure 6. The range of results for this sulfur cure system was in the range of 33 to 42 percent set for both Millathane E34 and Millathane 76.

Figure 4: Effect of Carbon Black on Abrasion Millathane M76

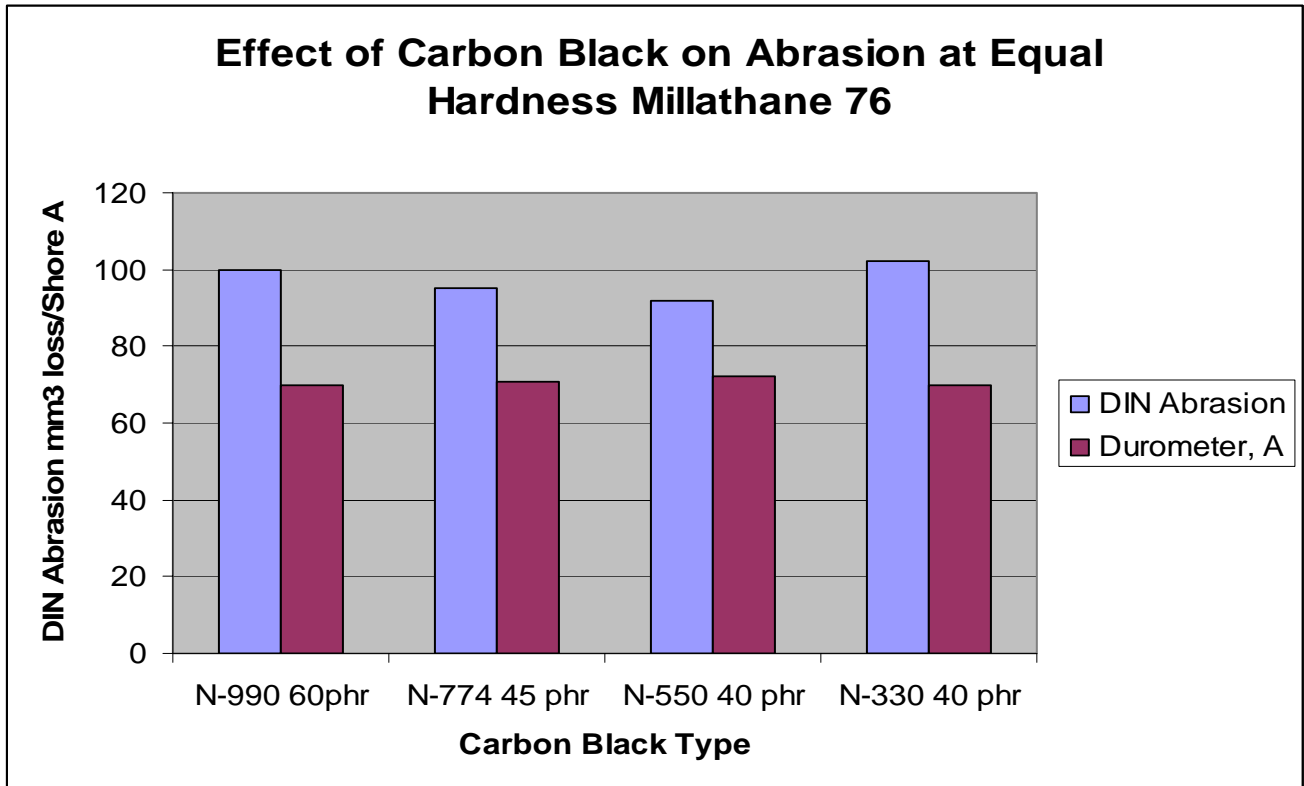


Figure 5: Effect of Carbon Black on Abrasion Millathane E34

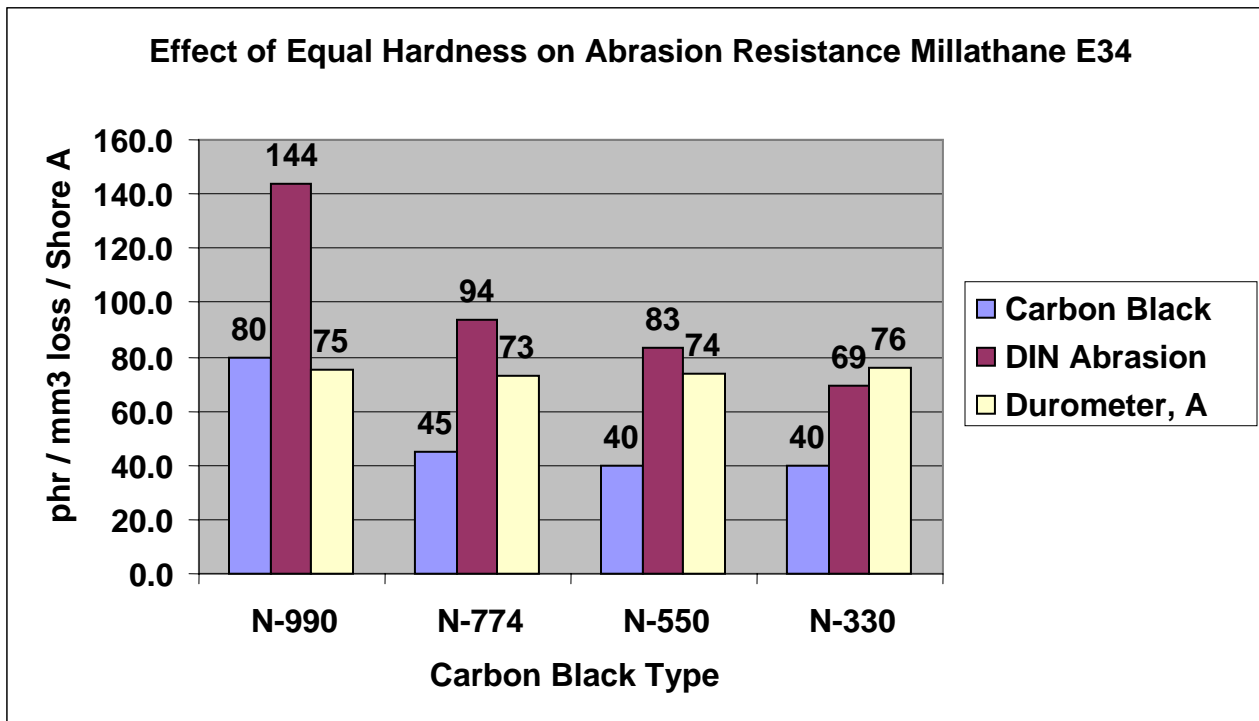


Table 3: PHYSICAL PROPERTIES VARIOUS CARBON BLACKS IN MILLATHANE 76

FORMULATION	PHR		PHR		PHR		PHR	
Millathane 76	100.0		100.0		100.0		100.0	
Zinc stearate	0.5		0.5		0.5		0.5	
Struktol WB222	1.0		1.0		1.0		1.0	
TP-95	5.0		5.0		5.0		5.0	
Thermax N-990	60.0							
N-774			45.0					
N-550					40.0			
N-330							40.0	
MBTS	4.0		4.0		4.0		4.0	
MBT	2.0		2.0		2.0		2.0	
Thanecure ZM	1.0		1.0		1.0		1.0	
Sulfur	1.5		1.5		1.5		1.5	
TOTAL	175.0		160.0		155.0		155.0	
PERFORMANCE PROPERTIES								
Rheometer, 320°F/ 160°C								
Cure Time, minutes, TC90	7		5		5		5	
Cure Temp. 320°F/ 160°C								
Durometer, A	70		71		72		70	
Tensile, psi, MPa	3178	21.9	3443	23.7	3334	23.0	4111	28.3
100% Modulus, psi, MPa	410	2.8	526	3.6	652	4.5	663	4.6
200% Modulus, psi, MPa	953	6.6	1236	8.5	1551	10.7	1496	10.3
300% Modulus, psi, MPa	1701	11.7	2030	14.0	2401	16.6	2385	16.4
Elongation, %	536		509		439		523	
Tear, pli, kN/m	244	42.7	210	36.8	188	32.9	298	52.2
Density	1.38		1.36		1.40		1.35	
Resilience, %	15		14		14		16	
DIN Abrasion, mm ³ Loss	100		95		92		102	
Compression set, % (22h @ 158°F 70°C)	39		36		38		45	

Table 3: PHYSICAL PROPERTIES VARIOUS CARBON BLACKS IN MILLATHANE E34

FORMULATION	PHR		PHR		PHR		PHR	
Millathane E34	100.0		100.0		100.0		100.0	
Zinc stearate	0.5		0.5		0.5		0.5	
Struktol WB222	1.0		1.0		1.0		1.0	
TP-95	5.0		5.0		5.0		5.0	
Thermax N-990	80.0							
N-774			45.0					
N-550					40.0			
N-330							40.0	
MBTS	4.0		4.0		4.0		4.0	
MBT	2.0		2.0		2.0		2.0	
Thanecure ZM	1.0		1.0		1.0		1.0	
Sulfur	1.5		1.5		1.5		1.5	
TOTAL	195.0		160.0		155.0		155.0	
PERFORMANCE PROPERTIES								
Rheometer 320°F/ 160°C								
Cure Time. Minutes TC90	12		11		11		11	
Cure Temp. 320°F/ 160°C								
Durometer, A	75		73		74		76	
Tensile, psi, MPa	2109	14.5	2646	18.2	2825	19.5	3713	25.6
100% Modulus, psi, MPa	610	4.2	574	4.0	679	4.7	675	4.7
200% Modulus, psi, MPa	1333	9.2	1215	8.4	1474	10.2	1454	10.0
300% Modulus, psi, MPa	1871	12.9	1796	12.4	2117	14.6	2218	15.3
Elongation, %	442		451		439		490	
Tear, pli, kN/m	206	36.1	238	41.7	263	46.1	271	47.5
Density	1.28		1.20		1.19		1.19	
Resilience, %	50		49		51		47	
DIN Abrasion, mm ³ Loss	144		94		83		69	
Compression set, %	36		35		33		34	
(22h @ 158°F 70°C)								

Figure 6: Effect of Carbon Black on Compression Set

